Comparing monitoring methodologies for assessing restoration success in peatlands

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Summary

Restoration specialists are often criticised for not establishing a proper monitoring program that would help judging the success of a restoration project. Here, we present a study case where monitoring has taken place for seven years after restoring a cut-over bog. The aim of this presentation is 1) to assess peatland restoration success when using the *Sphagnum* moss transfer restoration approach and 2) to compare different monitoring methods for assessing restoration success.

The site is a cut-over bog of 11.4 ha, of which 8.5 ha were restored in 1999. The restoration approach consisted mainly in reintroducing bog-plant diaspores, spreading a straw mulching, blocking the former drainage ditches, and applying a low dose of phosphorus fertiliser. A pre-restored (1999) vegetation point survey and three post-restored (2001, 2003 and 2005) surveys were conducted using a systematic grid of approximately 6900 points (every 3 m × 5 m). In addition to this line-point interception survey, permanent quadrats were established and surveyed every year since 1999. The recovery of vegetation was assessed with a reference ecosystem. In brief, *Sphagnum* had a frequency of occurrence of 55% from the line-point interception survey, which is close to what is found in the nearby reference system. The cover of the nursing moss *Polytrichum strictum* was twice as abundant in the restored site than in the reference ecosystem in 2003 but figures for 2005 show that it is decreasing slowly. The cover of the herb strata was also higher than in natural reference peatlands but we expect a decrease in the cover of the main herb species, *Eriophorum vaginatum* (cotton-grass) with time. Overall, the *Sphagnum* moss transfer restoration approach appears an efficient catalyst for restoring a moss carpet on cut-over bogs. Discrepancies between the two survey techniques are discussed for vegetation strata and particular species.

Key index words: peatland, restoration, monitoring of success, permanent plot, pin-point method

Introduction

Restoration specialists are often criticised for not establishing a proper monitoring program that would help judging the success of a given restoration project. Indeed, it is often difficult to appraise restoration success, because it requires clearly defined goals associated with an accurate monitoring program (Ehrenfeld, 2000) and a reference ecosystem for comparison that encompasses regional variation. In that respect, the choice of the sampling method used for vegetation monitoring is particularly critical as it can influence restoration success assessment (Korb *et al.*, 2003). Here we present an assessment of vegetation recovery carried out over 6 years and using two different methods: the line-point intercept method and the use of permanent plots.

Materials and methods

The experimental site

The research station of Bois-des-Bel, developed with the aim to intensively study the recovery of a peatland ecosystem after its restoration, is located 200-km east of Québec city (47°48' N, 69°28' W). Peat extraction stopped in 1980 and the mined section was abandoned. In 1999, PERG initiated a restoration project on the mined section (11.5 ha). The site was restored with the *Sphagnum* moss transfer approach according to the method described in Quinty and Rochefort (2003). A total area of 8.4 ha was restored, i.e. 8 of the initial 11 peat fields (restored zone of Fig. 1), and leaving 2.1 ha on the eastern side of the site un-restored i.e. submitted only to natural colonisation (non-restored zone of Fig. 1). Between these two zones, one peat field was used as a buffer zone (1 ha).

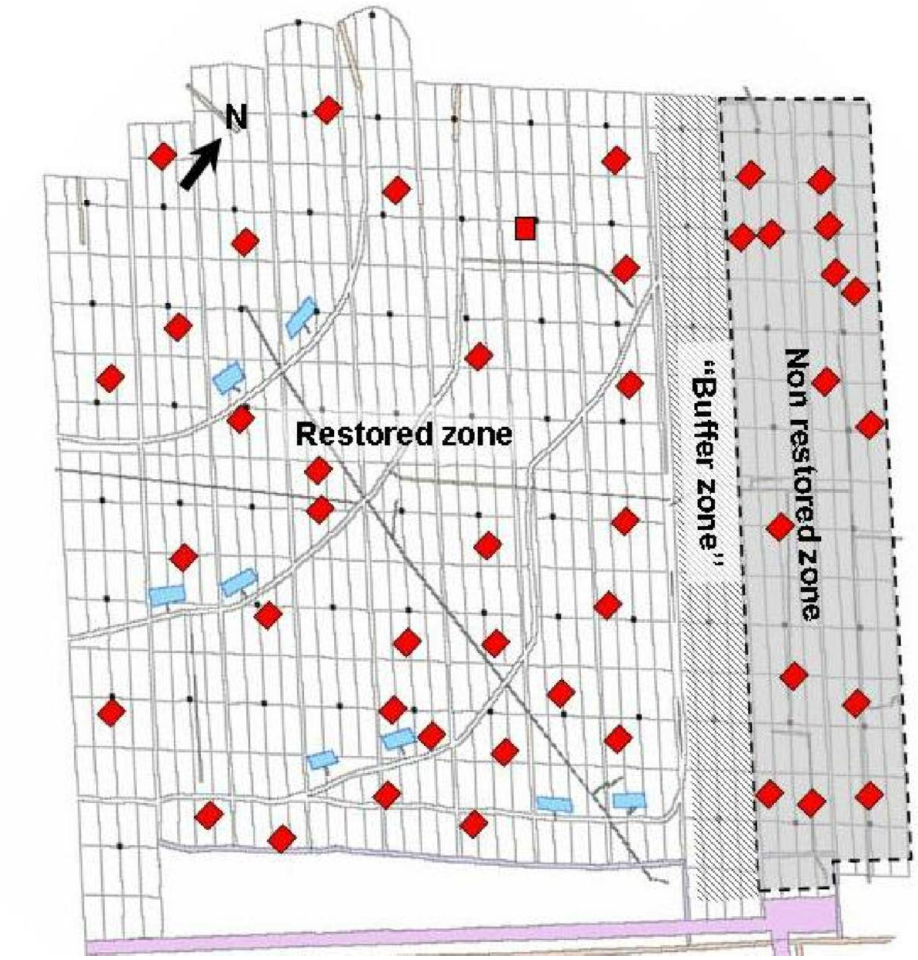

Figure 1. Map and GIS grid of the study site. Curved grey lines that cross the site are embankments and grey rectangles represent pools created for the restoration. The red rectangles are the permanent plots.

Vegetation sampling and data treatment

The methods described in the next sections were used to collect vegetation data over the site. We defined five vegetation strata according to their growth-form as following:

1- *Sphagnum* mosses;
2- Bryophytes, including mosses (other than *Sphagnum*), liverworts, and hornworts. Lichens were also considered in this strata (exclusively the species which grow on soil surface);
3- Ericaceae family;
4- Shrubs and trees (ligneous plants other than Ericaceae);
5- Herbs.

The line-point intercept method (LPI)

We used the line-point intercept method (Bonham, 1989) to collect data over the entire site. A vertical rod was placed along a 30m long transect every 3m i.e. at 10 equidistant points. Transects were moved every 5m from the beginning of the peat field. All plant species intercepted by the rod (6 to 8 mm in diameter) or by its upward projection were recorded then grouped into the defined vegetation strata. The surveys were conducted in the month of July, once prior to restoration (1999) and every two years after restoration (2001, 2003 and 2005). Total frequency for each species was calculated as the percentage of intercept points (hits) relative to the total number of points sampled, which was on average 4452 for the restored zone and 1225 for the non-restored zone. The number of sampled points varied slightly from year to year due to spatial inaccuracy when moving transects. Using this method, an estimate of total cover for each stratum can be calculated as the percentage of species hits of particular stratum, relative to the total number of points sampled.

Permanent plots

A total of 47 permanent plots were installed at the site: 32 in the restored zone and 15 in the non-restored zone (Fig. 1). Each plot measures 3 by 8m. Cover of plant strata was estimated at the plot scale with a modified Braun-Blanquet scale where 0 = 0%, + < 1%, 1 = 1-10%, 2 = 11-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-100%. Nested within the plots, six circular subplots of 70 cm in diameter were systematically surveyed for estimating the vegetation cover at the species level to the nearest % value. Vegetation cover in the plots was derived from mean vegetated cover in the sub-plots. Permanent plots were surveyed every year since 1999, in late August.

Results and discussion

Percent cover of bare peat, litter and frost-heaved dead woods definitively decreased from the year prior to restoration (97% the year of restoration) up to 6 years post-restoration. The non-vegetated area was less than 10% six years after restoration, meaning that all vegetation strata combined have reached over 90% total cover.

The establishment of *Sphagnum* diaspores was remarkable over the years and clearly higher in the restored zone in comparison with the zone with natural colonisation only. *Sphagnum* cover in the non-restored zone reached a maximum of 0.25 % six years after restoration while it attained 60% the same year in the restored zone with the line-intercept method (50% according to the permanent plot method). The *Sphagnum* cover is steadily expanding to reach the range of *Sphagnum* cover found in the natural sites (80% ± 17 SD). The cover of *Sphagnum* was essentially composed by *Sphagnum rubellum* (Fig. 2) which represented nearly three-quarter of the total species composition. *S. magellanicum* was the second most abundant species with 10% and 15% of the *Sphagnum* composition. Among the minor species, *S. angustifolium, S. fallax* and *S. cuspidatum* were observed most frequently. Surprisingly *S. fuscum* was called one of the most abundant species at 4 years post-restoration but proved to be a minor species when the survey was repeated two years later (six years post-restoration). In 2003 (four years post-restoration), it was the first time that the different species of *Sphagnum* were identified with the line-point intercept method and the individual stem were still small, making the identification difficult. Most likely *S. fuscum* was misidentified and over-estimated that year. It is not surprising to see *Sphagnum rubellum* dominating the post-restored lawns as it is a species that thrives well in peatland lawn biotopes.

Cover of ericaceous species has steadily increased in both the restored and non-restored zone over the seven years of monitoring (from 10% to 20-40%). However the dominant species are not the same. In the restored zone, a

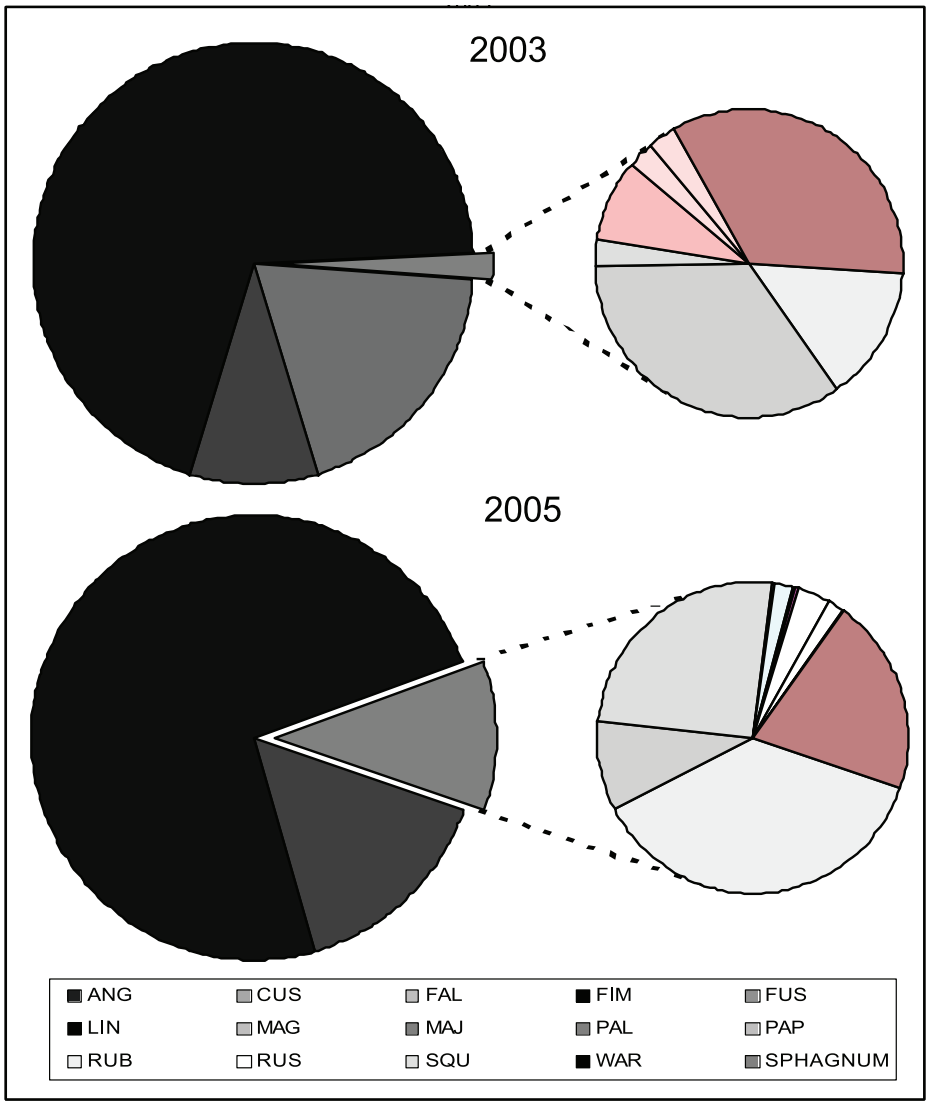

Figure 2. Fig.2. Proportion of the different *Sphagnum* species after the restoration. Percentages below 0.05 appear in black. The species of Sphagnum are: ANG = *S. angustifolium*, CUS = *S. cuspidatum*, FAL = *S. fallax*, FIM = *S. fimbriatum*, FUS = *S. fuscum*, LIN = *S. lindbergii*, MAG = *S. magellanicum*; MAJ = *S. majus*, PAL = *S. palustre*, PAP = *S. papillosum*, RUB = *S. rubellum*, RUS = *S. russowii*, SQU = *S. squarrosum*, WAR = *S. warnstorfia*, SPHAGNUM = undetermined species.

clear dominance of *Chamaedaphne calyculata* (L.) Moench is noted (29% versus 1% in the non-restored zone), whereas in the non-restored zone *Vaccinium angustifolium* Ait. (23 % versus 8% for the restored zone) and *Ledum groenlandicum* (16 % versus 12%) are dominant. The more humid conditions created by the newly established moss carpet appears to favour the development of *Chamaedaphne calyculata,* one of the ericaceous shrub species most adapted to wetter conditions in peatlands.

The cover of the herbaceous layer, including species of grasses, sedges, forbs and legumes, was 12 times greater in the restored zone compared to the regional reference ecosystems. This abundance is mostly driven by the flourishing development of *Eriophorum vaginatum L.* up to six years post-restoration but in the 7th year a marked decline is recorded as predicted by the work of Marcoux (2000) and Lavoie *et al.* (2005) .

Trees and shrubs (excluding the ones in the Ericaceae family) are still lagging behind in their development as their cover is less than that recorded in the natural nearby reference system.

Conclusion

The restoration techniques that were used seven years ago seem very effective for restoring the mined peatland in its entirety. (1) The *Sphagnum* carpet is well established and is dominated by *Sphagnum rubellum*. (2) Both non-vascular and vascular vegetation cover the entire peat surface of the site. (3) Fifteen different species of *Sphagnum* are present in the restored section, as well as several species of mosses and liverworts (16 species), *Ericaceae* (20 species), other shrubs (18 species) and herbs (55 species). The restoration procedure should drive this mined peatland towards a functional and 'typical' peatland ecosystem. One has to be aware of the differences given by each method used to assess vegetation establishment after restoration. Both methods, the line-point intercept and permanent plot methods show similar results in assessing *Sphagnum* moss occurrence but in general the line-point intercept method overestimates the abundance of vascular plants.

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