Scenario of future development with management

Z_0 is the only parameter of the model which can be manipulated. To keep the water table close to the surface of the bog, the base of the groundwater mound has to be raised. This can be achieved by managing the boundary drains, but - even more importantly - the drains in the surrounding pasture. If it is possible to raise the pasture by 1.5 m (Z_0 = 4.5m) the calculated height of the groundwater mound would be 6.8 m (Fig. 30.4c).

Discussion

Although the concept of the groundwater mound theory incorporates simplifications, it remains of threefold importance (Ingram, 1992). Firstly, it provides a simple explanation for the morphology of raised bogs. Secondly, it suggests how their stability is maintained. Thirdly, it indicates how one might predict the consequences of human cultural interference.

This study shows how the prediction of future scenarios is useful for management recommendations. The results of the calibrated model are similar to those made following the initial study (Bragg *et al.*, 1993). The data required to adapt the groundwater mound model to certain sites, hydraulic conductivity of the catotelm and standard meteorological data, are quite easy to obtain.

For conservation purposes it is important to understand that conservation of ombrotrophic raised bogs implicates management and conservation of the surrounding land. The application of the groundwater mound theory gives a valuable tool to establish such management concepts.

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Chapter thirty-one:

Rehabilitation Work on Post-Harvested Bogs in South Eastern Canada

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Introduction

While approximately 12% of Canada's landscape is covered by peatlands (Zoltai, 1988), the impact of agriculture, drainage, urbanisation and peat harvesting on bogs and fens has mainly been concentrated in the southern portion of the country. In southern Québec and in New Brunswick, peat harvesting dates back to the beginning of the century and is an important local industry for some communities. In the sixties and seventies, vacuum-harvesting gradually replaced the labour-intensive manual block-cutting technique.

In contrast to what can be found in other regions or countries, only the moderately decomposed *Sphagnum* peat was, and still is, mined from Canadian bogs. Peat mined in Canada is used mainly for horticultural purposes (Keys, 1992) and, more recently, for other industrial uses such as the production of absorbent boards and biofilters. Once peat mining reaches layers of peat that are too decomposed for the intended use, harvesting stops and peat fields are abandoned. In the last few decades, a number of sites were also abandoned for reasons not related to the status of the peat itself (e.g. a small company closing down its operations after a few years). Therefore, most abandoned peat fields are still covered by variable thickness of residual peat. Approximately 30 abandoned sites are found in Québec and New Brunswick (Line Rochefort, unpublished data). The size of these sites varies greatly and many sites are parts of larger peatlands that are still currently being harvested.

Abandoned, vacuum-harvested sites are characterised by relatively flat surfaces bordered by drainage ditches and are generally fairly young, having been abandoned between one to 15 years. In contrast, sites that were abandoned after mining with the block-cutting method are older and have characteristic alternate baulks and trenches. Revegetation patterns of sites harvested with the two methods also differ. Abandoned sites mined with the block-cutting technique seem to revegetate with peatland species more easily than do vacuum-harvested sites, although a *Sphagnum* moss layer may not necessarily be present in the newly established vegetation (Lavoie and Rochefort, 1996). Vacuum-harvested surfaces, in contrast, can remain almost bare even ten years after peat mining stops, and thus are likely to need some form of intervention to ensure the return of a typical peatland flora.

A multidisciplinary and collaborative research project

In 1993, a collaborative research project on peatland rehabilitation was launched in Québec. The objectives of the project were:

1. To develop restoration techniques that would allow abandoned peat fields to once again become functional wetland ecosystems.
2. To further build our knowledge of peatland fauna, flora and ecology in Québec.
3. To produce a restoration field guide for peat producers.

The project is a collaborative effort between university researchers, governmental and non-governmental agencies and the peat industry. A smaller research project involving the New Brunswick government and a peat company is also taking place in north-eastern New Brunswick.

Peatlands are complex ecosystems and research aimed at restoring abandoned sites to functional wetlands necessitates a multidisciplinary approach. This is well reflected by the research team which includes not only plant ecologists, but also bird, arthropod, microbiology and hydrology specialists. A number of graduate and undergraduate students and several research assistants are also involved. The multidisciplinarity and partnership components of the projects ensure a healthy exchange of information and opinions, and allows for a productive sharing of financial and material resources as well as expertise.

The ongoing projects also encompass a broad geographical range. Restoration experiments were conducted at three different vacuum-harvested sites in Québec and at one vacuum-harvested coastal site in New Brunswick (Fig. 31.1). In addition, comparison of the chemistry, fauna and flora of natural and post-harvested sites of different ages were conducted at several more vacuum-harvested and block-cut sites. Finally, extensive vegetation surveys of abandoned sites were conducted throughout south-eastern Canada.

During these projects, efforts were concentrated on developing restoration techniques adapted to vacuum-harvested peatland, not only because they seem to revegetate less easily than block-cut sites but also because these sites represent the type of residual surfaces that will be dominant in the future. Therefore, the planned restoration field guide will deal more specifically with the restoration of vacuum-harvested peat fields.

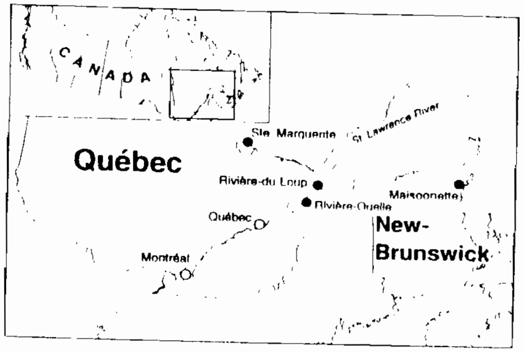

Fig. 31.1. Location of the vacuum-harvested peatlands used for restoration experiments in Québec and New Brunswick (indicated by the filled circles).

Approaches to vegetation re-establishment on cutover surfaces

A number of experiments throughout the project have specifically addressed the question of promoting moss and vascular plant recolonisation on to the remaining bare peat of cut-over surfaces. Indeed, the re-establishment of typical mire species, *Sphagnum* mosses in particular, is an essential element to the re-establishment of a functional peatland ecosystem (Wheeler and Shaw, 1995b).

A major hindrance to typical mire vegetation re-establishment on abandoned peat fields is the lowered water table, caused by drainage associated with peat mining (Wheeler and Shaw, 1995b). Another possible reason for the low rate of natural revegetation of these sites is that the remaining peat is almost devoid of plants. Some form of plant reintroduction thus seems necessary to ensure recolonisation of the surface by vascular plants and mosses. In contrast to situations found elsewhere, where peat can be harvested almost down to the mineral layer, an important peat layer remains on the abandoned sites in Canada. Water and peat chemistry in the four experimental peat fields were shown to resemble bog or poor fen conditions, with the exception of being somewhat nutrient enriched (H. Wind-Mulder, unpublished data). It was hypothesised that direct reintroduction of bog or poor-fen vegetation should be possible without retracing all the successional vegetation stages leading to peatland formation.

Plant re-introductions

Researchers have shown that almost any portion of a living *Sphagnum* plant, possibly with the exception of leaves, can regenerate a new individual when isolated from the parent plant (Poschlod and Pfadenhauer, 1989; Cronberg, 1991; Rochefort, Gauthier and Lequéré, 1995). Can this regeneration potential of *Sphagnum* be used to re-establish a moss carpet on bare peat?

We first attempted to answer this question in a greenhouse trial where the recolonisation potential of *Sphagnum* fragments exposed to different water levels was examined (Campeau and Rochefort, 1996). The plants were collected from the top 10 cm of the peat column, cut into fragments, and hand spread on a series of peat-filled containers where the water level was maintained at either 5, 15 or 15 cm below the peat surface. The containers were watered regularly to imitate, in quantity and quality, the water input received from the rain in the field. This experiment demonstrated that it is possible, starting from fragments sparsely distributed on the peat, to re-establish a complete *Sphagnum* cover. Results also showed that recolonisation success of *Sphagnum* strongly depends on the water level in the peat substrate (Campeau and Rochefort, 1996). At high water level, for most species tested, the fragments produced a complete *Sphagnum* cover within six months. In drier conditions however, only 10-20% of the surface of the peat-filled containers was covered by *Sphagnum* after six months (Campeau and Rochefort, 1996). Similarly, other researchers have also suggested that the water table in a cut-over site needs to be maintained very near the pear surface for *Sphagnum* mosses to have a chance to establish (Money, 1995; Wheeler and Shaw, 1995b).

Rewetting the cutover surface

In an attempt to rewet the four experimental post-mined peatlands bulldozed peat was used to block drainage ditches. Generally, blocking the ditches successfully raised the water table close to the surface in the spring and fall. In the summer, however, the water level tended to drop further, and to vary more, in the experimental sites than they would in an undisturbed bog (Fig. 31.2). These observations are not unique to North American cutover peatlands. Other researchers have encountered similar difficulties when raising the water table of post-harvested sites to try and ensure favourable conditions for peatland vegetation re-establishment (Schouwenaars, 1988; Wheeler and Shaw, 1995b). Large scale increases in the water table of a post-mined area may be further complicated by the fact that, in eastern Canada, these sites often lie adjacent to areas where peat is still being extracted. In other countries, like Switzerland, raising the water table to an effective level for restoration purposes may also be very difficult in cases where the remaining bog forms an elevated island surrounded by intensive agricultural land (Grosvernier *et al.*, 1995). On surfaces that are not permanently inundated, the peat surface might not only dry up on a warm summer day but often form a crust preventing *Sphagnum* fragments from gaining access to the water in the underlying wet peat (Grosvernier *et al.*, 1995; L. Rochefort and J. Price, unpublished data). Even when high water level conditions are achieved, such as in shallow pools, research suggests that only lawn forming species of Sphagna would be able to recolonise readily (Money, 1995).

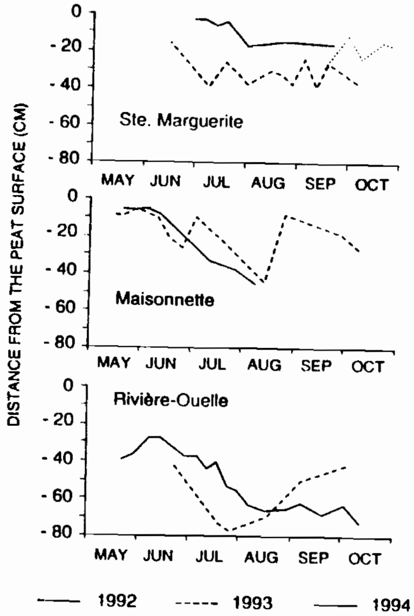

Fig. 31.2. Water table fluctuations in three experimental cut-over sites where drainage ditches were blocked with bulldozed peat.

Sheltering the reintroduced diaspores

Hence, *Sphagnum* fragments need to be kept relatively wet in order to survive and regenerate new individuals. In the field however, it is difficult to raise the water table to a level that will be sufficient to promote *Sphagnum* regeneration and growth. Our experiments thus concentrated on finding an alternative to a high water table in order to provide appropriate humidity conditions for *Sphagnum* and other bog plants to re-establish. This approach parallels that proposed by Grosvernier *et al.* (1995), who suggested that water table level, although it is a fundamental factor, may not be an exclusive necessity for the re-initiation of *Sphagnum* growth.

The project explored various methods to prevent the plant diaspores from drying up. Using an irrigation system composed of a pump and sprinklers, we attempted to wet the diaspores regularly during warm summer days (D. Bastien, MSc thesis in preparation; F. Quinty, unpublished data). The effect of enhancing the microtopography of the site (in order to create protected microhabitats that would be more suitable to diaspore regeneration) was tested, as was the use of covers, straw mulches and companion vascular plant species to shelter the diaspores against solar and wind desiccation. Finally, we synchronised plant re-introductions with the wettest period of the year (spring and fall) and thus provided a 'shelter in time' to the diaspores at the onset of their re-establishment.

Overview of results

Enhancing microtopography

The objective of an enhanced microtopography is to create a variety and abundance of protected micro-sites in which the diaspores stand a better chance of surviving and regenerating. It can be achieved by harrowing, ploughing or simply by repeatedly passing heavy machinery over the wet bare peat in the spring. Quinty and Rochefort (1997) showed that *Sphagnum* re-establishment is favoured in the depressions of an area with enhanced microtopography in comparison to flat areas seeded with *Sphagnum* diaspores at a similar density. Other field trials conducted at different sites corroborate these findings (J.-L. Bugnon, MSc in preparation, C. Ferland, MSc in preparation; F. Quinty, unpublished data).

Using a protective cover

The various field trials we have conducted with artificial covers, straw mulches and companion plant species repeatedly demonstrate the positive effect these have on typical mire species re-establishment, including *Sphagnum* mosses (Quinty and Rochefort, 1997). The positive effect of a protective cover may be related to the improved humidity and temperature conditions experienced by the diaspores at the peat-air interface (J. Price and F. Quinty, unpublished data; Grosvernier *et al.*, 1995).

At Ste. Marguerite, the wettest of our four experimental sites, a *Sphagnum* ground cover of approximately 20% was obtained after two years on plots where *Sphagnum* diaspores were reintroduced manually in the spring of 1994 at a density ratio of 1:10 (i.e. taking 1 m² square of material from a natural area and spreading it over 10 m² of cut-over peatland) and then protected by a straw mulch. Interestingly enough, both lawn and hummock species re-established equally well in these experiments, in contradiction with the low re-establishment of hummock species in comparison to lawn species observed when *Sphagnum* diaspores are reintroduced in shallow water or on floating rafts (Money, 1995).

At the driest of our three sites, Rivière-Ouelle, mechanically shredded material from the surface of a bog was reintroduced in 1993 at an initial density ratio of approximately 1:10. Although recolonisation was slower at this site, *Sphagnum* cushions are now developing beneath the straw, in association with other mosses such as *Polytrichum* sp. Typical vascular bog species, which were present in the reintroduced material as seeds or as pieces of roots and rhizome are also slowly becoming established. After two years, the total vegetation cover of the plots with straw mulch was 20%, including a 5% *Sphagnum* cover (F. Quinty and L. Rochefort, unpublished data). In contrast, plots with no protective cover show barely any moss or vascular plant recolonisation from the reintroduced material.

Field experiments conducted in New Brunswick demonstrated that a well established community of vascular plants can provide cover to effectively promote *Sphagnum* re-establishment (C. Ferland, MSc in preparation). These results corroborate the findings of Grosvernier *et al.* (1995) and Salonen (1992) on the positive effect of a plant cover on *Sphagnum* and vascular species re-establishment on bare peat.

Perspectives for peatland rehabilitation

Can sheltering really compensate for a water table that may not be optimal for the re-establishment of *Sphagnum*? Can bog plant fragments provided with a protective cover really be successful at recolonising peat fields where the water table, although high in the spring and fall, can drop 20, 40 or even 60 cm below the surface during the summer? And how much surface material will be needed as a source of diaspores, so that we are not destroying natural bogs in order to restore post-mined sites? To answer these questions, large scale restoration trials are currently underway in collaboration with peat producers, using the techniques which proved to be most promising in the small-scale experiments. The purpose of larger-scale restoration experiments is primarily to test the effectiveness of the proposed approaches and the stability of the re-established vegetation. These trials will also allow us to determine how restoration work can be done by locally available machinery and at what cost. In addition, they will provide the chance to assess the impact of collecting diaspores for restoration purposes on the natural source area.

Conclusion

It is clear that returning a post-harvested site to the state of functional peatland ecosystem is not only a matter of restoring a moss layer or a certain set of typical mire species. However, as these plants are a key component of bog ecosystems, their re-establishment on a cutover surface is one of the main challenges that needs to be addressed in order to succeed in rehabilitating post-mined sites. The results obtained so far in eastern Canada suggest that it could be possible to re-establish typical bog plant species, including *Sphagnum* mosses, on the seemingly harsh and inhospitable bare peat surface of a cutover peatland by using methods that are relatively simple and cheap, such as reintroducing shredded bog vegetation, using enhanced microtopography, and providing some sort of protective cover for the reintroduced diaspores. Obviously, only large-scale experiments and long-term data will demonstrate the success or failure of the approaches we are currently testing. We, however, believe that our finds to date do open up new and promising avenues for the rehabilitation of post-mined peatlands.

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