RE-ESTABLISHMENT OF SPHAGNUM PAPILLOSUM UNDER RELATIVELY STABLE WATER TABLE CONDITIONS

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SUMMARY

To assess the regeneration potential of *Sphagnum papillosum* on disturbed peatlands with and without *S. papillosum* fragment application, surface vegetation was removed from 20 study plots in a poor fen located in northern Minnesota, USA during the fall of 1994. *S. papillosum* fragments were spread on ten of the plots, with the other ten plots left bare. Re-vegetation, expressed as percentage cover, was monitored annually over a three-year period (1995-1997). Mean total percentage cover for plots with fragment applications was 84.9%, 96.8%, and 99.4%, for 1995, 1996, and 1997, respectively; compared to 20.8%, 44.7%, and 60.8% for plots without fragments. Mean percentage cover of other peatland plant species, predominantly *Carex* spp., for plots with fragment applications were 5.1%, 16.3%, and 13.0%, compared to 8.6%, 21.5%, and 18.8% for plots without fragments. Significant differences between treatments occurred in 1995 (p=0.011), 1996 (p=0.026), and 1997 (p=0.004). Therefore, although *S. papillosum* fragment applications increased total percentage cover, these were associated with a significant decrease in the percentage cover of other wetland plant species.

**Keywords:** *Sphagnum papillosum, water table, percentage vegetative cover, peatland restoration*

INTRODUCTION

Minnesota has an estimated 3 million hectares of peatlands (Olson et al., 1979) and is one of the leading states in the U.S. in both the conservation of wetlands and the harvesting of horticultural peat. Peatland restoration is essential in order to preserve both economic and environmental interests.

Peatland restoration is defined as the managed restoration of harvested peatlands to wetland vegetation and functional wetland status. Approximately 400 hectares of peatland in Minnesota are currently managed for the harvesting of *Sphagnum* moss peat. Under State and Federal regulations harvested sites must be restored to a natural state after harvesting has ceased.

According to the Minnesota Department of Natural Resources Peatland Reclamation Rules (Minnesota Department of Natural Resources, 1985), a peat company generally has two options in reclaiming a harvested site. The first option is to reclaim it to a specific end use such as forestry, agriculture, biomass production or wildlife habitat. The second option is to stabilize the surface with wetland or typical peatland vegetation and meet a 5-year cover standard, which is essentially the same as peatland restoration. The regulations regarding the second option specifically state that "during the fourth and fifth years following initiation of re-vegetation, a vegetated reclaimed area shall have a 75 percent live vegetative cover comprised of wetland or typical peatland species that are either planted or naturally occurring." Peat producers and State and Federal regulatory agencies currently prefer the second option.

*Sphagnum* species regenerate both by vegetative means and by germination of spores. Vegetative reproduction is by far the most common, although plants occasionally produce spores during the summer months (Darlington, 1964). Several field studies have shown the potential for regenerating *Sphagnum* moss by spreading live moss fragments on a suitable site (Elling & Knighton, 1984; Rochefort et al., 1995; Campeau & Rochefort, 1996). Restoration research to date has also shown that probably the most important factor in regenerating *Sphagnum* moss is a high and relatively stable water level (Wheeler & Shaw, 1995; Campeau & Rochefort, 1996).

*Sphagnum papillosum* Lindb. (McQueen, 1990) is a common component of pioneer plant assemblages occurring on some of the few post-harvested peatland sites in Minnesota that have re-vegetated naturally. This suggests its potential for use in
peatland restoration. *S. papillosum* is also the predominant moss species commercially harvested from peatlands in Wisconsin where it is commonly known as "top moss" or "floral moss". The concept of "Sphagnum farming" was the original reason for this study. With the recent interest in peatland restoration it became apparent that it could also serve as a best-case scenario for determining the maximum restoration potential for *S. papillosum* under relatively favorable conditions.

If post-harvested peatlands do not re-vegetate naturally, even under relatively favorable conditions, then restoration of these sites requires active site management in order to successfully re-establish *S. papillosum*. The objective of this study is to assess the regeneration potential of *S. papillosum* on disturbed peatlands with relatively stable water table levels.

**STUDY AREA**

The study was carried out on a poor fen bordering the Toivola South raised bog in northern Minnesota, USA (47°08' N, 92°49' W) in September 1994. Mean annual precipitation in this region is 685 mm, with 40-50% occurring in June, July, and August. Mean annual snowfall is 1270-1525 mm. Mean summer and winter temperatures are 17°C and -13°C respectively (Minnesota Climatology Working Group, 2000).

The peatland began forming on the bottom sediments of former glacial Lake Upham approximately 5,500 years ago (Olson et al., 1979). The site vegetation consists predominantly of a *S. papillosum* lawn with an overstorey of ericaceous shrubs and *Carex* spp. Small hummocks of *S. magellanicum* and *S. capillifolium* also occur.

At the time of site selection (June 1994) surface water pH was 4.00. Conductivity was 0.0 uS cm⁻¹, corrected for temperature at 20°C, with hydrogen ion contribution subtracted according to Sjörs (1952).

**MATERIALS AND METHODS**

To assess re-vegetation success with and without *S. papillosum* fragment application, surface vegetation (e.g. *Sphagnum* spp., ericaceous shrubs, and *Carex* spp.) was removed from 20 - 1.5 m x 1.5 m (2.25 m²) plots. The study was arranged in a randomized block design (5 blocks, each containing 4 plots) with *S. papillosum* fragments collected from the surrounding area, spread on ten of the plots, with the other ten plots left bare. The moss fragments were lightly packed to help keep them in place and maintain contact with the moist peat surface. A boardwalk was constructed at the site to provide access to each research plot with minimal disturbance.

*S. papillosum* fragments for use in the study were collected from within the same poor fen. The top 4 cm of each moss plant was collected and cut into two 2 cm pieces, one consisting of only stem material and the other of stem and capitulum. The moss fragments were applied at a density sufficient to completely cover the bare peat surface, approximately 12,500 fragments m⁻². For restoration purposes, the fragment application density is sometimes expressed as a ratio of the natural, undisturbed bog surface area from which moss fragments are collected to the area of bare peat surface on which they are spread (Campeau & Rochefort, 1996). Assuming that each moss plant yields two fragments, an application density of 12,500 fragments m⁻² requires 6,250 moss plants m⁻². At the undisturbed poor fen site from which the moss fragments were collected, the natural density was approximately 24,800 moss plants m⁻². The resulting ratio is approximately 1 part natural bog harvested to 4 parts bare peat restored, or 1:4. This ratio is considerably higher than the 1:15 ratio recommended by more recent studies (Quinty & Rochefort, 1997).

A monitoring well (3 inch diameter slotted PVC pipe) was installed at the center of the site in order to observe water table levels on a monthly basis throughout the growing season. The monitoring well was anchored to the mineral substrate beneath the peat layer to minimize movement as a result of water table fluctuations and frost heave. Only one monitoring well was installed since it was assumed that the water table would be approximately constant within the relatively small study area (10 m x 15 m). All water table measurements were made in relation to the top of the monitoring well.

Re-vegetation, expressed as percentage cover, was monitored each September over a three-year period (1995-1997) using a Cover-Point Optical Device (ESCO Associates Inc., Boulder, Colorado, U.S.A.). To avoid edge effects, only the interior 1 m x 1 m area of each plot was monitored. The Cover-Point Optical Device is designed for use in determining percentage vegetation cover using the point-intercept method (Clarke, 1986; Norland et al., 1992). The system consists of an optical device mounted on a horizontal bar, which is supported above the sampling area on one end by a standard photographic tripod and on the other by an adjustable support rod. The optical device, similar in appearance to a telescopic rifle sight, has 5x
magnification with extremely fine cross hairs for viewing a relatively dimensionless point. The horizontal bar is approximately 1 meter long with 10 stops at 10 cm intervals. The percentage vegetation cover is determined by looking through the eyepiece and recording hits and misses of vegetation using the fine cross hairs within the optics for each of 10 sample points across the bar. For this study 10 transects were made across each 1m x 1m plot for a total of 100 sampling points per plot. To assess re-vegetation composition, Sphagnum and other peatland plant species percentage covers were determined separately and also in combination when more than one species occurred at the same sampling point (e.g. one species at ground level and one in the canopy).

All statistical analyses were conducted using SigmaStat® version 2.0 or SAS System for Windows version 6.12 computer software. The SAS general linear models procedure was used to determine significant block and treatment effects. Data transformations were conducted when necessary to ensure data compliance with statistical assumptions of normal distribution and equal variance. Significant treatment differences were based on a p value <0.05.

RESULTS AND DISCUSSION

Water Table Fluctuations

As mentioned previously, during the course of the study, all water table measurements were made in relation to the top of the monitoring well. To adjust these measurements to correspond to the peat surface, the monitoring well height above the ground level was measured in May 1998. During the analysis of the water table data, it was noticed that the adjusted water table levels appeared higher than those observed in the field. Therefore, monitoring well height above the peat surface was again measured in July 1998. The July height measurement was approximately 7 cm less than in May. Since the monitoring well was securely anchored in the underlying mineral substrate, the only explanation was that the peat surface was fluctuating. The May measurement was taken during a relatively dry period, resulting in a lower peat surface level, while the July measurement occurred during a wet period, with a higher associated peat surface level.

To take this phenomenon into account, four monitoring well height measurements were taken over the course of the 1998 growing season at varying water table levels. The water table levels, in relation to the monitoring well, were plotted against the water table levels relative to the peat surface. The resulting regression line and equation presented in Figure 1 were used to adjust all measurements to correspond with the peat surface. A graph showing the adjusted water table levels for the three-year period is presented in Figure 2.

The water table level remained relatively stable in relation to the peat surface throughout the study period. The minimum water table level recorded during the study period was approximately 3 cm below the peat surface in June 1995, and the maximum was nearly 8 cm above the peat surface in August 1995, a
fluctuation range of about 11 cm. Although the raised portion of the Toivola South Bog has recently been developed for the harvesting of Sphagnum moss peat, the water levels in the surrounding poor fen have remained relatively high and stable, probably owing to continuity with a larger peatland complex. Water table level fluctuations are also less in fens than in bogs because fens are associated with the regional groundwater system (Boelter & Verry, 1977). The uppermost surface layer of a peatland, or “acrotelm”, which includes the living surface vegetation, recently dead vegetation, and newly formed peat above the zone of permanent saturation (Ingram, 1978) also helps to maintain a high and stable water table level (Schouwenaars & Vink, 1992). The acrotelm at the research site remains quite intact and therefore contributes to water table stability. The water table level remained above the peat surface for most of the study period, especially during the 1995 and 1996 growing seasons. Even though the water table level was quite high, there was no tendency for the moss fragments to wash away, most likely because they were packed after spreading and the plots were small and sheltered. This situation provided favorable conditions for Sphagnum and other peatland plant species throughout the three-year study.

Percentage Vegetation Cover

The mean percentage vegetation covers for 1995, 1996, and 1997, for plots with and without S. papillosum fragment application, are presented as pie charts in Figure 3. Results indicate significantly enhanced (p<0.001) re-vegetation on plots with S. papillosum applications. Mean total percentage covers for plots with fragment applications were 84.9%, 96.8%, and 99.4%, for 1995, 1996, and 1997, respectively, compared to 20.8%, 44.7%, and 60.8% for plots without fragments. These wide differences in total percentage cover were attributed primarily to the successful re-establishment of S. papillosum. Mean percentage covers by other peatland plant species, predominantly Carex spp., for plots with fragment applications were 5.1%, 16.3%, and 13.0%, compared to 8.6%, 21.5%, and 18.8% for plots without fragments. Significant differences between treatments occurred in 1995 (p=0.011), 1996 (p=0.026), and 1997 (p=0.004). Therefore, although S. papillosum fragment applications increased total percentage cover, they were associated with a significant decrease in the percentage cover of other wetland plant species.

A study of natural re-vegetation on five post-harvested, nutrient-poor peatlands in the USA and Canada (Famous et al., 1991) revealed less than 25% vegetation cover after 4 to 10 years. Most of these peatlands, however, were not actively managed for restoration and were characterized by low and frequently fluctuating water table levels.

CONCLUSIONS

The results from the first 3 years of this study are presented in this paper. The research indicates that under relatively favorable conditions, plots with S. papillosum fragments applied may achieve 84.9% mean vegetation cover within one year and up to 99.4% within three years. Plots without S. papillosum fragment applications achieved 60.8% mean vegetation cover after 3 years. It remains to be seen if the plots without fragment applications can achieve the 75% cover required by Minnesota Department of Natural Resources regulations within the 5-year time frame. In any case, it is important to note that the conditions for Sphagnum growth (high and stable water level, close proximity to bog vegetation, and high moss fragment application density) in this study were much more favorable than those usually encountered at post-harvested peatland sites. Therefore, this study should be considered the best-case scenario for S. papillosum re-establishment. Less favorable results are to be expected on most sites.

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REFERENCES


Fig. 3. Mean percent cover for study plots with and without Sphagnum papillosum fragments applied, for 1995, 1996, and 1997 (n=10).

1 Predominantly Sphagnum papillosum but may include Sphagnum capillifolium and/or Sphagnum recurvum.

2 Other species may include:
Andromeda glaucophylla
Carex limosa
Carex oligosperma
Chamaedaphne calyculata
Drosera rotundifolia
Scheuchzeria palustris
Vaccinium oxyccoccus


Minnesota Department of Natural Resources. (1985) *Department of Natural Resources, Peatland Reclamation General Provisions, Chapter 6131.* State Register and Public Documents Division, Department of Administration, St. Paul, MN, USA. 17 pp.


