Sphagnum Moss of Four Bog Habitats

BIOS 569 - Praticum in Aquatic Biology

Elizabeth L. Broghammer
54533 Irish Way #305
South Bend, IN 46637
Dr. Hellenthal
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Abstract. *Sphagnum* is an important component of bogs. Its ability to hold water and exchange hydrogen ions for nutrients from the nutrient poor soil are key adaptations that allow *Sphagnum* to thrive in bogs. Species of *Sphagnum can be used as indicators of a bog's pH and nutrient state. Sphagnum magallanicum* and *S. recurvum*, which illustrate a positive association in the study area, are found in drier and more acidic habitats than *S. cuspidatum*. *Sphagnum cuspidatum* has a negative association with both *S. magallanicum* and *S.recurvum*; it is found submerged on the open waters edge of the mat. The chemical and physical features of one bog, Reddington, in conjunction with the species of *Sphagnum*, suggest that it is in an earlier stage of succession and less oligotrophic. Over the four bogs studied, six species were identified in Goegebic County, MI; as of 1964 only one of these species had been recorded in the county (Darlington, 1964).

INTRODUCTION

All bodies of water can be described by physical, chemical, and floristic composition. These characteristics, when used together, enable classification of lakes as oligotrophic or eutrophic. Eutrophic lakes have been characterized as nutrient rich, highly productive, with small surface area, moderate depth, and depleted oxygen in the hypolimnion. Oligotrophic lakes, on the other hand, are nutrient poor, have low organic productivity, are larger in size and depth, and the amount of oxygen decreases in the epilimnion as the temperature increases. Oligotrophic lakes typically are phosphorus limited and may have excess nitrogen (Wetzel, 1975).

Bogs are one of the many varieties of aquatic habitats. The bogs in the Upper Peninsula of Michigan are typically kettle-hole lakes, formed when ice from the last glaciers was covered by sand and debris by the retreating glacier. Eventually the ice melted leaving a deep basin that filled with water; these basins generally had neither an inlet nor an outlet. Once a bog is formed it is resistant to conditions that would alter water balance and peat accumulation (Mitch, 1993). The preservation of bogs is due to poor drainage resulting from the precipitation-evaporation balance (Crum and Planisek, 1988).

There are several characteristics that make the bog habitat a unique, oligotrophic, aquatic environment. First, there is a low level of primary productivity. Mosses account for one-third to one-half of the total production and *Sphagnum* mosses are the dominant mosses (Mitch, 1993). Second, nutrients in the bog habitat are very limited and the recycling of these nutrients is slow. Nutrients enter into bogs either from precipitation or dust falling onto the peat surface (Larsen, 1982).

Another feature is the high acidity of bogs which is important in the vegetation of bogs. Glaser (1987; as cited in Mitch, 1993) provided five reasons for the high acidity: (1) the cation exchange between the environment and Sphagnum, (2) oxidation of sulfur compounds to sulfuric acid, (3) acid atmospheric deposition, (4) biological uptake of nutrient cations by plants, and (5) build-up of organic acids by decomposition.

Bogs are also peat producers. Peat, the characteristic soil of bogs, is strongly acidic and mineral poor (Etherington, 1983). The acid environment slows bacterial activity decreasing the rate of decomposition which allows for peat accumulation (Mitch, 1993). Peat develops in anaerobic and waterlogged conditions (McQueen, 1990), and in bogs it is formed from *Sphagnum*, grasses, and sedges (McQueen, 1990; Etherington, 1983).

Sphagnum mats are typically found in bogs. They are created by the outgrowth of *Sphagnum* away from the land into the open water. The floating mat impedes drainage (Crum, 1976) and is responsible for keeping the bog cool. In the spring, the mat serves as an insulator preventing the ice from melting, and in the summer, absorbs water from the surroundings (Niering, 1966).

The *Sphagnum* species are water absorbent, causing the mat to be sponge-like. *Sphagnum* have the ability to hold 15-23 times more water than their dry weight (Mitch, 1993). Growth of *Sphagnum* depends on nutrients and water supply (McQueen, 1990; Larsen, 1982). It is able to locate in nutrient poor bogs because there is limited competition because very few vascular plants can survive in an area with so few nutrients (McQueen, 1990). *Sphagnum* receives nutrients in exchange for hydrogen ions (McQueen, 1990; Mitch, 1993); this not only provides the moss with required nutrients, but it creates an acid habitat ideal for itself (McQueen, 1990).

Sphagnum mosses serve as indicators of the environment. Different species are in control in each stage of bog succession (Crum, 1976), and each species has a specific habitat preference. The mosses grow typically along three gradients: a wet-to-dry gradient, related to the height above water which they grow; a nutrient gradient, related to the amount of nutrients available and easily detected by pH readings; and a gradient of sunlight tolerance. In some species, exposure to sunlight does not influence growth but will cause a color difference between the plants that are in areas of high sunlight exposure and those plants that are in areas of low sunlight exposure (McQueen, 1990).

Because *Sphagnum* species have specific habitat preferences, identifying the species present provides information on the pH range and nutrient availability. Does this mean that the same species of *Sphagnum* will be found along common environmental gradients? The purpose of this research is to survey the *Sphagnum* species in four bog habitats, to determine if there is an association among species, and if species have different mean pH values.

METHODS AND MATERIALS

Surveys were conducted on Reddington Lake, Tender Bog, Ed's Bog, and North Gate Bog located on the University of Notre Dame Environmental Research Center (UNDERC) near Land O' Lakes, WI.

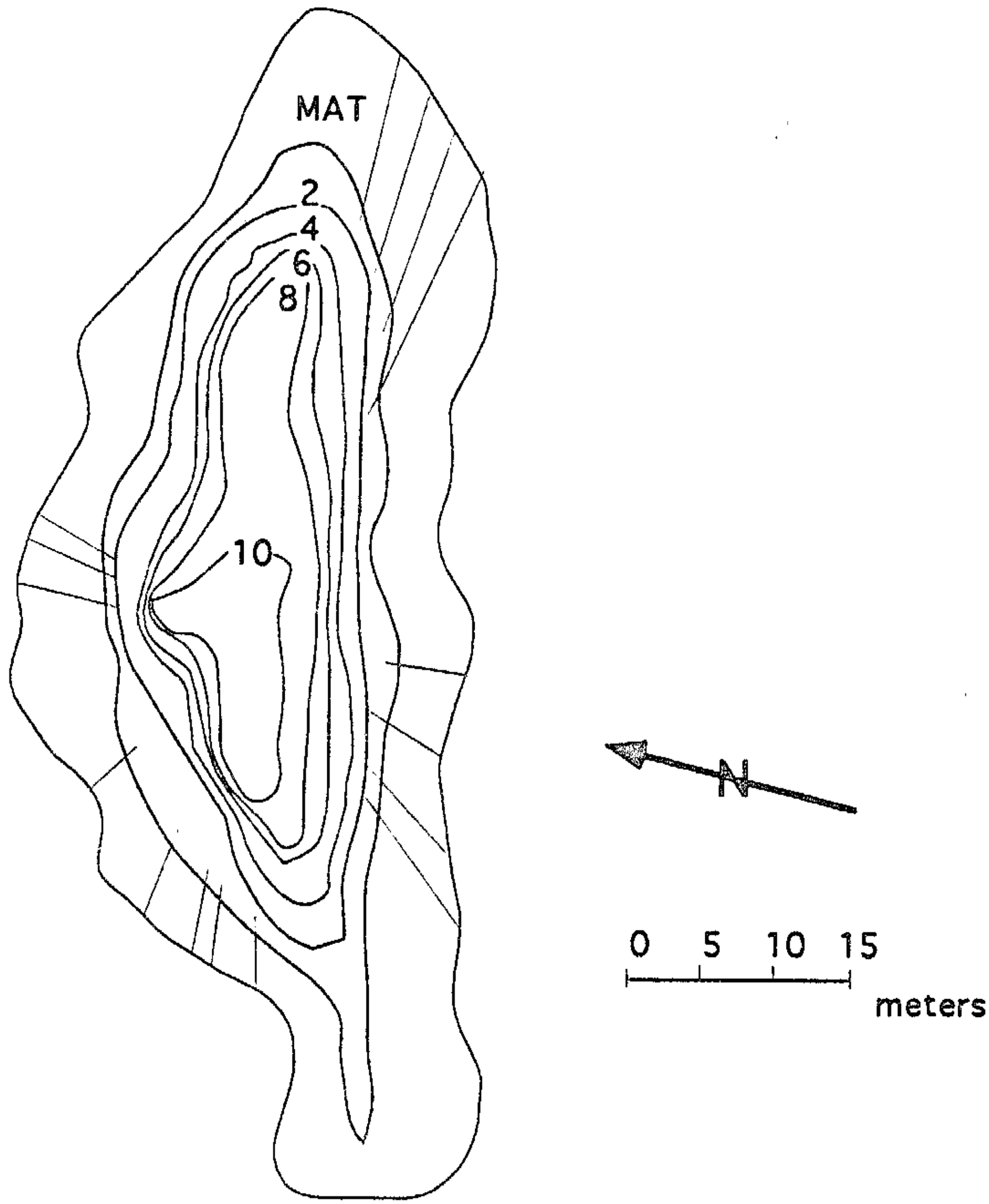
Water Chemistry

At each bog a dissolved oxygen and temperature (DO/temp) profile was constructed for May 30 and July 16. After calibration of the DO/temp meter to air temperature and altitude, the DO/temp probe was lowered by 1M increments until it reached the sediment at the deepest region of the bog. At these times a 1 liter sample of water was obtained at 1 meter from the surface and 1 meter from the sediment. These samples were tested for color, pH, conductivity, nitrate, phosphate, and hydrogen sulfide using Hach water chemistry analysis (Walters, 1989).

Collection and Analysis

Each bog was also surveyed for the species of *Sphagnum* present from the forest tree line to the open water. Only the middle third of the mat on the east, west, north, and south sides of the bog was surveyed. Four transect lines were marked with ribbon tied to a tree at location determined by a random numbers table (Figures 1-4). Along each transect of the mat, five 0.25m

Figure 1: Transect Lines of Tender Bog



TENDER BOG
University of Notre Dame--UNDERC
Depth contour interval=2 meters

Figure 2: Transect Lines of Ed's Bog

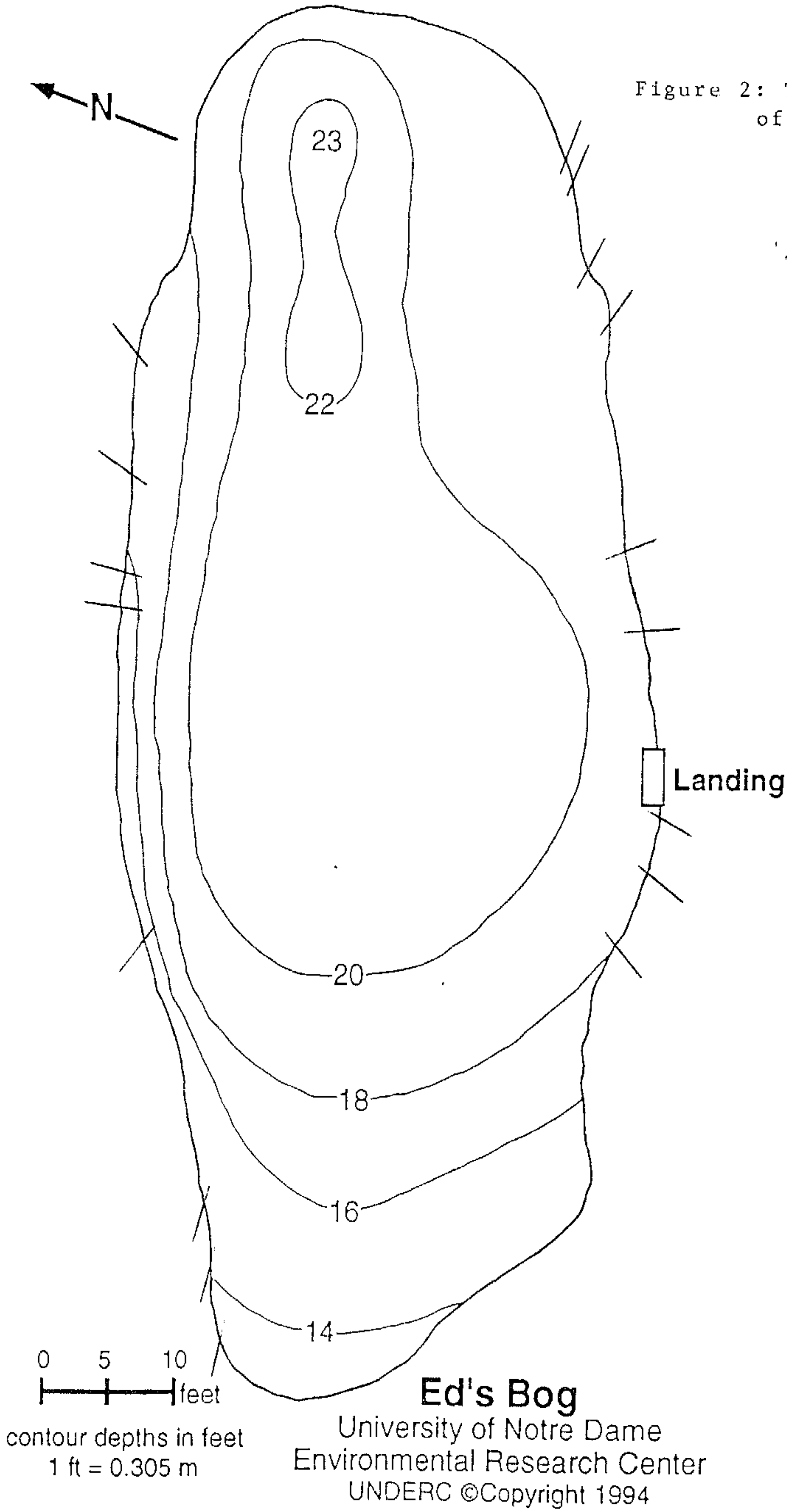


Figure 3: Transect lines of North Gate Bog

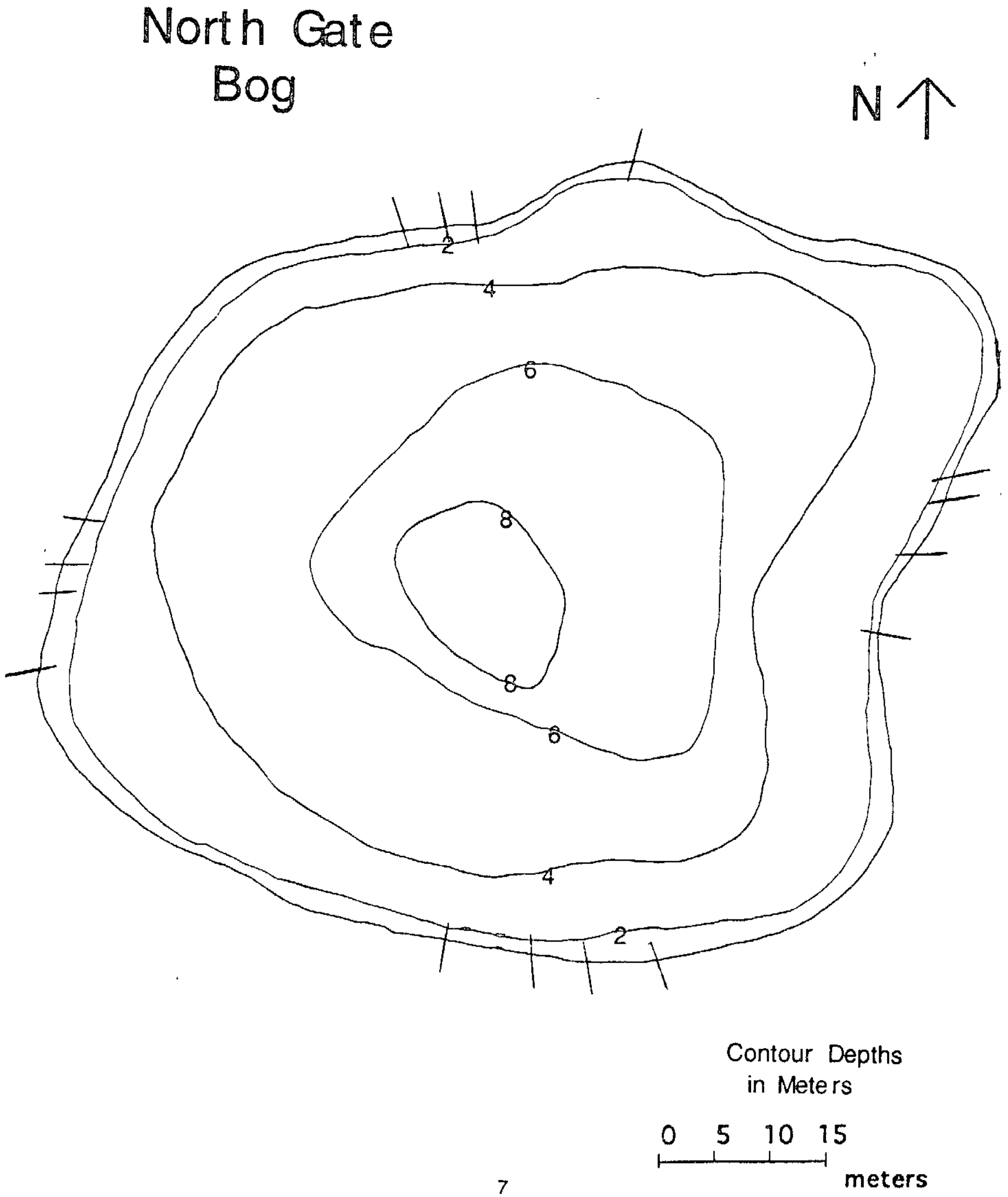
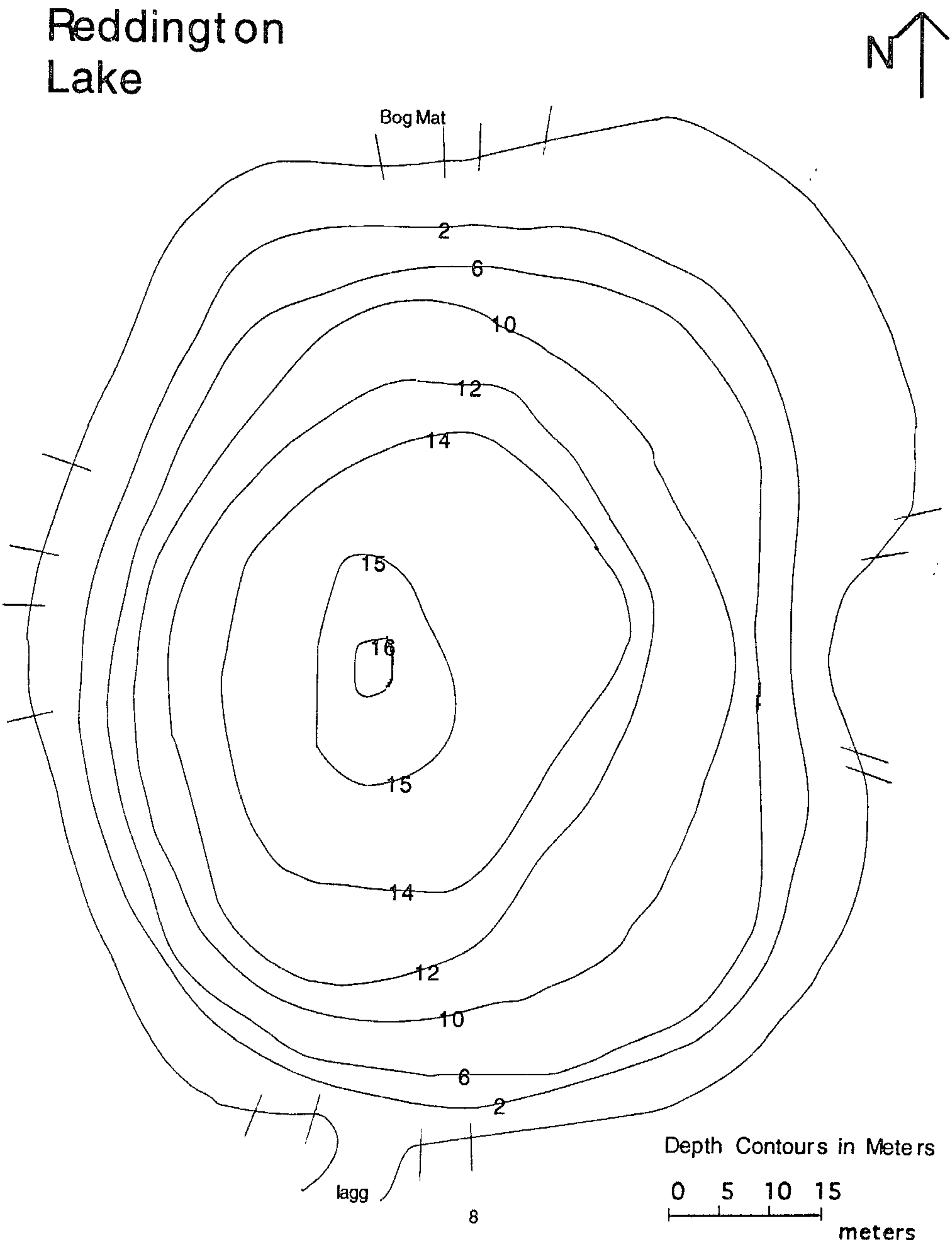


Figure 4: Transect Lines of Reddington Lake



by 0.25m quadrats were equally spaced; in some areas only three quadrats were used because of the small width of the mat. The quadrats were marked off by a rigid frame and surveyed. It was generally necessary to collect the forth and fifth samples by boat. The survey included a collection of the species of *Sphagnum* present within the quadrat and a soil sample form the first, third, and fifth quadrats.

In the lab the *Sphagnum* specimens were separated, lightly pressed, dried for 48 hours at room temperature, and then placed in individual envelopes for later identification. The preserved specimens and observations about the habitat provided the necessary information to identify the specimens in September. Identification was based on McQueen (1990) in conjunction with Crum (1988). A voucher specimen was prepared for each *Sphagnum* species identified.

Upon returning from the field a small portion of the soil sample was suspended in deionized water, allowed to equilibrate for 15 minutes (Causton, 1988) and then the pH was determined using an electronic pH meter.

Statistical Analysis

Calculations and statistical analysis were performed to figure frequency, species association, pH means, and association between pH and species. To calculate the relative frequency the following two equations were used:

$$\text{(1) Frequency of species} = \frac{\text{\# points at which species x occurs}}{\text{total \# points}}$$

$$\text{(2) Relative Frequency (RF)} = \frac{\text{Frequency of species x}}{\text{sum of all frequencies}} \times 100$$

To find whether there was any association between species in each bog and overall, 2x2 contingency tables were analyzed. Evaluation was based on the Yate's chi-square results unless one or more of the cells had an expected value <5. If this was the case, then the Fisher Exact test was used. To determine whether associations were positive or negative the Interspecific association coefficient was calculated using the following procedure:

(1) a 2x2 contingency table was set up so that the total occurrence of species A < than that of species B. Each cell was labeled a - d.

		species B	
		present	absent
species A	present	a	b
	absent	c	d

(2) Based on the table one of the following equations was used:

(a) if $ad \geq bc$ then $C = \frac{(ad - bc)}{(a+b)(b+d)}$

(b) if $bc > ad$ and $d > a$ then $C = \frac{(ad - bc)}{(a+b)(a+c)}$

(c) if $bc > ad$ and $a > d$ then $C = \frac{(ad - bc)}{(b+d)(c+d)}$

Association of *S. magallanicum*, *S. recurvum*, and *S. cuspidatum* to a specific pH was determined by one-way analysis (ANOVA) combined with Tukey Multiple Comparison; results were based on probability 0.05. Two ANOVAs were performed. The first ANOVA and Tukey test was done on a data set in which the pHs were of quadrats in which only one species was sampled. A second ANOVA and Tukey test was done on a data set where pH was listed for a species even if more than was species was sampled in that quadrat.

RESULTS

Tender Bog and Ed's Bog did not show a considerable change in their water chemistry between May 30 and July 16 (Tables 1,2). Reddington and North Gate had an increase in sulfur and phosphorus 1m from the bottom (Tables 3,4). North Gate had a slight decrease in both these elements near the surface and Reddington's surface showed a decrease of phosphorus from the surface. Of the four bogs, Ed's Bog has less nitrogen at the surface than the bottom; Reddington showed a higher pH and higher concentration of phosphorus. The DO/temp profiles (Tables 5-8) indicated a decrease in oxygen in the epilimnion as temperatures increased in all four bogs.

Six species of *Sphagnum* were identified in the four bogs. The frequencies of *S. magallanicum*, *S. recurvum*, and *S. cuspidatum* were similar in North Gate, Ed's Bog, and Tender Bog (Table 9). At Reddington there were differences in the frequencies of the *S. magallanicum* and *S.recurvum*. There was no *S. cuspidatum* sampled, and there were three additional species, *S. fimbriatum*, *S. squarrosum*, and *S. capillifolium*, all with relatively low frequencies.

Among the species overall there is a positive association between *S. magallanicum* and *S. recurvum*, and there are negative associations between both these species and *S. cuspidatum* (Table 10). In comparing the associations found within individual bogs there are some distinctive differences. Ed's Bog and North Gate have the same association patterns. Tender Bog and Reddington had no association between *S. magallanicum* and *S. recurvum*. Reddington also had an additional three species, all of which show no association to another species.

Table 1: Water Analysis of Tender Bog

	May 30, 1994 1m below surface	July 16, 1994 1m below surface	May 30, 1994 10m below surface	July 16, 1994 10m below surface
nitrogen	1.00 mg/l	1.00 mg/l	1.40 mg/l	1.35 mg/l
phosphorus	0.02 mg/l	0.025 mg/l	0.02 mg/l	0.04 mg/l
sulfate	0.00 mg/l	0.00 mg/l	0.00 mg/l	0.30 mg/l
pH	4.47	4.39	4.61	4.61

Table 2: Water Analysis of Ed's Bog

	May 30, 1994 1m below surface	July 16, 1994 1m below surface	May 30, 1994 7m below surface	July 16, 1994 7m below surface
nitrogen	0.45 mg/l	.40 mg/l	0.55 mg/l	0.60 mg/l
phosphorus	0.017 mg/l	0.04 mg/l	0.76 mg/l	0.115 mg/l
sulfate	0.00 mg/l	0.00 mg/l	0.00 mg/l	0.00 mg/l
pH	5.12	4.85	4.99	4.74

Table 3: Water Analysis of Reddington

	May 30, 1994 1m below sur.	June 20, 1994 1m below sur.	July 16, 1994 1m below sur.	May 30, 1994 10m below sur.	June 20, 1994 12m below sur.	July 16, 1994 14m below sur.
nitr.	0.70 mg/l	0.06 mg/l	0.65 mg/l	1.05 mg/l	1.20 mg/l	1.50 mg/l
phos.	0.10 mg/l	0.39 mg/l	0.05 mg/l	0.146 mg/l	1.03 mg/l	2.54 mg/l
sulf	0.00 mg/l	0.00 mg/l	0.00 mg/l	0.00 mg/l	0.30 mg/l	0.30 mg/l
pH	6.32		6.00	5.94		5.81

Table 4: Water Analysis of North Gate

	May 30, 1994 1m below surface	July 16, 1994 1m below surface	May 30, 1994 7m below surface	july 16, 1994 7m below surfae
nitrogen	0.85 mg/l	0.60 mg/l	1.45 mg/l	1.35 mg/l
phosphorus	0.07 mg/l	0.04 mg/l	0.07 mg/l	0.04 mg/l
sulfate	0.10 mg/l	0.00 mg/l	0.30 mg/l	1.0 mg/l
pH	4.48	4.65	4.93	5.05

Table 5: D.O./Temp of Tender Bog

	May 30, 1994 temp (C)	May 30, 1994 D.O. (mg/l)	July 16, 1994 temp (C)	July 16, 1994 D.O. (mg/l)
air	21.5		18.9	
surface	17.9	4.90	19.5	3.5
1m	11.0	1.35	16.0	1.1
2m	6.0	1.30	7.21	1.38
3m	5.0	1.25	5.5	1.15
4m	5.0	1.20	5.0	1.1
5m	5.0	1.20	5.0	1.05
6m	5.0	1.20	4.9	1.0
7m	5.0	1.15	4.9	0.98
8m	5.0	1.13	5.0	0.95
9m	5.15	1.10	5.0	0.90
10m	5.15	1.10	5.05	0.90
11m	5.10	1.10		

Table 6: D.O./Temp of Ed's Bog

	May 30, 1994 temp (C)	May 30, 1994 D.O. (mg/l)	July 16, 1994 temp (C)	July 16, 1994 D.O. (mg/l)
air	23.1		20.0	
surface	18.2	4.15	20.9	3.34
1m	12.0	2.70	16.8	1.85
2m	6.0	0.95	8.5	1.05
3m	5.5	0.90	6.0	0.90
4m	5.5	0.85	5.9	0.89
5m	5.5	0.85	5.9	0.80
6m	5.5	0.82	5.5	0.80
7m	5.3	0.82	5.5	0.78

Table 7: D.O./Temp of Reddington

	May 30, 1994 temp (C)	May 30, 1994 D.O. (mg/l)	June 20, 1994 temp (C)	June 20, 1994 D.O. (mg/l)	July 16, 1994 temp (C)	July 16, 1994 D.O. (mg/l)
air	27.8		23.8		24.0	
surface	22.0	7.3	26.2	6.8	21.5	6.4
1m	14.0	4.0	18.2	1.45	18.9	3.8
2m	6.9	1.3	7.5	1.30	12.4	0.80
3m	5.9	1.2	6.2	1.32	8.0	0.60
4m	5.1	1.15	5.2	1.32	6.0	0.60
5m	4.9	1.15	5.0	1.30	5.5	0.60
6m	4.9	1.1	4.9	1.30	4.8	0.55
7m	4.9	1.05	4.8	1.25	4.8	0.55
8m	4.9	1.00	4.8	1.22	4.5	0.50
9m	4.9	1.00	4.8	1.20	4.5	0.50
10m	4.9	0.95	4.8	1.18	4.5	0.50
11m	4.9	0.91	4.8	1.12	4.5	0.50
12m	5.0	0.87	4.9	1.12	4.5	0.48
13m			5.0	1.10	4.8	0.48
14m			5.0	1.10	4.9	0.48
15m			5.0	1.2	4.9	0.40
16m			5.05	1.2	5.0	0.40
17m			5.00	0.95		

Table 8: D.O./Temp of North Gate

	May 30, 1994 temp (C)	May 30, 1994 D.O.(mg/l)	July 16, 1994 temp (C)	July 16, 1994 D.O.(mg/l)
air	26.8		23.0	
surface	18.5	7.3	21.0	5.8
1m	12.9	0.79	18.5	1.60
2m	6.2	0.61	9.9	1.40
3m	5.2	0.61	6.8	1.05
4m	5.0	0.60	5.2	1.00
5m	5.0	0.60	5.0	0.90
6m	5.0	0.60	5.0	0.85
7m	5.1	0.60	5.0	0.80
8m	5.2	0.6	5.0	0.75

Table 9: Frequency of *Sphagnum* species

	number	freq	RF
North Gate			
total samples	47		
S. Magallanicum	25	0.532	34.3
S. recurvum	22	0.468	30.1
S. cuspidatum	26	0.553	35.6
Tender Bog			
total samples	59		
S. magallanicum	27	0.458	35.1
S. recurvum	31	0.525	40.2
S. cuspidatum	19	0.322	35.6
Ed's Bog			
total samples	61		
S. magallanicum	33	0.541	34.0
S. recurvum	35	0.574	36.1
S. cuspidatum	26	0.475	29.9
Reddington			
total samples	65		
S. magallanicum	53	0.815	55.8
S. recurvum	26	0.400	27.4
S. capillifolium	6	0.092	6.3
S. fimbriatum	4	0.062	4.2
S. squarrosum	6	0.092	6.3
S. cuspidatum	0	0.000	0.0
overall			
total samples	232		
S. magallanicum	138	0.595	42.7
S. recurvum	71	0.306	22.0
S. cuspidatum	114	0.491	35.3

Table 10: Species Association

Species	Bog	chi-sq	P	Fisher	Assoc. Coeff
mag / cus	NG			.0000090	-0.695
mag / rec	NG			.000357	0.612
rec/ cus	NG			.000001	-0.821
mag / cus	Ed's	24.700	.0000		-0.843
mag / rec	Ed's	19.806	.0000		0.991
rec / cus	Ed's			.0000	-0.539
mag / cus	TB			.000012	-0.885
mag / rec	TB	0.027	.8697		0.063
rec / cus	TB	17.433	.0000		-0.800
mag / rec	Redd			1.0000	-0.028
mag / fim	Redd			.017953	-0.693
mag / cap	Redd			1.0000	0.583
mag / squar	Redd			.008777	-0.591
rec / cap	Redd			.388697	-0.583
rec / squar	Redd			.388697	-0.583
mag / cus	overall	74.446	.0000		-0.716
mag / rec	overall	13.411	.0003		0.307
rec / cus	overall	56.546	.0000		-0.771

species abbreviations:

mag = *S. magallanicum*

cus = *S. cuspidatum*

rec = *S. recurvum*

fim = *S. fimbriatum*

cap = *S. capillifolium*

squar = *S. squarrosum*

bog abbreviations:

NG = North Gate

Ed's = Ed's Bog

TB = Tender Bog

Redd = Reddington

The results of the ANOVA show that in the independent data sets the mean pH of the different species are not different. In the data sets that are dependent, the mean pH of each species is different. The Tukey Multiple Comparisons indicates that in this data set *S. cuspidatum* has a different mean pH than the *S. magallanicum* and *S. recurvum*.

DISCUSSION

In the identification of my samples I chose to take a conservative view in the classification of the species S. recurvum. I felt that this was necessary because Crum (1988) has one species *S. recurvum* with several varieties while McQueen (1990) treated each variety as a species.

In North Gate, Tender Bog, and Ed's Bog the frequency of *S. magallanicum*, *S. recurvum*, and *S. cuspidatum* are about the same. The similar relative frequencies of each species within a bog could be an indication of specific zonation of the mat within that bog. My sampling was also not entirely random. I determined the placement of my transects through a random number table, but along each transect my quadrats were equally spaced.

These three bogs are very similar in their physical and chemical characters. They all have a forest that surrounds the bog with an open *Sphagnum* carpet mat extending from the forest to the open water. Near the open water of Tender and Ed's bogs there is dense shrubbery that grows out over the water. Because of their similar physical and chemical characteristics, the bogs would have the same zonation. I feel that the frequency is a representation of the various zones of a bog.

In Reddington there was no *S. cuspidatum* sampled, and over half the samples had *S. magallanicum*. Physically, Reddington is different than the other three bogs. It is surrounded by a lagg which is inhabited by *Nuphar* and *Nymphaea* and is also much deeper. Laggs are the remains of flowing groundwater whose path has been diverted around the central peat mat (Wetzel, 1975). The lagg is described as a false bottom of suspended organic matter in which macrophytes such as *Nuphar* and *Nymphaea* may become rooted (Crum, 1988). The *Sphagnum* mat between the lagg and open water is not similar to the mats of the other three bogs nor is it uniform within itself. On the north and south sides of Reddington the mat is not exposed; it is covered by a wooded forest. The mat of the west side of Reddington is a typical exposed Sphagnum carpet with a few sparse trees in the middle, and numerous pitcher plants. The east side is characterized by shrubs, with some exposure of the *Sphagnum* carpet near the lagg.

Chemically the water of the open portion of Reddington Lake is different from that of the other three bogs. It has a considerably higher pH than the other bogs and also has more phosphorus. These are indicators of more nutrients in the bog. *Sphagnum* removes the nutrients from the environment in exchange for hydrogen ions, resulting in a lower pH. Because of the physical and chemical differences of Reddington, it might be expected that there would be different species of *Sphagnum* found.

As shown in the results, these species of moss, *S. fimbriatum*, *S. capillifolium*, and *S. squarrosum*, were found only in Reddington.

Based on the results of the water chemistry, Sphagnum species, and physical characteristics of Reddington, I believe it may be in an earlier stage of succession than the other bogs. Its higher concentration of phosphorus makes it less oligotrophic than Tender Bog, Ed's Bog, or North Gate. It is also less acidic and is believed to possess a false bottom (known from mapping of bottom).

The positive association overall and in North Gate and Ed's Bog between *S. magallanicum* and *S. recurvum* is an indicator that the two will be found in similar habitats. Tender Bog and Reddington both showed no association. No association does not mean that an association is not possible, but with the data set it is not evident. In looking at the contingency tables, they show that the species were evenly distributed through the four cells. This could be due to the small sample size.

S. magallanicum and *S. recurvum* both showed a negative association with *S. cuspidatum* in North Gate, Tender Bog, and Ed's Bog. A negative association means that it is unlikely that the two species will occur in the same habitat. *S. cuspidatum* grows in submerged or shallow pools; *S. magallanicum* and *S. recurvum* grow in drier areas and are unable to grow submerged (Crum, 1988).

The resulting no association of *S. magallanicum* with *S. capillifolium*, and *S. recurvum* with both *S. capillifolium* and *S. squarrosum*, is due to the small number of samples obtained in the collection. Again, no association means that with the data set an association of the two species is not evident.

It is important to examine the difference in results of the ANOVAs. The difference can be explained by the high pH of Reddington. It is 1.2 logarithms higher in alkalinity than the most acidic of the remaining bogs. This results in a bias of the ANOVAs. Because in Reddington there was no *S. cuspidatum* sampled, the significantly higher pH of Reddington had no effect on the mean pH of *S. cuspidatum*. This could create a bias keeping the mean pH of *S. cuspidatum* lower, where in *S. recurvum* and *S. magallanicum* the high pH of Reddington could have raised their mean pH values. The *S. magallanicum* and *S. recurvum* found in Reddington had higher pH values that could have increased the mean pH values so there was no difference in the three means.

Due to the positive association of *S. magallanicum* and *S. recurvum* it is logical that their mean pH values are similar because they inhabit the same regions of the mat. The same logic is true of the different mean pH values between those two species and *S. cuspidatum*. A negative association is an indicator that the species do not inhabit the same sites and therefore could be expected to have different pH values.

CONCLUSIONS

Further study of the species of *Sphagnum* present in North Gate, Tender Bog, Ed's Bog, Reddington, and other bogs, should include a more descriptive analysis of the habitat and of the other primary flora. It is clear that the species present are influenced by their surroundings. It is important to gain an understanding of how different species of *Sphagnum* are involved in lake succession.

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