The Effect of the Addition of Nitrogen and Phosphorous on *Sphagnum* Moss in Bogs and Intermediate Fens in the Upper Peninsula of Michigan

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Stacey A. Leicht
727 Pasquerilla Hall East

Dr. Scott Bridgham
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ABSTRACT

There has not been a lot of work done on the effect of nutrient addition on peatlands. It is known that in Europe, eutrophication has caused the loss of species diversity, and therefore loss of rare species of plants. In this study, the effect of the addition of N, P, and N and P in nine peatlands (three bogs, three intermediate fens and three rich fens) on the growth and species diversity of *Sphagnum*. There was no significant difference found in the species diversity of *Sphagnum* within the bogs and intermediate fens. Within the bogs, there was also no significant difference found in the growth of *Sphagnum*. However, within the intermediate fens, there was a significant difference found between plots treated with N and plots treated with P. This data pointed to the addition of N being detrimental to the growth of *Sphagnum*.

INTRODUCTION

Peatlands are wetlands in which the rate of plant growth is greater than that of plant decomposition resulting in an accumulation of organic matter known as peat (Crum 1988). The specific types of peatlands used in this study were bogs, intermediate fens and rich fens. To distinguish between these types, one has to look at the source of water and nutrients—that is, if they are ombrotrophic or minerotrophic. Bogs are ombrotrophic because water and nutrients are received only through precipitation (Crum 1988). There are two reasons why a bog can only receive water and nutrients in this manner. The first is that due to the many layers of peat, input of minerals from the soil is blocked (Crum 1988). The second is due to the bog's perched water table which also isolates it from the ground water (Bridgham et al. 1996). Intermediate and rich fens are minerotrophic because they receive their water and nutrients via groundwater as well as precipitation. One result of the differing methods of nutrient input are differing types of vegetation. In bogs, *Sphagnum* mosses are the dominant vegetation with a percent cover as great as 100% in some places. Bog vegetation also includes conifers (*Larix laricina* and *Picea mariana*), ericaceous shrubs (*Chamaedaphne calyculata, Ledum groenlandicum*), and some graminoids (*Carex oligosperma*). In intermediate and rich fens, graminoids (grasses and sedges) are the dominant plant species, along with forbs (Bridgham et al. 1996). The variables that influence plant communities are hydrology, pH, and nutrient availability.

The current paradigm in peatland ecology maintains that a nutrient gradient exists along the ombrotrophic-minerotrophic gradient with fens containing higher nutrient availability than bogs (Bridgham et al. 1996). However, studies have shown that N, P, both N and P, or K to be the limiting nutrients in different peatlands (Bridgham et al. 1996). In some bogs, P has been identified as the limiting nutrient, in others, N in a low-N site, but P in a high-N site (Bridgham et al. 1996). While in some mesotrophic fens N or P is the limiting nutrient. This limitation depended on the successional status of the fen, and if it had been mowed or not (Bridgham et al. 1996).

These nutrients, especially N and P, can have variable effects on a plant community's net primary production (NPP). In the Netherlands, Verhoeven et al. (1996) showed that in fens either

N or P could be the limiting factor, while he showed that bogs either have P or K as the limiting factor. Verhoeven's study was supported by the work of Clymo and Hayward who observed that adding phosphate to a bog increased the growth rate of *Sphagnum compactum, S. auriculatum, S. cuspidatum, and S. tenellum* (1982). Chapin's work in northeastern Minnesota showed that by adding high concentrations of N, *Sphagnum* spp. shows a negative response (1998). Low N inputs increased the NPP in the bog, while high N decreased the NPP of bryophytes in the third year: indicating a possible toxic effect of high N on the moss (Chapin 1998). P, however, increased the NPP of the fen (Chapin 1998). There was no subsequent change in cover in these areas although species specific biomass changes occurred (Chapin 1998). Looking at these results, it is evident that though there is no consistent limiting factor, that nutrient influx into a wetland will have an effect not only on the plant communities of the peatland, but on the whole ecology of the peatland. Thus, we need to better understand the effects of nutrient addition so that we can anticipate what will result from unwanted nutrient influx due to agriculture and other N addtions.

The purpose of this study was to determine the effects of nutrient influx on vegetation communities across the ombrotrophic-minerotrophic gradient. Our first hypothesis was that the diversity of moss species in the wetlands would decrease due to the addition of fertilizer. The second was that the added nitrogen would negatively effect growth of the moss. The third was a study of the growth of the hummocks and hollows in the bogs studied. It was expected that the growth of the hummocks would be less than that of the hollows and that this may be affected by nutrient addition. This study ultimately gave more insight into the effects of nutrients on peatlands, specifically the effect on the diversity and growth of *Sphagnum*.

Materials and Methods

Sites

The sites used for this study were nine peatlands at the University of Notre Dame Environmental Research Center in Vilas County Michigan. Three of the peatlands were bogs (pH 4), three were intermediate fens (pH 5) and three were rich fens (pH 6). The bogs had a 100% to nearly 100% cover of *Sphagnum* moss, ericaceous shrubs and few graminoids. The intermediate fens had a high cover of *Sphagnum* with a higher percentage of graminoids and forbs than the bogs.

Treatment Plots

During the summer of 1998 treatment plots were established in nine peatlands. Within each peatland, four 32 m^2 treatment plots were established. The treatment of each plot was delineated by the color of the tape on the PVC pipe marking the four corners. Pink tape was for N, yellow was for P, blue was for N and P, and no tape was the control. Within each treatment plot, five 1 m^2 permanent plots were established for cover analysis, and growth.

Water Tables

Within each of the peatlands, water wells were established in order to monitor the depth of the water table every two weeks. Perforated pipes were placed in the middle of each peatland and water level measured using a meter stick.

Fertilization

The treatment plots were fertilized twice in one growing season, once in late May (May 29-June 1) and once in early July (July 6- July 7). At each time period, the concentration of the fertilizer used was 3g/m^2/yr nitrogen and 1g/m^2/yr phosphorous total. For the nitrogen treatment, urea was used, for the phosphorous treatment, superphosphate. Dry fertilizer was spread using hand-held seed spreaders.

Cover Analysis

The cover of each *Sphagnum* species was determined in the five permanent plots within the treatment plots. The percent cover of *Sphagnum* sp. was determined using the nickel method. In this method, a nickel was randomly placed on the surface of the plot, the moss beneath it collected, separated by species, and the stems counted.

Determination of Moss Production

To determine the growth of the moss in the plots, the cranked wire method described by Clymo (1970) was used. A cranked wire was placed in each of the five permanent plots within each treatment area. In bogs, three hummock and hollow associations were chosen, and cranked wires were placed on a hummock and in a hollow to compare their production values.

Permanent Slide Collection

A slide collection of the stem leaves of *Sphagnum sp*. identified in this study was established using the protocols in Crum (1992). First, the stem leaf of the *Sphagnum* was carefully removed and placed on a slide. Next, the dye, methylene blue, was placed on the leaf until the leaf absorbed it. The dye was wicked off and the mounting medium (a 1:1 mixture of water and corn syrup) was placed on the leaf. A cover slip was applied, and clear nail polish used to ring the cover slip. This collection has been left at UNDERC for future use.

Statistics

For each peatland, growth of the moss was measured and the Shannon-Weiner diversity index was calculated for the *Sphagnum*. Using the SYSTAT program, significance of the growth values and the diversity of the *Sphagnum* was determined using ANOVA.

RESULTS

The species diversity of the *Sphagnum*, which was calculated using the Shannon-Weiner index showed no significant difference between the treatment plots within the bogs (p=0.174, Figure 1a) or the treatment plots in the intermediate fens (p=0.551, Figure 1b). There was no significant difference between the treatment plots in the bogs versus the treatment plots in the intermediate fens. Rich fens were not used for analysis because the controls lacked *Sphagnum*.

The growth of Sphagnum within the treatment plots of the bog were not significantly different from each other (p=0.584, Figure 2a). However, when the growth of the *Sphagnum* within the treatment plots of the intermediate fen were compared, there was a significant difference between the plot fertilized with N and the plot fertilized with P (p=0.010, Figure 2b). Thus, the growth of the *Sphagnum* in the plots fertilized with N was hindered compared with that of the P. The N, therefore, slightly depressed moss growth while P slightly increased moss growth. However, neither was enough to be different from the controls. {When comparing the treatment plots with the same treatment plots in the bogs and intermediate fens, there was no significant difference between the control plots (p=0.320), the N and P plots (p=0.505) or the P plots (p=0.922).} But, there was a difference between the N plots in the bogs and the N plots in intermediate fens (p=0.024). In this case, it seems that the N suppressed the growth in the intermediate fen more than the bog.

The growth of the *Sphagnum* between hummocks and hollows and between hummocks and hollows in different treatment plots in the bogs could not be compared due to the lack of success using the cranked wire method. There was a general trend of the hummock moss growing less than the hollow moss, but the problems of wires sliding down in the loose capitulum prevented any further analysis.

The height of the water tables during the growing season is shown in Table 1. It goes slightly against the normal trend of the wetlands getting drier as the summer progresses because of some late summer rains.

Discussion

The diversity between bog and intermediate fen is not significantly different even in the controls. The lack of significant difference in the diversity is most likely due to a longer period of time needed for the fertilizer to change the composition of species in the treatment plots. The fertilizer may eventually decrease the diversity of *Sphagnum* present in the peatlands as seen in England, where eutrophication of the peatlands has caused a decrease in species diversity, resulting in a loss of rare plants (Bridgham et al. 1996). It could be hypothesized that the plots treated with N will lose their diversity first because of the significant effect on growth. If the growth of *Sphagnum* is affected, then it is probable that certain species will die out due to nutrients reaching toxic levels, giving way to the few species that are able to handle the increased N.

In the intermediate fens, there was a significant difference in the growth of *Sphagnum* in the plots fertilized with N versus those fertilized with P. The N, therefore, slightly depressed moss growth while P slightly increased moss growth. In a fen in northern Minnesota, the NPP of the community of the plants was positively effected by the addition of high N and high P (Chapin 1998). Unfortunately, because of missing cells, the bryophyte functional group in this experiment could not be studied individually (Chapin 1998). Thus, further study will be necessary in order to determine the affect of N on the bryophytes individually in order to see what type of effect there is. In the bog, high N negatively effected bryophyte NPP in the third year of Chapin's experiment (1998). Though there was no significant negative growth in the N treatment plot of our bogs, the graph does show there is a downward trend. When this experiment is continued next summer, it would be expected that there would be a negative effect on growth.

The failure to be able to compare the growth of Sphagnum on hummocks versus hollows and between treatments in the bogs was due to the cranked wire method (Clymo 1970). This method worked well in the closely-packed capitula of the hummocks, but in the loose capitula of the hollows the wires often sank, or fell to the side resulting in unusually high growth or lack of a measurement altogether. This problem could be remedied by using cranked wires in the hummocks and by tying a string to the *Sphagnum* in the loosely packed capitula of the hollows.

Future experimentation would include fertilization of the plots next summer in the same way to see if there is any significant increase or decrease in the species diversity or growth of the *Sphagnum*. Using a different method of measuring growth of the *Sphagnum*, it will be possible to see if there is indeed a significant difference in growth of *Sphagnum* on hummocks and in hollows, and to compare these numbers between treatments.

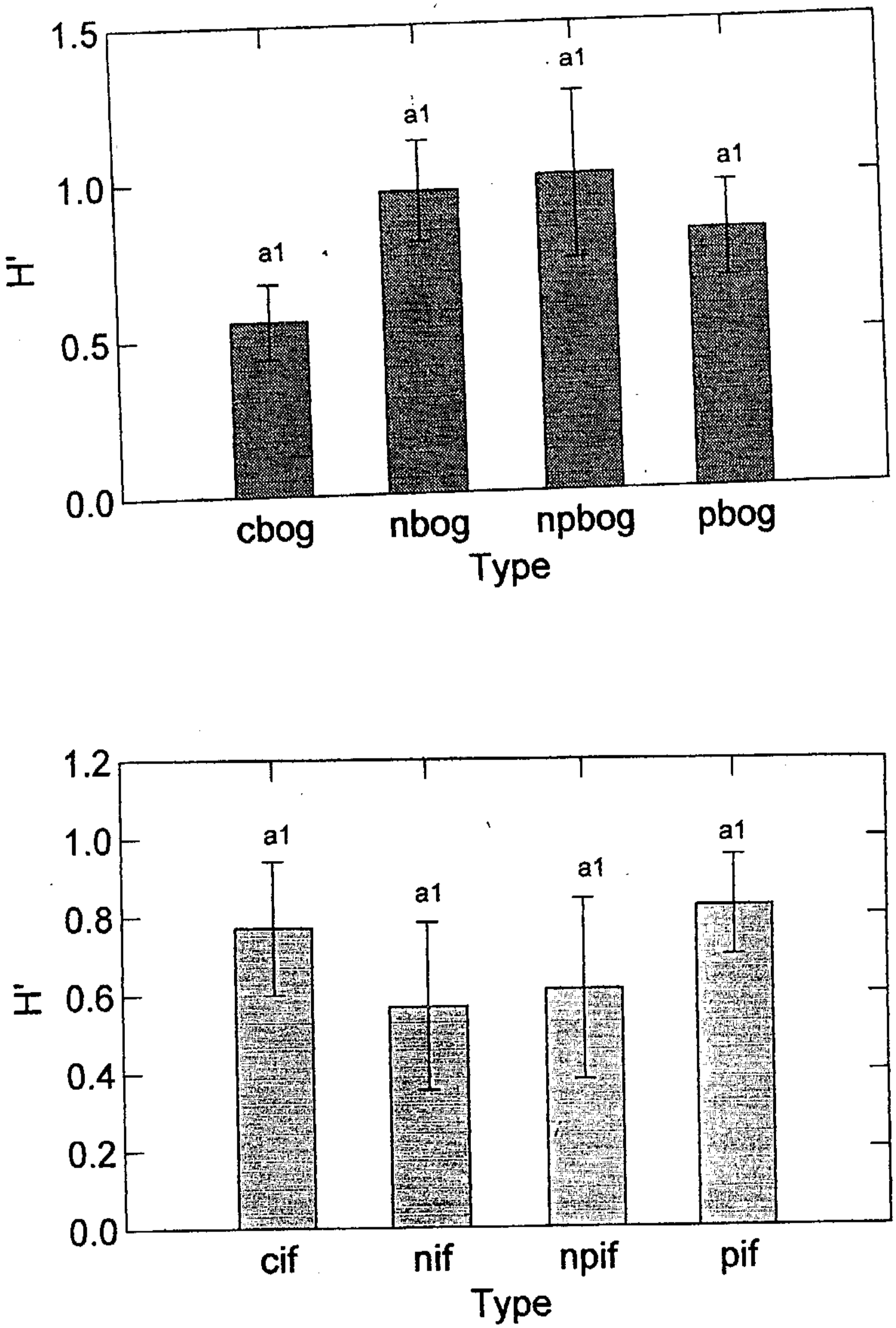

Figure 1- a) Graph depicting the H' number in the bogs versus the treatment plots. b) Graph depicting the H' number in the intermediate fens versus the treatment plots. Error bars represent the standard error. The letters atop the error bars show if there is significant difference between the plots in the graph. The numbers atop the error bars show if there is significant difference between the individual treatments between the two graphs (a and b).

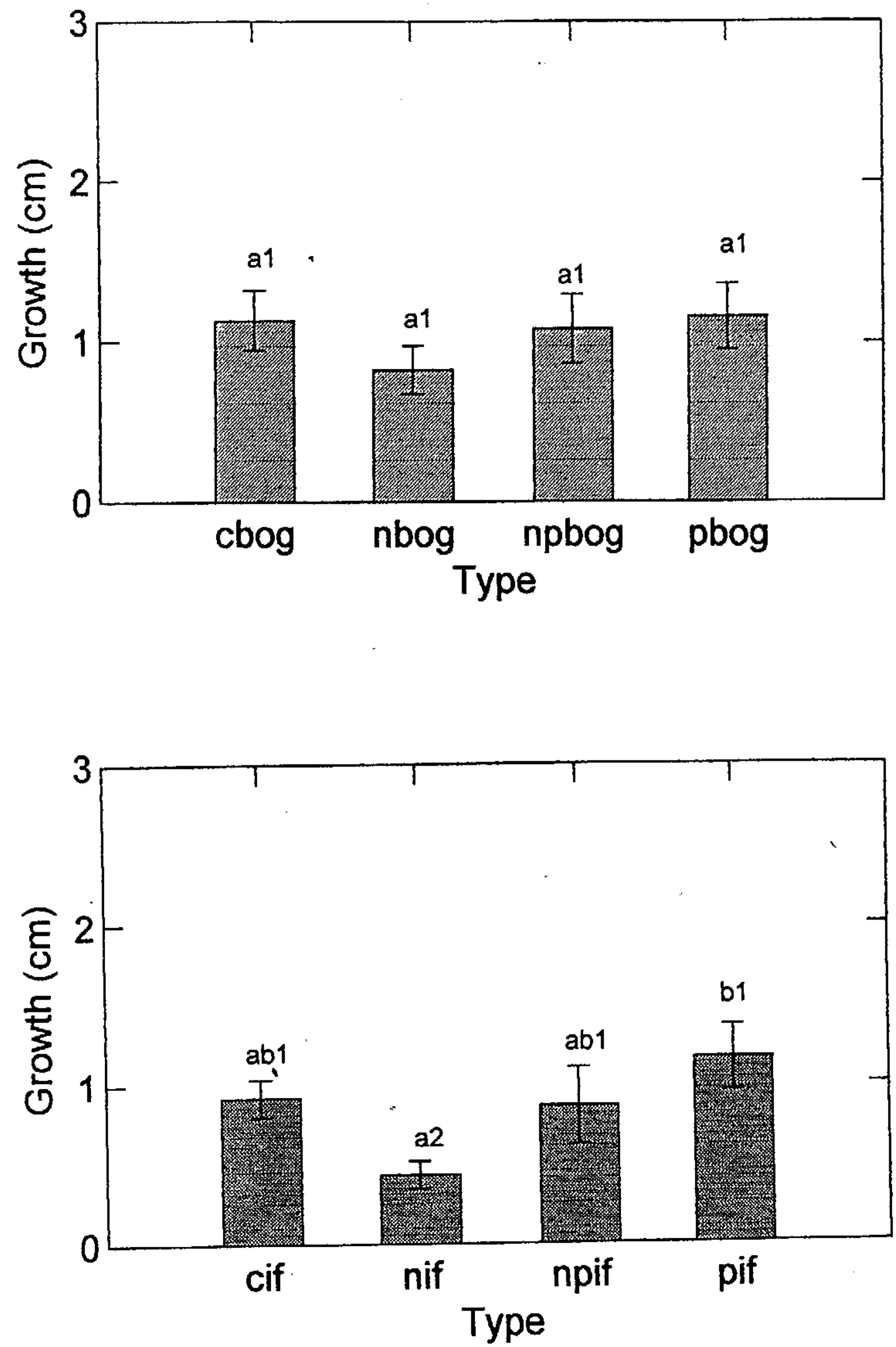

Figure 2- a) Graph depicting the growth in the bogs versus the treatment plots. b) Graph depicting the growth in the intermediate fens versus the treatment plots. Error bars represent the standard error. The letters atop the error bars show if there is significant difference between the plots in the graph. The numbers atop the error bars show if there is significant difference between the individual treatments between the two graphs (a and b).

Table 1- Table showing the height of the water tables in the wetlands at three times. The first measurement was taken June 6, the second June 26, and the third July 11.

Water Table Values			
Wetland	**Measurement 1 (cm)**	**Measurement 2 (cm)**	**Measurement 3 (cm)**
County Road B	-0.5	-11.0	+2.0
Donut	-1.0	-1.0	+17.0
South Gate	-6.0	-3.0	-1.5
Degobah	-3.7	-10.0	-3.6
IF1	-3.8	-9.8	-3.6
Nih	-2.2	-7.9	-2.0
Bolger	+11.9	+33.0	+50.0
RF2	+7.0	---	+21.0
Ward	+13.7	+8.7	+13.8

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Species List of *Sphagnum* Identified at UNDERC

County Road B.
S. angustifolium
S. capillifolium var. tenellum
S. cuspidatum
S. fuscum
S. magellanicum

South Gate
S. angustifolium
S. cuspidatum
S. fallax
S. magellanicum
S. quinquefarium
S. subtile

Donut Bog
S. angustifolium
S. capillifolium var. tenellum
S. cuspidatum
S. magellanicum
S. teres

Nih
S. angustifolium
S. centrale
S. cuspidatum
S. fimbriatum
S. magellanicum
S. palustre
S. recurvum

Degobah
S. angustifolium
S. centrale
S. cuspidatum
S. fallax
S. fimbriatum
S. magellanicum
S. palustre
S. squarrosum
S. teres
S. warnstorfi

IF1
S. fallax
S. fimbriatum
S. magellanicum

RF2
S. squarrosum
S. warnstorfi

Bolger
S. angustifolium
S. cuspidatum
S. fallax
S. palustre
S. squarrosum

Ward
S. centrale
S. magellanicum
S. teres