Peatland Restoration Guide

Plant Material Collecting and Donor Site Management

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INTRODUCTION

This fascicle has been prepared to make available knowledge acquired on the management of donor sites since the publication of the *Peatland Restoration Guide, Second Edition*[1] in 2003. It is intended primarily for the peat industry, including Veriflora® certified producers who are required to apply measures regarding donor sites to maintain their certification[2]. This update replaces the section of the 2003 Guide about plant collection (pp. 36–45 in the English version) and it focuses on the plant collecting phase as well as the selection and management of donor sites. The numerous restoration projects carried out since 2003 have demonstrated how important this step is to the success of restoration work.

[1] Quinty, F. and L. Rochefort, 2003. *Peatland Restoration Guide, Second Edition*. Canadian Sphagnum Peat Moss Association and the New Brunswick Department of Natural Resources and Energy. Québec City, Québec.

[2] Underlined words refer to text in breakout boxes.

This fascicle begins with a brief review of the moss layer transfer technique and offers recommendations for the selection and management of donor sites. The methods for collecting plant material and the time and resources needed for this operation are then described.

The approach presented in this fascicle specifically addresses *Sphagnum* dominated peatlands (bogs and poor fens). However, measures regarding the restoration of fens (peatlands dominated by sedges and fen true mosses) are mentioned at the end of the document.

CERTIFICATION

The Veriflora® *Responsibly Managed Peatlands Certification Program* includes obligations for the selection, use and management of donor sites. Certified horticultural peat producers must demonstrate that they have identified one or more donor sites representing at least 10% of the current peat extraction area. If the donor site(s) represents less than 10% of the peat extraction area, the producer must provide a justification demonstrating that there are sufficient diaspores available for the restoration, for example, by the use of plant material from peatland areas that will be opened for peat production in the future or by the use of the donor site more than once.

Donor sites must have the following characteristics:

- they must not be located in areas of high ecological value;
- they may include donor sites already in use or *Sphagnum* farming sites;
- they may be included in buffer zones;
- their species composition must be appropriate for the restoration goals;
- they must provide diaspores of sufficient quantity and quality (viability).

Regarding this last point, the producer is obliged to evaluate the quantity and quality of the diaspores collected from the donor site on a regular basis. If the evaluation shows insufficient quantity or quality, the producer must take steps to enlarge the donor site or select another site.

With the exception of cases where plant material will be collected from a new peat field being opened for peat extraction, the producer must manage the donor sites to ensure that the vegetation and species composition remain viable.

MOSS LAYER TRANSFER TECHNIQUE

The moss layer transfer technique developed by the Peatland Ecology Research Group (PERG) is based on active reintroduction of peatland plant species combined with rewetting through hydrological management. This technique has been used in more than one hundred restoration projects in Canada and is used in many other countries. According to a recent study[3], it leads to a successful reestablishment of more than 80% of the species found in the plant material and it limits the presence of non-peatland species on restored sites to only 3% to 6% cover. Moreover, long-term vegetation monitoring (> 10 years) points to

[3] PERG, manuscript submitted.

a decrease in these non-peatland species with the development of the moss carpet. The success of the moss layer transfer technique is largely related to how well the restoration work is done, as well as the meteorological and hydrological conditions during the restoration period. It involves several steps:

- Planning;
- Preparing the surface of the site to be restored (cleaning of surfaces, removing the biological crust, levelling, creation of terraces for uniform rewetting, creation of ponds, etc.);
- Collecting vegetation from the donor site;
- Spreading the plant material and diaspores;
- Adding a protective straw mulch;
- Fertilizing;
- Blocking the drainage ditches;
- Monitoring.

This fascicle focuses on collecting vegetation from the donor site.

PLANT MATERIAL AND DIASPORES

The proposed method for collecting plants results in the collection of the entire moss carpet that forms the surface of a donor site. This mix, which includes everything that lies at the surface, is called "plant material" and it contains plant diaspores.

Diaspores consist of all the propagative parts of a plant that can produce a new plant. They include seeds and spores (moss "seeds"), as well as roots, stems, leaves, branches, etc.

CHOOSING THE DONOR SITE

The first step in collecting plant material is to select a donor site of the appropriate size that contains the right plant communities. The two crucial factors to consider when choosing a donor site are the **composition of the plant communities** and its **size**. Access to the site should also be taken into consideration, especially if you expect to collect plant material more than once from the same site.

Plant Communities

The composition of the plant communities of the donor site plays a key role in the success of the restoration. Although peatland vegetation may appear to be a more or less uniform layer of mosses at first sight, it is actually very diverse. For restoration purposes, *Sphagnum* species should be the dominant component of donor site vegetation because they are largely responsible for the unique characteristics of these ecosystems and the accumulation of peat. However, not all *Sphagnum* species are equally appropriate for this purpose. Species that form hummocks or lawns, such as *Sphagnum fuscum*, a small brown species, and *Sphagnum rubellum*, a red moss, offer the best potential for establishing a moss layer on the restoration site. In contrast, green and elongated *Sphagnum* species are often associated with wetter or aquatic environments and should be avoided.

In addition to *Sphagnum*, the plant material must also contain pioneer plant species such as bog haircap moss (*Polytrichum strictum*). The presence of that species is important, even in small quantities, since a few plants are sufficient to produce a multitude of spores that are preserved in the moss and that will germinate during the restoration. The presence of ericaceous shrubs, coniferous trees or other vascular plants does not matter as long as the composition of the moss carpet is adequate.

The use of a poor quality donor site – one that does not have the appropriate moss communities – will have a direct impact on the success of the restoration, possibly slowing down the restoration process or even resulting in a waste of time, money and effort.

SPHAGNUM

Sphagnum species are nonvascular plants from the moss family. They have the distinction of being "engineering species", meaning that they contribute to modifying their environment so as to create the conditions they need themselves. For example, they are able to retain phenomenal amounts of water relative to their weight and can acidify the surrounding substrate, helping to create a wetland where other species have difficulty becoming established and where decomposition is slowed. It is this ability to resist decomposition that makes *Sphagnum* species so exceptional. In boreal peatlands, the accumulation of organic matter composed largely of *Sphagnum* leads to the formation of peat, a unique substrate both from an ecological point of view and as a raw material for the preparation of growing media.

BOG HAIRCAP MOSS

Bog haircap moss (*Polytrichum strictum*) is a pioneering moss that plays a particularly important role in peatland restoration because it has the ability to stabilize the peat surface and create favourable microclimatic conditions for the establishment of *Sphagnum*. It spreads quickly when fertilized with phosphorus and tolerates periods of drought. It is considered as a companion species because it supports and allows the growth of other plants. Choosing a donor site where it grows or incorporating it into the plant material is highly recommended.

These suitable plant communities must cover the entire surface of the donor site. Introducing inappropriate *Sphagnum* or other moss species, or no mosses at all, to the restoration site may result in failure of the restoration and a waste of efforts, time and money. To make sure that the donor site has the appropriate plant communities, the *Practical guide to the identification of plants in Québec's ombrotrophic peatland*[4] can be used to identify indicator species. It may be appropriate to hire a specialist (botanist, biologist or other) to identify and delineate potential donor sites for a given peatland. Table 1 presents a list of indicator species for adequate donor sites.

Table 1. Indicator species for adequate or poor donor sites for restoration of *Sphagnum* dominated peatlands

INDICATOR SPECIES FOR ADEQUATE DONOR SITES	INDICATOR SPECIES FOR POOR DONOR SITES
Sphagnum mosses	
Dominance of hummock ("mound") or lawn species: *Sphagnum angustifolium* *Sphagnum capillifolium* *Sphagnum flavicomans* (Maritimes Provinces) *Sphagnum fuscum* *Sphagnum magellanicum* *Sphagnum rubellum* *Sphagnum warnstorfii* (West of Canada)	**Dominance of species growing in wet or aquatic habitats (often green or yellowish mosses):** *Sphagnum fallax* *Sphagnum cuspidatum* *Sphagnum papillosum*
Other mosses and lichens	
Polytrichum strictum (bog haircap moss)	**Forest or dryland species including:** *Pleurozium schreberi* *Hylocomnium splendens* Lichens
Trees and shrubs	
Picea mariana (small black spruce) *Chamaedaphne calyculata* (leatherleaf)	*Andromeda polifolia* (bog rosemary)
Other elements	
Dominance of *Sphagnum* lawns and hummocks Continuous carpet of moss	Dominance of graminoid (grass-like) plants Dense and tall (> 50 cm) ericaceous cover with abundance of dead leaf litter and few mosses

[4] Hähni, M. and R. Pouliot, 2011. *Practical guide to the identification of plants in Québec's ombrotrophic peatland*. APTHQ. Rivière-du-Loup, Canada.

In Eastern Canada, donor sites that meet the criteria listed above are generally treeless, facilitating plant collecting and machinery circulation. In the Prairie Provinces, peatlands may have relatively dense black spruce cover. In this case, the diaspore collecting techniques must be adapted to overcome the difficulties caused by the presence of trees.

Donor sites that are as close as possible (adjacent, whenever feasible) to the sites to be restored should be prioritized thus minimizing transport and the distance to be cleared for machinery access roads. Similarly, opting to collect diaspores from several smaller areas with sparse tree cover rather than from one densely wooded site can simplify the collecting operation, but it may also substantially increase transport and travel time.

In some cases, the trees on the donor site can be removed prior to or at the same time as the diaspore collecting operations. Depending on the density of the stand, trees can be cut down using specialized equipment or removed with an excavator or backhoe when collecting the moss layer. These trees generally have no commercial value because of their small size, but they can be used to build access roads and culverts.

In some instances, the trees have been shredded and incorporated into the plant material with good results. The collecting operations in these cases were carried out on frozen ground, using a mulcher mounted on a tractor to chip and shred the trees and plant material all together. However, the resulting material is quite different from that obtained when trees are cut down, as it includes a large proportion of wood chips. This is a fast and efficient method for operations on more wooded peatlands.

Size of the Donor Site

The size of the collecting area is very important, as it determines the amount of plant material available for the restoration project. The PERG has conducted many experiments to determine how much plant material should be reintroduced for site restoration. Enough plant material must be used to promote rapid formation of a new moss carpet while minimizing the harvest area, especially given that donor sites often occupy limited areas. Minimizing the size of the donor site also helps reduce the amount of plant material to be transported, which in turn reduces transportation costs and the impact on natural sites.

A convenient method has been developed for estimating the amount of plant material required: it uses a simple proportion between the collecting area and the area of the site to be restored. In theory, a 1:15 ratio is appropriate, but in reality, ratios from 1:12 to 1:10 are used in order to compensate for the difficulties involved in collecting plant material, the subsequent losses of that material and the presence of trees in the harvest area. For treed donor sites, the presence of trees must be compensated for because the base of trees is often devoid of mosses and in the case trees are removed the root crown leaves a disturbed area that is not suitable for plant collecting.

Types of Donor Sites

In general, there are three options with regard to the type of donor site:

1. use peatland sectors that will be opened for peat production in the relatively short term;
2. use dedicated sites from which plant material can be collected one or more times;
3. use diaspores collected in a *Sphagnum* farm.

1. Sectors to be opened for peat production

Plant material can be collected from areas that are being or will be opened for peat production in the near term. This option can facilitate the work – particularly because access to the donor site is better – and minimizes damage to natural peatlands. It reduces costs by "killing two birds with one stone", since the surface vegetation must be shredded to prepare the peatland for peat extraction in any case.

Areas targeted for peat production are also highly likely to include the plant species needed for restoration, such as an almost complete carpet of hummock-forming or lawn *Sphagnum* species, as well as bog haircap moss. But even in this case, it is essential to make sure the species are appropriate for the restoration and that plants are still alive before collecting plant material. This is particularly true for donor sites located near previously or currently extracted peat fields, because drainage of these areas can affect the vigour and viability of *Sphagnum* populations.

Special care is needed when collecting plant material from fields that have already been drained in preparation for peat extraction. V-ditchers can expel peat over the *Sphagnum* carpet up to several metres from the ditch itself. This peat can reduce the regenerative potential of *Sphagnum*, especially if some time has passed since the drainage ditches were dug. In addition, collecting this peat – which lacks regenerative capacity – will dilute the plant material and unnecessarily increase the volume of material to be transported and handled. The viability of *Sphagnum* can also be affected by the lowered water table caused by ditching. Thus, if conditions permit, it is better to collect plant materials before digging the drainage ditches or only from the central part of the fields after the ditches have been dug.

In addition, drainage ditches sometimes expose the mineral deposits underlying the peat, which can lead to ruderal or invasive plants establishment. If these species colonize the adjacent fields, they reduce the quality of the plant material to be collected and increase the risk of introducing these undesirable species to restoration sites.

It is also possible that local or regional development projects involve works in peatlands that would lead to the destruction of the vegetation cover. Collaboration with the concerned authorities could help to get these plants if they are suitable for restoration. Such opportunities can reduce the expenses related to restoration and limit the impact on natural undeveloped peatlands.

2. Dedicated donor sites

Some restoration projects, notably the Bois-des-Bel restored peatland in Québec and the Seba Beach restored peatland in Alberta, have demonstrated the possibility of collecting plant material more than once from the same site. Under the right conditions, the vegetation of a donor site will regenerate to the point of reforming a complete plant cover sufficiently thick to allow collecting plant material again after a period of 5 to 10 years. This possibility paves the road to developing dedicated donor sites that can be used more than once during the period peat will be extracted from a peatland and hence the restoration process.

Developing dedicated donor sites has several advantages for peat producers:

- ensures a source of quality plant material;
- facilitates plant material collecting;
- reduces costs;
- allows for better planning of restoration projects.

The lack of donor sites is an obstacle to the restoration of many peatlands. This is mainly the case for peatlands that were opened for peat production before restoration became common practice and before provincial regulations strongly encouraged or obliged producers to restore peatlands once peat extraction activities are finished. Identifying donor sites by characterizing the plant communities before opening a peatland for peat production is a good option.

Dedicated donor sites are generally located on the edge of the peatland, where the peat is not thick enough or the area is too small to justify opening fields for peat extraction, but which meet the criteria for use as donor sites. In these cases, it is even more important to make sure the plant community includes the appropriate species for restoration (Table 1) since the site is to be used more than once.

3. Diaspores collected in a Sphagnum *farm*

Sphagnum farming sites can also be used when they reach maturity, that is to say when they have a thick enough plant cover dominated by *Sphagnum*. Indeed, a recent study[5] has determined that plant material derived from a *Sphagnum* carpet with a complete cover and having reached a thickness of 5 cm is as effective for restoration as that collected in natural sites. With a lower volume (a 5 cm thick mat compared to a 10 cm mat as recommended below), the cultivated material provided a recovery and a diversity of plant species similar to those of sites restored with diaspores from natural peatlands.

Such a 5 cm *Sphagnum* mat can be generated in 3 to 4 years of cultivation if the production site (farm) is equipped with an adequate water control system. If the *Sphagnum* farm is specifically aimed at the supply of plant material for restoration, it is recommended to prepare the cultivation site according to the species sought for restoration (Table 1).

[5] Hugron, S. and L. Rochefort (2018). *Sphagnum* mosses cultivated in outdoor nurseries yield efficient plant material for peatland restoration. Mires and Peat 20: 1-6.

This type of donor site can be very beneficial if you are in an area where pristine peatlands or where natural fragments are rare or protected, or for restoration site far from donor sites for which transportation costs are high.

Establishing Donor Sites

Putting in place some measures to manage a donor site will facilitate the work and reduce the restoration costs.

- **Removing trees:** Uprooting or cutting down trees, even small ones, will facilitate the work and circulation of the plant collecting machinery, especially if the trees are large. However, doing so increases the costs of the plant collecting step. If the site is to be used more than once, tree removal may increase the usable area, provided that mosses grow well in the areas where trees have been removed. The use of a mulcher to shred the surface (including trees), as is commonly the case in Alberta, also allows the management of dedicated donor sites.
- **Creating access roads:** Sites suitable for collecting plant material are often located on edges of peatlands currently under peat extraction, just beyond the perimeter drainage ditches. It might be a good idea to install one or more permanent culverts at strategic locations to provide access to donor sites. A path able to support the weight of machinery can be created by laying a bed of branches or tree trunks, preferably next to a drainage ditch where conditions are already somewhat drier.
- **Avoiding damage to plants and soil:** Plant material gets quite heavy when saturated with water. Loaded trailers can get bogged down and damage the soil, creating ruts and complicating the work. When this happens, a natural reflex is to drive around and avoid the deeper ruts, even if it means creating more. This can result in severe damage to the donor site, making it even more susceptible to the formation of ruts due to the loss of the root system that provides support to machinery. In addition, the plant cover will take longer to re-establish, rendering the site unusable for a longer period of time. Soil damage can be minimized by collecting plant material in early spring when the ground is still frozen (see *Collecting plant material in spring on frozen ground*).
- **Controlling the hydrological conditions:** Donor sites located next to peat production sites are often affected by drainage, particularly by the main perimeter ditch. As this drainage causes the surrounding zones to dry out, the plant community changes, progressively losing the characteristics of a good donor site. Better control of the water table – by creating a buffer zone between the donor site and the drainage ditch, for example – helps to maintain appropriate vegetation for donor sites.

COLLECTING PLANT MATERIAL

General Procedure for Collecting Plant Material

Collecting plant material for restoration simply involves shredding and harvesting the top 10 cm of the vegetation cover in a donor site (figures 1 to 4). The material can be shredded on-site using a rotovator (rotary tiller) or a mulcher. Another strategy is to collect the material without shredding it and simply stacking it until ready to use. However, not all equipment is recommended for these operations, as shown in Table 2.

The ideal plant material consists of fragments from one to several centimetres long, separated from each other or still forming small tufts of moss carpet. Individual fragments are easier to spread and yield better, more uniform restoration results than do chunks of intact moss carpet. However, it is important not to shred the plants into pieces that are too small or to the point of making a slurry. The ideal fragment size is between 1 and 3 cm. If the material is shredded on site, the operating mode must be adjusted depending on the equipment used to make the fragments. For example, rotary tillers moving too fast will produce chunks that are too big. As a general rule, the prevailing conditions (moisture, bearing capacity of the ground, tree cover, distance to the restoration site, collecting season) should be carefully considered to determine the most appropriate equipment and method.

FRAGMENT SIZE

With the exception of the almost microscopic leaves, any part of the top ± 10 cm of *Sphagnum* can form a new plant. Greenhouse experiments showed that even fragments as small as 0.5 cm have the potential to develop into a new plant under optimal growing conditions. However, the surface vegetation should not be cut into fragments that are too small to minimize the stress on the plants. Always bear in mind that the plant material is composed of live diaspores and must be handled with care.

Table 2. Equipment that has been used in North America to collect plant material and its efficacy.

PLANT SHREDDING	
Rotary tiller *(rotovator)*	Yields good results. Recommended equipment.
Frandent rotary harrow	Yields good results. Does not shred the plants into fragments that are too small.
Chopper	Shreds the plants into fragments that are too small unless the tractor is moving fast. To avoid.
Mulcher	Shreds the moss carpet, shrubs and even trees into small fragments. Rugged enough to use on sites with large-diameter trees or to collect plant material in winter.

Excavator with wide bucket	Can yield a uniform harvest if the moss carpet is homogeneous. However, the collecting depth must be very carefully controlled.
Disc harrow	Goes too deep and collects dead plant material. To avoid.
Bulldozer	Yields good results when collecting plant material on frozen ground.
Levelling auger	Collects a lot of dead plant material with roots and large clumps of plants. To avoid.
Clamshell bucket	Collects dead plant material with roots and large clumps of plants. To avoid.
COLLECTING AND STACKING PLANT MATERIAL	
Rake and conveyor for collecting roots	Yields good results on fields being opened for peat extraction.
Bulldozer	Used on frozen ground, yields good results for stacking plant material.
Scraper blade or similar attachment behind a tractor	Used on frozen ground, yields good results for stacking plant material. However, not as strong as a bulldozer for pushing plant material.
Levelling auger	Can be used to pile shredded plant material in windrows.
Front loader	Yields good results, especially using a bucket with teeth, but often lacks flotation, particularly when loading trailers.
Clamshell bucket	Works well for loading plant material after it has been stacked, but inefficient when collecting and stacking plant material.
Snowblower	Inappropriate. Too heavy, damages the vegetation, leaves too much material on the ground. To avoid.

Figure 1. Rotary tiller shredding plants when collecting plant material.

Figure 2. Collecting plant material after using a rotary tiller.

Figure 3. Collecting and picking up plant material with an excavator with wide bucket.

Figure 4. Collecting with a clamshell bucket after plant material has been stacked.

Collecting Depth

The depth at which the plant material is collected plays an important role in the success of plant establishment, especially for mosses. Experiments have shown that the regeneration potential of moss fragments decreases rapidly with collecting depth (Figure 5). Although *Sphagnum* carpets are sometimes very thick, only the top 10 cm have the ability to regenerate. In terms of restoration work, although collecting plant material to a depth of 20 cm may give the impression of providing more plant material, the reality is that this approach simply results in handling material composed of 50% dead fragments. Given the cost, time and effort involved in collecting, handling and transporting plant material, it is strongly recommended that attention be paid to the collecting depth, limiting it to only the top 10 cm.

Some sites have flat and uniform surfaces that facilitate collecting operations, but most peatlands have uneven surfaces with alternating hummocks and hollows. When this is the case, the best approach is to limit the harvest to the top 10 cm on the hummocks and not to worry about the non-shredded vegetation left on the site, mostly in the hollows. In fact, the vegetation at the bottom of the hollows is usually less desirable for restoration than the hummock-forming ones. Using a ratio of donor site to restoration site between 1:10 and 1:12 (instead of 1:15) allows for consideration of those unharvested portion of the donor site.

Collecting only the top 10 cm of surface vegetation also has the advantage of ensuring faster recovery of the donor site; the root system of the shrubs and herbs remains intact and the moss fragments left on the site can easily regenerate. However, plant collecting must be done with great care to avoid damage and allow recovery or repeated use of a donor site.

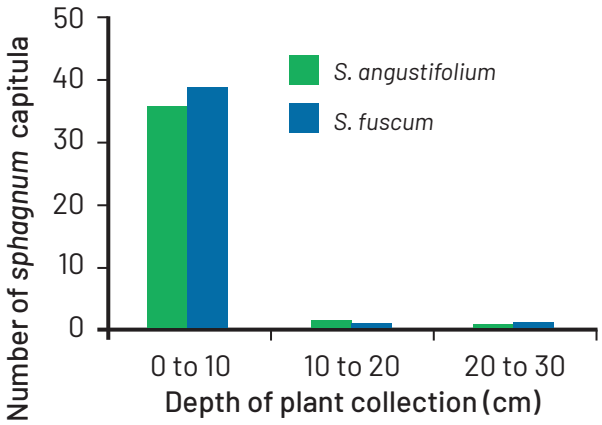

Figure 5. The regeneration capacity of *Sphagnum* diaspores decreases with increasing collecting depth. The regenerative capacity is estimated from the number of newly formed capitula.

Collecting Plant Material on Frozen Ground

Collecting plant material in early spring has many advantages since the ground is still frozen. Experience with this approach has demonstrated that four elements contribute to the harvest efficiency and overall success of collecting operations:

1. the frozen ground supports the machinery better;
2. the uniform hard surface makes it easier to collect plant material, greatly reducing losses;
3. the frozen ground ensures that material from too great a depth is not collected, maximizing the proportion of material with high regenerative potential;
4. the frozen ground protects the donor site from damage by the machinery or the formation of ruts.

Field observations show that when plant material is harvested on frozen ground, the root system of the plants remains intact, helping to ensure rapid recovery of vegetation on the donor sites. Taken together, these findings have highlighted that creating access roads and collecting diaspores on frozen ground is a good strategy.

CREATING ACCESS ROADS ON FROZEN GROUND

Collecting and transporting plant materials are expensive operations because of the time it takes and the risk of machinery getting bogged down. This risk can be avoided if the ground is completely frozen to a sufficient depth. On the other hand, bumpy access roads force the tractors pulling trailers loaded with plant material to slow down and can lead to machinery breakdowns. It is therefore generally a good idea to grade the access roads in the fall, before the ground freezes.

In the Prairie Provinces, collecting diaspores in the early spring while the soil is still frozen is strongly recommended. With less snow cover than in Eastern Canada and cold winter temperatures, the ground easily freezes to a sufficient depth. On the other hand, the soil thaws more quickly, so it is important to plan the timing of the operations to take advantage of the short time frame during which the ground remains frozen while the snow cover has decreased.

Delineation of the donor site

It is critical that the donor site is delineated in the fall before the planned collecting when the plants are easy to see and identify. The site and access roads must be staked out so that they will be clearly visible even when there is a layer of snow on the ground. Elements to avoid (e.g., bog pools, islands of vegetation to avoid or to preserve) can also be identified and marked at this time.

Preparation and freeze-up of the donor site and access roads

Donor sites with a lot of trees tend to accumulate thicker snow cover, which can keep the ground from freezing to a sufficient depth. In these cases, it is best to remove the trees before winter if there is a risk that the ground will have thawed (or never frozen at all) before the plant collecting operations in the spring. This also applies to the access roads. Attention must be paid to anything that could cause snow to accumulate and interfere with the harvest in the spring, such as peat piles along the access roads.

Despite the cold North American winters, the ground in natural peatlands often does not freeze completely. Snow cover that accumulates long before temperatures reach the freezing point can even keep the top layer of the ground from freezing solidly. Thus, certain measures should be implemented to ensure that the ground of the donor site and access roads freezes to a depth sufficient to support the machinery, especially in the more temperate Maritimes Provinces.

Snow acts as a good insulator because it is filled with air. To allow frost to reach the ground, the snow has to lose its insulating properties. The easiest and cheapest method is to compact the snow ideally just before a period of intense cold. Any equipment available, such as a tractor or bulldozer, can be used provided it can move over the peatland and is heavy enough to compress the snow. Snowmobiles can also be used if the snow cover is too deep for tractors to get through. Snow compaction is recommended for access roads as well as donor sites. Depending on the weather conditions, it may be necessary to compact the snow a few times over the course of the winter so that the ground can freeze to a suitable depth.

Figure 6. Frozen access road.

COMPACTING SNOW

It is amazing how much surface a tractor can cover in one hour and at a relatively low cost. Since donor sites are generally small (one tenth the size of the restoration site), compacting the snow with a tractor can be done quickly. Heavier equipment can compact the snow much more efficiently than tractors. The cost of snow compaction is low compared to the benefits it provides for collecting plant materials in the spring.

Depth of the frozen layer

The frozen layer must be about 15 cm thick to support machinery. Bearing in mind that the top 10 cm will be removed when collecting plant material, the surface should be frozen to a depth of 25 cm before beginning the harvest. This is the minimum because the work may extend over a long period of time during the spring thaw. It is important to note that the depth of the frozen layer can vary considerably on a site. For example, there is often a frost-free zone around tree stands because snow accumulates in the shelter they provide. Drained peatlands freeze much faster than natural bogs, so access roads in drained areas require less preparation.

To determine whether the frost layer is sufficiently thick to start the harvest, measuring the frost depth at various locations on the donor site and access roads is recommended.

The spring thaw is very slow in Eastern Canada. In the Lac-Saint-Jean region of Québec, for example, frozen ground thaws at a rate of about 15 cm in 20 days when daily temperatures vary from 10°C and -3°C.

Snow removal

After a winter with heavy snowfall, it may be necessary to start collecting plant material before the snow is completely melted and temperatures become too mild. In such cases, the snow cover must be removed so that the harvest can begin. Snow must be removed one to three days before a rotary tiller is used or plant material is collected, allowing enough time for the surface vegetation layer to thaw. In addition, rotary tillers can be easily damaged if used on completely frozen ground. Snow removal using a powerful snowblower is recommended because snow is heavy in the spring. Pay special attention not to reach the top of the hummocks when removing the snow, since this is where the plant material with the best regeneration potential is found; it is better to leave a thin snow cover and let it melt naturally than losing the best plant material.

Collecting and transporting plant material

The procedure for collecting plant material in the spring is similar to collecting in the fall but the work is usually easier because the ground is frozen. Heavier equipment can thus be used, increasing the efficiency of the harvest operations and potentially reducing costs. However, it is best to take into consideration the following:

- The hummocks remain frozen for a long time and can create bumpy conditions that might be difficult for machinery to deal with;
- The additional water from the rapid snowmelt can make the shredded plant material very wet and more difficult to collect, sometimes resulting in significant loss of material.
- Tractors may have difficulty pulling large loads of plant material if they are slipping on frozen surfaces.
- The location of the piles of plant material is very important. When harvested, the plant material can contain a lot of snow and ice that will slowly melt during the spring and summer, resulting in soft ground surrounding the piles. It is advisable to locate the plant material piles on well-drained ground and avoid low spots.

Figure 7. Rotary tiller on frozen ground.

Figure 8. Stacking plant material collected on frozen ground.

STORING PLANT MATERIAL

For various reasons, there might be delays between collecting and spreading the plant material, so it may be necessary to store it for a certain period of time. The plant material should be used in the same season or at the latest in the beginning of the next growing season following its harvest. For example, plant material collected in the spring should be used by the following fall at the latest, while plants collected in the fall could be used until the following summer. The plant material (especially from vascular plants) loses its regenerative ability after this time. Material harvested in the fall and stored in piles until the next summer regenerates as well as material harvested in the spring.

RESOURCES, TIME AND COST

Resources and average time and cost were estimated based on data provided in large part by peat producers who conducted restoration work across Canada. Plant collecting is the operation that requires the most time and resources of all the operations involved in peatland restoration. The time required varies greatly depending mainly on conditions at the donor site. For example, if the donor site is very wet or if access is difficult, the amount of plant material loaded on the trailers must be reduced and more trips will be necessary. The time required to transport the plant material also depends on how far the donor site is from the restoration site. Thus, the collecting operations should be carefully planned and appropriate methods used (harvesting to the right depth, loading the right amount to avoid getting stuck) so as to reduce costs as much as possible. This also means that good donor sites are very valuable.

The equipment used to harvest plant material also influences the time required as some machinery is more efficient than others (Table 2). To minimize delays and wasting time, it is important to follow proper procedures and assign sufficient manpower to collecting operations. The numbers provided in Table 3 represent the average number of machine-hours required for the operation. Thus, a total of nine machine-hours may include one front loader and two tractors with trailers used for three hours each. Note that numbers and areas (hectares) are calculated in relation with the restoration site, not the donor site.

Collecting plant material in the spring requires donor site preparation, snow compaction to allow the ground to freeze and snow removal from donor sites and access roads, all of which can increase the total time required for collecting operations. These additional hours can however be offset by the efficiency gained from transporting plant material on frozen ground. For one hectare of land, it takes less than two hours to compact the snow cover and about five hours to remove 30 to 40 cm of snow. Given that a one-hectare donor site provides enough material for a 10 to 12 hectares restoration site, the extra cost of preparing for a spring harvest is negligible when calculated on the basis of the area to be restored. Since harvesting in the spring helps avoid other problems, it may be advantageous to put in the extra time it takes.

Table 3. Time and equipment required for collecting plant materials.

	Machine-hours/ha	Equipment ($/ha)
Shredding plant material	3	No special equipment needed
Collecting and transporting plant material	9.2	No special equipment needed
TOTAL	12.2 machine-hours per hectare	$0

REGENERATION OF DONOR SITES

When done correctly, collecting diaspores does not cause much damage to the donor site. More specifically, after the harvest, it generally takes 5 to 10 years for the *Sphagnum* layer to regenerate. Typically, the composition of the vascular plant community will undergo some changes. After plant material is collected, donor sites are wetter and more homogeneous. The new plant community will therefore differ from what is usually observed in untouched peatlands. The shrub and tree cover will usually be less dense, since woody species require specific conditions to germinate and grow more slowly than herbaceous plants. On the other hand, the growth of certain plants is fostered by these changes. Competitive and wetland species are usually more abundant in the first years following plant collecting. Among other species, cottongrass (*Eriophorum vaginatum*) tends to densely colonize donor sites in the early years after completion of collecting operations, then disappears around the fifth year. In all cases, these results show how important it is to harvest plant material with care. Carefully assessing site conditions, planning the operations and following the advice provided in this fascicle will help promote regeneration of the donor site and ensure that the collecting operations are carried out efficiently.

RESTORING FENS

While bogs are dominated by *Sphagnum* mosses, the vegetation in fens is characterized by mosses usually not found in bogs and by an abundance of herbaceous plants such as sedges. Due to the nature of fens (enriched surface water supplies, different species), their restoration is generally approached at the landscape scale and may include several techniques. In some cases, introducing diaspores is not necessary; restoring the hydrological conditions suffices to allow the typical plant communities of natural fens to return. In other cases, an adapted version of the moss layer transfer method must be used. For fen restoration, only the top 5 cm of vegetation is collected. In addition to mosses, this material often includes a thin peat layer with its seed bank. Certain fen species cannot be introduced by the transfer of surface materials and methods such as collecting and transplanting rhizomes must also be used. In addition, water flow in fens requires thorough planning of the restoration operations so that damage to the donor sites is limited and movement of machinery is facilitated. Working on frozen ground is strongly recommended.

Fen restoration methods are still the subject of active research. New approaches will be developed as research progresses with the goal of restoring the widely variable fen conditions and the plant communities found in these ecosystems.

The PERG has produced a guide that specifically addresses fen restoration[6] in the light of knowledge gained to date.

[6] GRET (2016). Restauration des tourbières minérotrophes: État des connaissances 2015 (*Restoration of Mineral Fens: Current knowledge 2015*). Groupe de recherche en écologie des tourbières, Université Laval, Québec. 22 pages and 3 appendices.
See also PERG. (2017). Fen restoration in Manitoba – Final report. Peatland Ecology Research Group, Université Laval, Québec. 49 pages and 3 appendices.

SUMMARY

- Donor sites should be completely covered with a moss carpet dominated by *Sphagnum* species and including *Polytrichum* (bog haircap) mosses as well.
- Use a donor site that is 10 to 12 times smaller than the site to be restored.
- Collect or shred the surface vegetation with suitable equipment, taking only the top 10 cm on average.
- Treeless sites make it easier to carry out the operations with machinery.
- Collect and pile up the plant material, then load it onto trailers to bring to the restoration site.
- Although the plant material gradually loses its regenerative potential, it can be kept for at least six months in piles.
- Collecting plant material from bogs being opened for peat extraction reduces costs and avoids disturbances that would otherwise be caused to natural peatlands.
- Where possible, prioritize collecting on frozen ground to limit the impact on the donor site. The working window is small, but heavier equipment can be used because the bearing capacity of the ground is better, increasing the efficiency of operations.

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