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REINTRODUCTION OF FEN PLANT COMMUNITIES ON MINEROTROPHIC REMNANT SURFACES AFTER PEAT EXTRACTION

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SUMMARY

The Moss Layer Transfer Technique (MLTT) has been developed to restore industrially peat-extracted bogs. It has been applied successfully to several peatlands across Canada over the last 20 years. Recently, the need has emerged for a similar technique focusing on sites that have been harvested down to their sedge peat layers, where richer and less acidic conditions prevail. In 2009, a peatland presenting these conditions was restored after 50 years of peat extraction. The site was rewetted and three restoration techniques inspired by the MLTT were applied. Five years after the restoration, vegetation surveys have been conducted to assess the efficiency of technique at restoring fen plant covers. The results were compared to similar surveys conducted in an undisturbed area of the donor site as well as in a natural fen adjacent to the restored site. Surprisingly, none of the restoration techniques were efficient at establishing plant covers similar to the reference sites, especially for bryophyte species. In sites where fen species already colonized the surface spontaneously, rewetting could be sufficient to support the recovery of typical vascular plants communities. When profiling the surface is necessary, our results showed that reintroducing donor material is an essential step toward the return of fen species.

Keywords: *moderate-rich fen, peatland restoration, diaspore transfer, rewetting.*

INTRODUCTION

Following industrial activities of peat extraction for horticultural substrates production, the highly disturbed remnant surfaces are hardly recolonized by typical peatland communities and active restoration efforts have to be deployed to ensure their recovery (Lavoie *et al*., 2003, Rochefort *et al.,* 2003, Poulin *et al.,* 2005). In the last 20 years, the Moss Layer Transfer Method (MLTT) has been developed to address the need for an efficient large-scale restoration method for bogs (Quinty and Rochefort 2003, Rochefort *et al,*. 2003). The MLTT consists of six major steps: 1) site preparation: the surface of the extracted bog is profiled to remove any spontaneously established vegetation, to flatten dome-shaped peat fields and to expose fresh peat; 2) diaspore collection: donor material is harvested in a natural fen; 3) diaspore introduction: a thin layer of donor material is spread mechanically on the site; 4) diaspore protection: straw mulch is spread over the donor material; 5) fertilization: slow-release phosphorus fertilizer is applied; 6) rewetting: drainage ditches are blocked or filled to retain water and raise water table level on the site. The MLTT has nowadays been applied in more than 60 restoration projects across Canada (L. Rochefort - unpublished data) and has proven to be an efficient method to enhance bog vegetation recovery (González and Rochefort 2014).

For industrial reasons or because of site characteristics (e.g. shallower peat deposits, nature of the underlying mineral substrate, water circulation patterns), the peat surface left after the cessation of extraction activities can sometimes present richer and less acidic conditions than the former bog conditions. In these cases, restoration toward a fen ecosystem is often more appropriate (Wind-Mulder *et al.,* 1996, Wind-Mulder and Vitt 2000, Triisberg *et al.,* 2014). It is however unknown which restoration method should be applied. Numerous fen restoration projects have been conducted in Europe, but their overall objectives differ from the ones pursued in North America. While European restoration usually aims at repairing fens drained for agriculture by restoring their biodiversity, North American restoration projects usually take place on post-extraction sites devoid of vegetation and focus on the return of the ecosystem functions (Rasran *et al.* 2007, Graf and Rochefort 2008a, Lamers *et al*., 2015). The restoration methods applied are therefore not directly transferable. In USA and Canada, successful trials of small-scale fen restoration trials have been conducted using sedge plantations and rewetting (Cooper and MacDonald 2000) as well as donor material introduction (Cobbaert *et al.,* 2004, Graf and Rochefort 2008a, 2008b). These results suggest that restoration methods based on some of the steps of the MLTT could be efficient at restoring fens on a larger scale. In this context, distinct restoration methods should be tested and developed for North American fen restoration projects. This project presents the results of the first fen restoration project at the ecosystem-scale following horticultural peat extraction activities in North America. For the purpose of this extended abstract, only partial results are presented and discussed as a scientific manuscript has been submitted for publication in Botany. Please consult and refer to the published article *Reintroduction of fen plant communities on a degraded minerotrophic peatland* for complete results.

METHODS

The Bic-St-Fabien research station is located in Eastern Canada (province of Québec). The 15 ha site is a former bog used for industrial horticultural peat extraction for 50 years before the activities ceased in 2000. In 2009, the site was partly covered with *Schoenoplectus tabernaemontani* (C.C. Gmelin) Palla, *Alnus rugosa* (DuRoi) Sprengel, *Salix sp.* and *Typha latifolia* (Linnaeus) (L. Rochefort – unpublished data). The pore water averaged over the site presented moderately minerotrophic conditions: pH: 6.1 ± 0.3, mean ± sd, n=80 and corrected electric conductivity: 334 ± 158 µS cm^{-1}, mean ± SD; n=80 (L. Rochefort - unpublished data; according to values presented in Vitt *et al.,* 1995). Restoration work towards a fen ecosystem was realised from winter 2009 to spring 2010. Donor material was collected mechanically in a nearby natural fen margin dominated by brown mosses (total cover: 55%). Rewetting was performed by backfilling and blocking former drainage ditches with decomposed peat. No fertilizer was applied. Because of site characteristics, three restoration techniques were tested on the site: **1) Mechanical technique** (2.18 ha): peatland surface was profiled, donor material was introduced and protected by straw mulch, both spread mechanically; **2) Profiling technique** (3.55 ha): surface was profiled but without plant introduction; **3) Rewetting technique** (4.85 ha): ditches were blocked, with no modification to the surface to preserve the spontaneously established vegetation in place.

In order to compare the establishment of fen plants communities in each restored sector, vegetation surveys were conducted 5 years after the restoration. Sampling units were installed in each restored. Within each unit, all vascular plants species were identified in four systematically located 1 m x 1 m quadrats. The ground surface covered by each species was estimated, as well as the total surface covered by all vascular plant strata. Similar surveys were also conducted in two natural fen portions at the margin of the restored site and in an undisturbed sector of the donor site to allow comparisons with nearby natural fen ecosystems that could act as propagule sources. The bryophytes were surveyed using a similar method, in 12 quadrats (25 cm x 25 cm). Plant recovery for each restoration technique was compared using descriptive statistics (mean and standard error of different vegetation classes at the plot level).

RESULTS

Five growing seasons post-restoration, vegetation covers were considerably lower in all restored sectors than in the reference ecosystem (Fig. 1). Vascular plant covers were relatively high in the sectors restored by the Rewetting technique, but the proportions of covers associated to species found in the Reference ecosystem were the lowest. At the opposite, the low vascular plant covers observed in the Profiling and Mechanical techniques showed the highest proportions of species associated to the reference ecosystem (55 and 80 % respectively). The plant communities, however, differed greatly between these two sectors: the Mechanical technique was dominated by *Myrica gale* Linnaeus, *Trichophorum alpinum* (Linnaeus) Persoon and *Sanguisorba canadensis* Linnaeus, which are all found in the reference ecosystem, while the Profiling technique was mainly covered by *Carex aquatilis* Wahlenberg and *Eriophorum vaginatum* Linnaeus, the latter being absent from the reference ecosystem.

While bryophytes formed a major component of the reference ecosystem (mean cover from 37% to 71%), their covers were lower in all restored sectors. Brown mosses were virtually absent from all sectors except the Rewetting technique, where it was very variable.

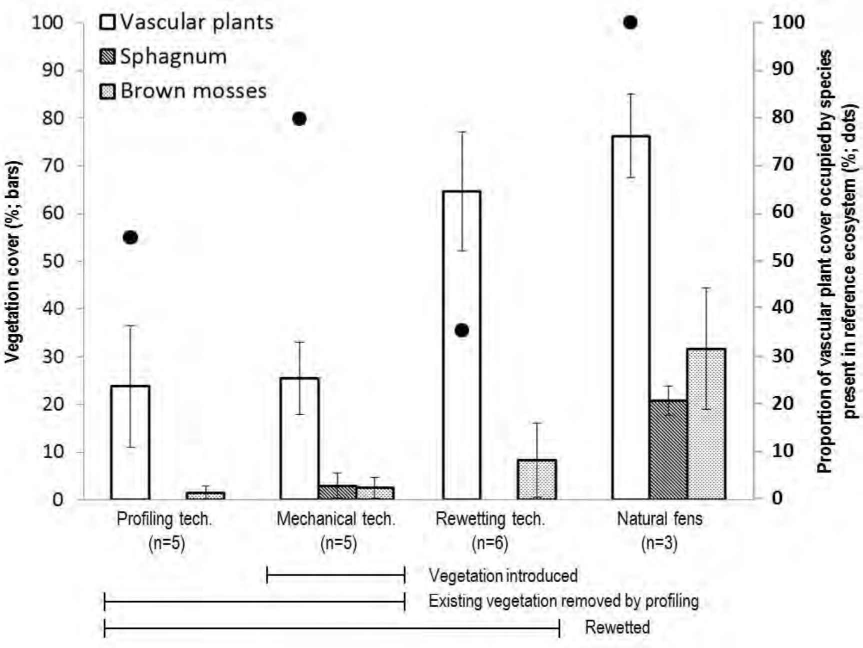

Figure 1: Plant cover (% ± SE) by plant groups in restored sectors (bars) and the proportion of vascular plant cover occupied by species also found in the reference ecosystem (dots). The number of plots (n) by sector is proportional to its size, except for the reference ecosystem where vegetation surveys were performed in three nearby natural fens.

DISCUSSION

Five growing seasons after restoration, none of the techniques applied to restore the Bic-St-Fabien peatland allowed the establishment of vegetation covers similar to the ones observed in the natural fens used as reference ecosystems. The bryophyte communities, which usually form a major part of fen vegetation (Rydin and Jeglum 2013), only established very scarcely. In the sectors where donor material was introduced, the covers obtained suggest that *Sphagnum* and brown mosses might be recalcitrant to mechanical manipulations (including during diaspore collection and spreading steps). This idea is reinforced by the observation that manual introduction of similar donor material elsewhere on site evolved into well-established bryophyte carpets. The Rewetting technique, in which no donor material was introduced, supported the higher brown mosses cover. This could be explained by the presence of bryophytes on this sector prior to restoration work, as well as the creation of conditions (water availability, protective sedge cover) favorable to their establishment and expansion.

The vascular plant communities established in each sector were different in terms of plant composition and covers, the most vegetated being the Rewetting technique. However, the absolute cover associated with the species also found in the natural fens were similar in all sectors regardless of the restoration technique applied, ranging from 15 to 23%. During the restoration, rewetting was performed at the site level and led to a significant rise of the water table (Malloy and Price 2014) in all sectors. In the Rewetted technique, the vegetation that was present before the restoration was preserved and still dominated five years later. As with the brown mosses, spontaneously established vascular plants probably benefited the favorable conditions provided by the rise of the water level. The Rewetting technique could therefore be considered in restoration projects in areas where fen-type vegetation is already in place.

When the site to restore has to be profiled to flatten or reorganise the surface, the conjunction of bare peat areas and high water levels might lead to erosion or frost heaving. In the sector where the Profiling technique was applied, both phenomena, combined with the absence of diaspores to initiate revegetation, resulted in very low plant covers. This technique is therefore not suggested for fen restoration. Donor material could not only promote the establishment of species from the reference ecosystem, but also speed up the colonization process which could facilitate surface stabilization and enhance fen-type communities‘ growth. However, the vascular plant covers installed following the Mechanical spreading of material were also very low. These disappointing results could be explained by various reasons, including the effect of surface instability the choice of the donor site based on the bryophytes communities. The mechanical manipulation of the bryophytes also appears to impede their recovery and improvement of these steps is essential for large-scale restoration. The effect of donor material timing and collection method should also be further investigated.

CONCLUSION

The restoration of the Bic-St-Fabien peatland is the first ecosystem-scale fen restoration project following horticultural peat extraction in North America. Contrary to our assumptions, the three techniques tested did not lead to identifying a restoration method that could be prescribed to the site level to ensure fen-type vegetation establishment. On the contrary, it highlights the need to consider local site conditions and combining restoration techniques. In areas where fen vegetation established spontaneously, the Rewetting technique could lead to the expansion of the communities already in place by providing favorable conditions. When profiling the surface is needed to ensure better water circulation, to expose fresh peat or to construct erosion control features, diaspore introduction is necessary to launch the establishment of fen vascular plants and bryophytes species, but more research have to be carried out about efficient mechanical reintroduction of material.

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