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The natural revegetation of a harvested peatland in southern Québec: A spatial and dendroecological analysis[1]

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Abstract: In North America peat has been harvested for horticultural use since the beginning of the 20th century. Many peatlands are now abandoned after decades of mining, and natural revegetation of peat occurs. To document the revegetation patterns of these bare organic surfaces, we studied the Cacouna-Station bog which is representative of abandoned peatlands in Québec (Canada). The Cacouna-Station bog is characterized by mined trenches (block-cut) alternating with raised balks, and by sections which were bulldozed for harvesting with modern methods *i.e.* vacuum. Three sections within the peatland were selected to study the spatial distribution of plants, according to the vegetation structure and harvesting method. Trees were sampled to describe establishment patterns in each section. Twenty years after abandonment, the block-cut trenches were well-revegetated (> 50% plant cover) by typical peatland species. However, *Sphagnum* species are much more common in natural conditions than at Cacouna-Station, where they are restricted to a small portion of the peatland. Moisture deficit in the upper peat layer likely explains this situation. Additional drainage contributed to lower the water table in the bulldozed section where *Betula populifolia* proliferated. Tree species were unable to establish during harvesting activities. In the trenches, however, there was a sharp rise in the number of *Larix laricina* seedlings, two years after mining was abandoned. This 2-year lag is possibly related to the occurrence of a good year for seed production. Height and diameter data from tamarack and birch growing in the trenches suggest that seedlings were suppressed under the dense ericaceous shrub cover. The scarcity of *Sphagnum* and mosses in the majority of trenches along with the absence of a new acrotelm indicate that the Cacouna-Station bog is not returning to a functional peatland ecosystem.
Keywords: harvested peatlands, restoration ecology, *Sphagnum, Larix laricina, Betula populifolia,* ericaceous shrubs.

Résumé: En Amérique du Nord, la tourbe est récoltée à des fins horticoles depuis le début du 20[e] siècle. Plusieurs tourbières sont aujourd'hui abandonnées après des décennies d'exploitation et la revégétation naturelle des sites est en cours. Nous avons étudié les patrons de revégétation à partir des substrats organiques dénudés dans la tourbière de Cacouna-Station. Cette dernière est représentative de l'ensemble des tourbières abandonnées du Québec (Canada). La plus grande partie du site de Cacouna-Station est caractérisée par une succession de tranchées (d'où la tourbe fut extraite sous forme de blocs) alternant avec de petits terre-pleins. On trouve également une section où la surface de la tourbe fut nivellée en vue d'une récolte à l'aide d'aspirateurs. Nous avons étudié la répartition spatiale des plantes dans trois sections de la tourbière qui ont été retenues en fonction de la structure de végétation et de la méthode de récolte. Les arbres ont été échantillonnés pour décrire le patron d'établissement de la végétation arborescente. Vingt ans après l'abandon des activités de récolte, les tranchées sont bien revégétées (couverture végétale > 50 %) par des espèces typiques des milieux tourbeux. Les sphaignes sont toutefois beaucoup plus abondantes dans les tourbières naturelles que dans la tourbière de Cacouna-Station où elles sont confinées à une petite section. La rareté des sphaignes est probablement attribuable à la faible humidité à la surface du dépôt tourbeux. La section nivelée pour la récolte à l'aspirateur a fait l'objet d'un drainage additionnel, ce qui a contribué à abaisser davantage le niveau de la nappe phréatique et n'a permis la croissance que du *Betula populifolia.* Les espèces arborescentes peuvent difficilement s'établir tant que durent les activités d'exploitation. Dans les tranchées, toutefois, on observe une augmentation rapide du nombre de plantules de *Larix laricina*, deux ans seulement après l'abandon des activités. L'attente d'une année de forte production de graines explique peut-être ce délai de deux ans. Les données dendrométriques (hauteur et diamètre), obtenues des mélèzes et des bouleaux croissant dans les tranchées, suggèrent que les gaules sont surcimées par le couvert relativement dense que forment les éricacées arbustives. La rareté des sphaignes et autres mousses dans la majorité des tranchées, ainsi que l'absence d'un nouvel acrotelme, indiquent que cette tourbière ombrotrophe ne se reconstitue pas en un écosystème tourbeux fonctionnel.
Mots-clés: tourbières exploitées, écologie de la restauration, *Sphagnum, Larix laricina, Betula populifolia*, éricacées arbustives.

Introduction

Restoration ecology is a new field in the environmental sciences. The term restoration was defined by Jordan, Peters & Allen (1988) as the return of "degraded biological communities to their original state with human help" *i.e.* "the recreation of entire communities of organisms, closely modeled on those occurring naturally" (p. 55). Restoration methods are well developed for ecosystems like prairies (Kline & Howell, 1987), forests (Ashby, 1987), lakes (Welch & Cooke, 1987) and coastal salt marshes (Jordan, Peters & Allen, 1988). However, knowledge of peatland restoration is sketchy. In Europe, peat has been harvested for horticultural or fuel use since the 18th century (Smart, Wheeler & Willis, 1989). In some countries (Great Britain, Germany, Poland), less than 30% of the original peatland

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area remains in unharvested condition (Kivinen & Pakarinen, 1980). In The Netherlands, the total area of bog relicts is only about 9 000 ha (Schouwenaars, 1993). In Canada, less than 0.02% (16 000 ha) of the total peatland area is currently being used for horticultural peat harvesting and only 1 500 ha have been fully harvested (Keys, 1992). However, in New Brunswick and the southern part of Québec, peatlands face pressure from industrial and agricultural interests. These two provinces are the main peat moss producers in North America (Keys, 1992) and the conversion of peatlands to agricultural lands caused the disappearance of more than 70% of peatlands in some regions of the St. Lawrence Lowlands (Laframboise, 1987). Consequently, there is a great interest from conservationists, but also from the peat moss industry, to restore harvested peatlands to functional ecosystems.

Many peatlands in Europe and North America are abandoned today after decades of mining. Prior to peat harvest, ditches are dug to drain the site. The surface vegetation is then removed, and the peat deposit is harvested by hand using shovels, or mechanically by tractor-drawn vacuum machines. Only the weakly decomposed *Sphagnum* peat is harvested for horticultural use (Keys, 1992). A post-harvested peatland is a harsh environment. The remaining peat deposit is devoid of plants and viable seeds. Recolonizing species face moisture deficiency in the uppermost peat layer, partly caused by the drying effect of wind action (Salonen, 1987). The first attempts to restore harvested peatlands were conducted in Germany (Eggelsmann, 1988), United Kingdom (Meade, 1992) and The Netherlands (Schouwenaars, 1993). These attempts were limited to the rewetting of peat deposits (by filling or blocking drainage ditches). Recent trials in Finland and Québec to facilitate plant reestablishment suggested that nutrient fertilization (Salonen, 1994) or the spreading of *Sphagnum* diaspores protected by artificial ground covers (Campeau & Rochefort, 1995; Quinty & Rochefort, 1995; Rochefort, Gauthier & Lequéré, 1995) enhance the revegetation process.

A concurrent approach to understand the processes involved in peatland regeneration and, consequently, to improve restoration techniques is the study of the natural revegetation of abandoned bogs. Many studies in Europe (Eggelsmann & Schwaar, 1979; Salonen, 1987; 1990; 1994; Smart, Wheeler & Willis, 1989; Poschlod, 1992; Salonen, Penttinen & Särkkä, 1992; Salonen & Setälä, 1992; Cooper & McCann, 1995; Money, 1995) described the revegetation of mined peatlands at different time scales. General surveys of post-harvested peatlands in Québec (Rochefort & Lavoie, unpubl.) and in central and eastern North America (Famous, Spencer & Nilsson, 1991) showed that > 90% of bogs where peat was harvested by hand (block-cut) are well revegetated (plant cover > 50%). These sites are characterized by mined trenches alternating with raised balks. Most of them were abandoned prior to 1970. The main plants colonizing balks and trenches are ericaceous shrubs and tamarack (*Larix laricina*). However, in Québec, only 0.1% of the balks and 17.5% of the trenches have a *Sphagnum* cover > 50%, (Rochefort & Lavoie, unpubl.). The revegetation of peatlands harvested by vacuum machines and abandoned in the 1980's and 1990's seems to be very slow and dominated mainly by cotton-grass (*Eriophorum vaginatum*) and birches (*Betula papyrifera*, *B. populifolia*). *Sphagnum* are rare on these sites. These different revegetation pathways could give relevant information on major factors allowing the recolonization by plants of a bare peat surface.

To document revegetation patterns of post-harvested peatlands more precisely, we studied a site located in the Rivière-du-Loup region, Québec (Cacouna-Station bog). The natural revegetation of this bog is representative of the general situation in Québec, according to our survey of the abandoned peatlands of the province (Rochefort & Lavoie, unpubl.). The Cacouna-Station peatland was harvested by hand (block-cutting technique) and is well revegetated by ericaceous shrubs, tamarack and birch 20-30 years following abandonment. Only a small fraction (≈ 5%) of the total area has a *Sphagnum* cover > 50%. A section of the block-cut peatland was recently prepared to harvest peat using vacuum machines, but was abandoned at the end of the 1980's. Three different sections of the peatland were selected (according to vegetation structure and harvesting method) to study the spatial distribution of plants. Trees were sampled to describe their establishment in each section. We attempted to link the regeneration pathways to physico-chemical characteristics or harvesting history. This is one of the first detailed studies in North America into the natural revegetation of post-harvested peatlands and, to our knowledge, the first one that includes dendroecological aspects.

Material and methods

Study site

The Cacouna-Station peatland (47° 52' N, 69° 27' W) is located 10 km north-east of the city of Rivière-du-Loup (Québec) and 6 km from the south shore of the St. Lawrence River. In the Rivière-du-Loup region, raised bogs are sparsely distributed and restricted to small depressions (< 3 000 ha). The peat lies on marine clays of the Champlain Sea and the thickness of the deposit may reach 10 m in undisturbed sites (Gauthier & Grandtner, 1975). Data from Saint-Arsène, the weather station closest (2 km) to the study site, indicate that the mean annual temperature is about 3°C, the mean temperature for the coldest month (January) -12°C, and that of the warmest month (July) 18°C. The mean annual precipitation totals 924 mm, 27% of which falls as snow (Environment Canada, 1993).

The altitude of the Cacouna-Station bog is 83 m and its total area is 179 ha. The peatland is divided into north and south by a railway. Fourteen aerial photographs of the bog (scale 1: 40 000 to 1: 10 000) were taken between 1948 and 1991. The harvest (block-cutting) of the peat probably began around 1945 (Leverin, 1947; D. Lequéré, pers. comm.). Approximately 60% and 90% of the site was under harvesting in 1948 and 1961, respectively, as shown on aerial photographs by the presence of mined trenches and hurdles or sheds for peat blocks. The southern half of the peatland was progressively abandoned between 1963 and 1970. In 1970, only some sections of the northern half of the bog were still harvested. The last year of block-cut harvesting was in 1975 (G. Lavoie, pers. comm.). About 1-2 m of peat was removed during the harvesting period. Between 1983 and 1989, an area of 15 ha located in the northern half of the peatland was bulldozed each year (1) to level the peat deposit (formerly characterized by trenches alternating with balks), (2) to prevent plant reestablishment, and (3) to allow an additional peat harvest using tractor-drawn vacuum machines. Additional drainage ditches were dug, separating the bulldozed section into smaller (≈ 30 m × 250 m) units. However, no peat was removed during this period and the bog was finally abandoned in 1989.

Selection of sampling sections

In August 1994, each section of the peatland (divided by old tracks permitting peat transport or by drainage ditches) was visited to characterize the vegetation structure of every balk, trench, or bulldozed unit. We adapted the classification of vegetation structure of Payette & Gauthier (1972) to the particular case of post-harvested peatlands. For each balk, trench and bulldozed unit, we estimated the cover of the following structures: (T) tree, (E) ericaceous shrub, (H) herb, (S) *Sphagnum*, (M) moss, (L) lichen and (B) bare peat. Five cover classes were used: (1) < 1%, (2) 1-10%, (3) 11-25%, (4) 26-50% and (5) > 50%. Only the two main vegetation structures (*i.e.* those with the highest cover) were retained to characterize a balk, a trench or a bulldozed unit (for example, a trench S_5T_3 has a *Sphagnum* cover of > 50% and a tree cover between 11 and 25%). A total of 266 balks, 280 trenches and 16 bulldozed units were then characterized, respectively. Balks had a similar vegetation structure (E_5B_5, E_5B_4 or B_5E_4) throughout the peatland. Two main groups of trenches were found, *i.e.* E_5B_5 (80% of the trenches), with a *Sphagnum* cover of < 10%, and E_5S_5 or E_5S_4 (10% of the trenches). All the bulldozed units had a similar vegetation structure (T_5B_5 or B_5T_4).

The only section of the bog where E_5S_5 vegetation structure was found was selected for sampling. It was located at the western end of the peatland, north of the railway, and was named the *Sphagnum* (S) section. It was characterized by 10 wide trenches (12-14 m × 90 m) separated by narrow balks (1-2 m × 90 m). A section with E_5B_5 balks and trenches located a few meters north of the S section was also selected. This section was judged representative of the majority of the other parts of the peatland and was named the Ericaceous shrub (E) section. It was characterized by 6 wide trenches (14 m × 90 m) also separated by narrow balks (1-2 m × 90 m). The last year of block-cut harvesting of E and S was 1975. Finally, one of the four bulldozed units bordering the E and S sections was randomly chosen for sampling and was named the Bulldozed (B) section. The advantage of selecting these three sections (S, E and B) is their different harvesting history and revegetation pattern, although they were situated a few meters apart.

Sampling

Three trenches of the E and S sections (E3, E4, E5 and S2, S5, S9) were randomly chosen for sampling. Balks were not sampled because of their narrowness and because they were highly disturbed by walking trails. The vegetation was described in September 1994 using the sampling point method (Bonham, 1989). The presence/absence of all species of vascular plants, mosses, *Sphagnum*, liverworts and lichens covering a small point (diameter: 1 cm) every 2 m along 6 or 7 transects (2-m apart and 90-m long) was noted. The transects numbered 1, 3, 5 and 7 (if present) were used to sample trees. The nearest tree (seedling, sapling or mature tree) within a circle of a 4-m radius around a sampling point located every 4 m along the selected transects was sampled. Total height and basal stem diameter of sampled individuals were measured, and a stem section was taken at the collar. In the laboratory, tree rings were counted on the fine-sanded cross-sections.

At every 8 m along each transect, the relative elevation of the sampling point was measured using a theodolite. Thickness of the acrotelm, *i.e.* the upper layer of the peat having a live matrix of growing plants (Ingram, 1978), was also measured by excavating a peat section. Total peat thickness was estimated using an iron rod every 8 m along a line placed at the center of the trench.

Depth of the water table was measured (September 14, 1994) at a sampling point located at the center of the trench. Five to ten days prior to the measurement, a hole was dug and left to be filled by ground water. A water sample of the E_4 and S_5 trenches was also taken for chemical analyses.

The same measurements were taken in the B unit. However, the vegetation was described along 8 transects 4 m apart and 264 m long. The presence/absence of plant species was noted every 4 m along the transects. The transects numbered 1, 3, 5 and 7 were used to sample trees. The nearest individual tree within a circle of 4-m radius around a sampling point located every 8 m along the selected transects was sampled. Every 8 m along the transects 1, 3, 5 and 7, the relative elevation of the point and thickness of the acrotelm were measured. The total peat thickness was estimated using an iron rod every 16 m along a line placed at the center of the section. Depth of the water table was measured (September 14, 1994) at a sampling point located at the center of the section. A water sample was also taken for chemical analyses.

Nomenclature follows Scoggan (1978-1979) for vascular plants, Anderson, Crum & Buck (1990) for mosses, Anderson (1990) for *Sphagnum*, Stotler & Crandall-Stotler (1977) for liverworts and Egan (1987) for lichens.

Chemical analyses

Water samples were sent to the Peat Research and Development Centre Inc. (Shippagan, New Brunswick) for chemical analyses. Samples were filtered on a 0.45-μm cellulose acetate filter prior to analyses. Specific conductance was adjusted to 20°C and corrected for [H^+] following Sjörs (1952). NH_4^-N was analyzed by steam distillation. Element content was obtained by atomic absorption (Ca, Fe, K, Mg, Na) or colorimetric methods (P). Cl, NO_2^-N, NO_3^-N and SO_4 content was obtained by ionic chromatography.

Results and discussion

Physico-chemical characteristics

The microtopography of the trenches was characterized by a rounded profile (Figure 1), as a result of the block-cutting technique. Surface vegetation and wood fragments buried in the peat were continuously dumped in the center of the mining trench during peat extraction. Some mounds were apparent in the S trenches and corresponded to *Sphagnum* hummocks. The slope was steeper in the E (0.46-0.91%) than in the S (0.13-0.45%) trenches (Table I). In the B unit, the topography was flat, with a small depression of less than 50 cm from 200 to 240 m (Figure 2a). The mean peat thickness of the E and S trenches was about 2 m and that of the B unit 2.5 m (Table I). Following the abandonment of the peatland, a new acrotelm was formed only in the S trenches, under a *Sphagnum*, *Polytrichum* or *Eriophorum* carpet. The mean thickness was 11-13 cm, but 20-30 cm under *Polytrichum strictum* hummocks.

The water level was just beneath the peat surface in the S trenches, 12 to 25 cm lower in the E trenches, and 51 to 59 cm lower in the B unit (Table I). Even though 1-2 m of peat was harvested, the water chemistry of the Cacouna-Station bog is similar to that of *Sphagnum* dominated peatlands (bogs and poor fens) of Québec and Alberta (Rochefort, unpubl.; Vitt & Chee, 1990). However, slight

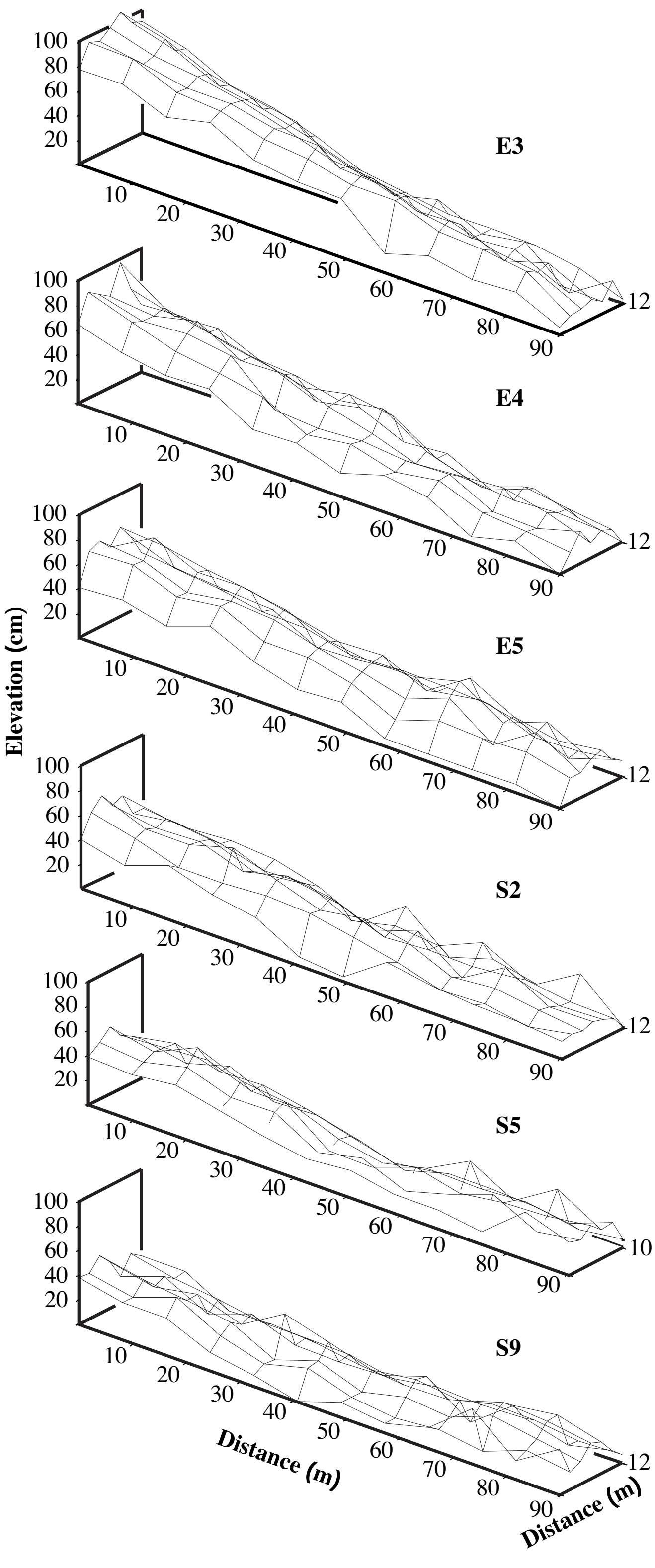

FIGURE 1. Microtopography of the ericaceous shrub (E) and *Sphagnum* (S) trenches. Vertical scale is exagerated.

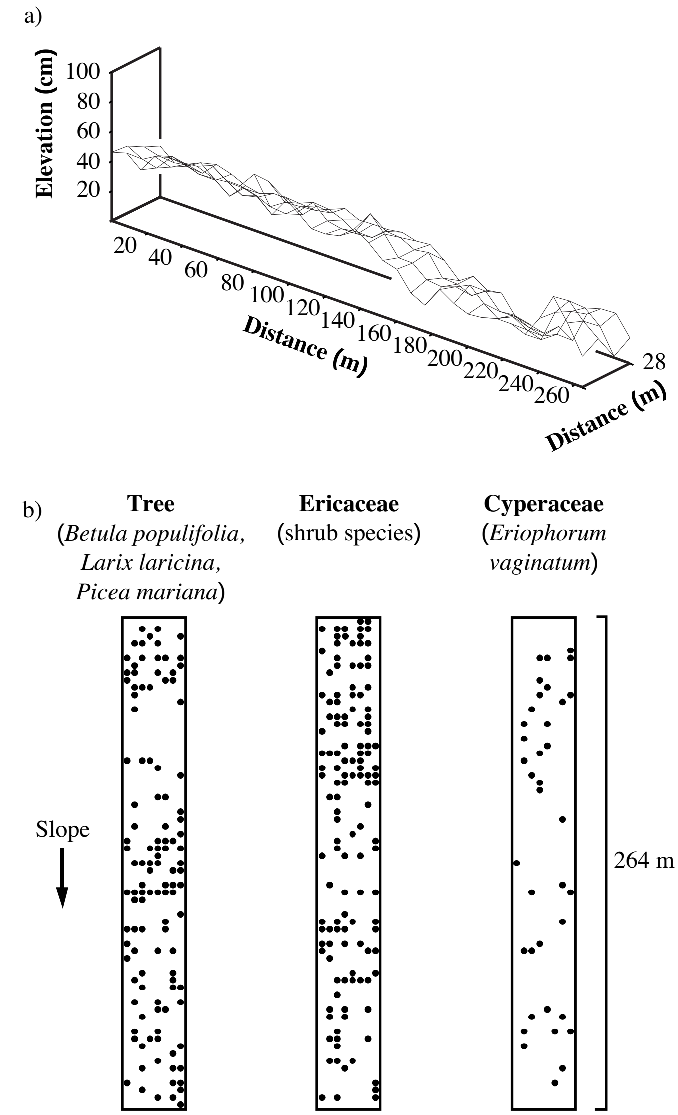

FIGURE 2. a) Microtopography of the bulldozed section. Vertical scale is exagerated. b) Spatial distribution of trees, ericaceous shrubs and of cotton-grass in the bulldozed section. A taxon covering a sample point (located every 4 m along transects 4 m apart) is represented by a dot.

TABLE I. Physical and chemical characteristics of the ericaceous shrub trenches (E), *Sphagnum* trenches (S) and bulldozed unit (B) of the Cacouna-Station peatland

Trench or unit	E3	E4	E5	S2	S5	S9	B
Slope (%)	0.91	0.70	0.46	0.45	0.21	0.13	0.08
Peat thickness							
N	12	12	12	12	12	12	17
Mean ± σ (cm)	209 ± 28	214 ± 25	200 ± 28	227 ± 33	191 ± 13	177 ± 14	250 ± 49
Acrotelm thickness							
N	42	42	42	42	42	42	136
Mean ± σ (cm)	0	0	0	13 ± 7	11 ± 6	13 ± 6	0
Water level (cm)[1,2]							
September 14, 1994	-27	-26	-31	-14	-13	-6	-65
Surface water chemistry[1]							
pH		3.54			4.19		3.84
Conductivity (μS)		7.71			40.61		26.39
NH_4^-N (mg/L)		0.60			0.40		1.90
NO_2^-N (mg/L)		< 0.01			< 0.01		< 0.01
NO_3^-N (mg/L)		0.02			0.01		0.02
SO_4 (mg/L)		0.56			0.20		0.64
Ca (mg/L)		2.14			4.29		2.50
Cl (mg/L)		1.42			1.49		1.70
Fe (mg/L)		0.58			0.63		0.40
K (mg/L)		0.17			1.09		0.68
Mg (mg/L)		0.97			2.14		0.75
N (total; mg/L)		4.68			4.48		7.67
Na (mg/L)		2.26			4.65		1.84
P (mg/L)		0.04			0.04		0.08

[1] The sampling point was located at the center of the section.
[2] A negative value indicates a water level beneath the peat surface.

enrichments were noticed for base cations (Ca, Mg and Na) and nitrogenous nutrients. Ca and Mg indicate a minerotrophic influence not found in undisturbed bogs, but still well below the conditions of moderate-rich fens (*sensu* Vitt & Chee, 1990). The high Na content probably reflects the maritime influence of the St. Lawrence Estuary. Although it is only based on two water samples (E_4 and S_5), it is noteworthy that the concentrations of NH_4^-N and NO_3^-N of the Cacouna-Station site are higher than levels found in undisturbed peatlands across Canada but lower than those of harvested and recently abandoned bogs (Wind-Mulder, Rochefort & Vitt, unpubl.). This intermediate nutrient status could reveal that vegetation uptake does not balance mineralization even after 20 years of abandonment.

SPATIAL DISTRIBUTION OF VEGETATION

A total of 31 plant species was recorded for all trenches or bulldozed units sampled (Table II). There was at least one species recorded in 90-99% of sampling points in E and S, in contrast with the B unit (48%). Three tree species were noted (*Larix laricina*, *Picea mariana* and *Betula populifolia*). Ericaceous shrubs were very abundant and uniformly distributed (E and S; Figure 3). The main species were *Chamaedaphne calyculata*, *Kalmia angustifolia* and *Ledum groenlandicum*. *Vaccinium angustifolium* was more common in the E than the S trenches. The main difference between E and S is with Cyperaceae, mosses and *Sphagnum*. *Eriophorum vaginatum*, *Carex brunnescens*, *Polytrichum strictum* and *Sphagnum* species were much more common in S than in E. In S_5 and S_9, Cyperaceae, mosses and *Sphagnum* had clearly their highest density in the lower and wetter part of the slope, while trees were more common in the upper and drier part. In the B unit, *Betula populifolia* was by far the main plant species (Table II; see also Figure 2b), and no *Sphagnum* or mosses were observed.

The block-cut sections of the Cacouna-Station peatland are well revegetated by typical peatland species growing in undisturbed bogs of the Rivière-du-Loup region (Gauthier & Grandtner, 1975). Colonizing species are regularly recorded in post-harvested peatlands throughout the world (*e.g. Eriophorum vaginatum*; Eggelsmann & Schwaar, 1979; Salonen, 1987; 1994; Smart, Wheeler & Willis, 1989; Poschlod, 1992; Money, 1995) and in North America (*e.g. Chamaedaphne calyculata* and *Kalmia angustifolia*; Green, 1983; Famous, Spencer & Nilsson, 1991; Jonsson-Ninniss & Middleton, 1991). *Sphagnum* species are much more common in undrained bogs (Gauthier & Grandtner, 1975) than in the Cacouna-Station peatland where they are restricted to a small part of the site. It is reported that *Sphagnum* species cannot survive with a yearly average water table lower than 40 cm below the surface in continental or sub-maritime climate (Schouwenaars, 1988). This could explain in part the unsuccessful *Sphagnum* recolonization in the E and B sections where the water table was at ≤ 30 cm below the surface. However, further hydrological studies are needed since it is recognized that the water table of drained peatlands fluctuates more rapidly than in natural sites (Nicholson, Robertson & Robinson, 1989; Okruszko, 1989). Other factors such as an irregular microtopography (creating windbreaks) or the proximity of a diaspore source (Salonen & Setälä, 1992; Poschlod, 1995) could also play a major role in the revegetation success.

The vegetation of the bulldozed section is very different from natural bogs. Additional drainage of this section between 1983 and 1989 lowered the water level and allowed only the growth of *Betula populifolia*. This species grows successfully on peat and tolerates a wide range of

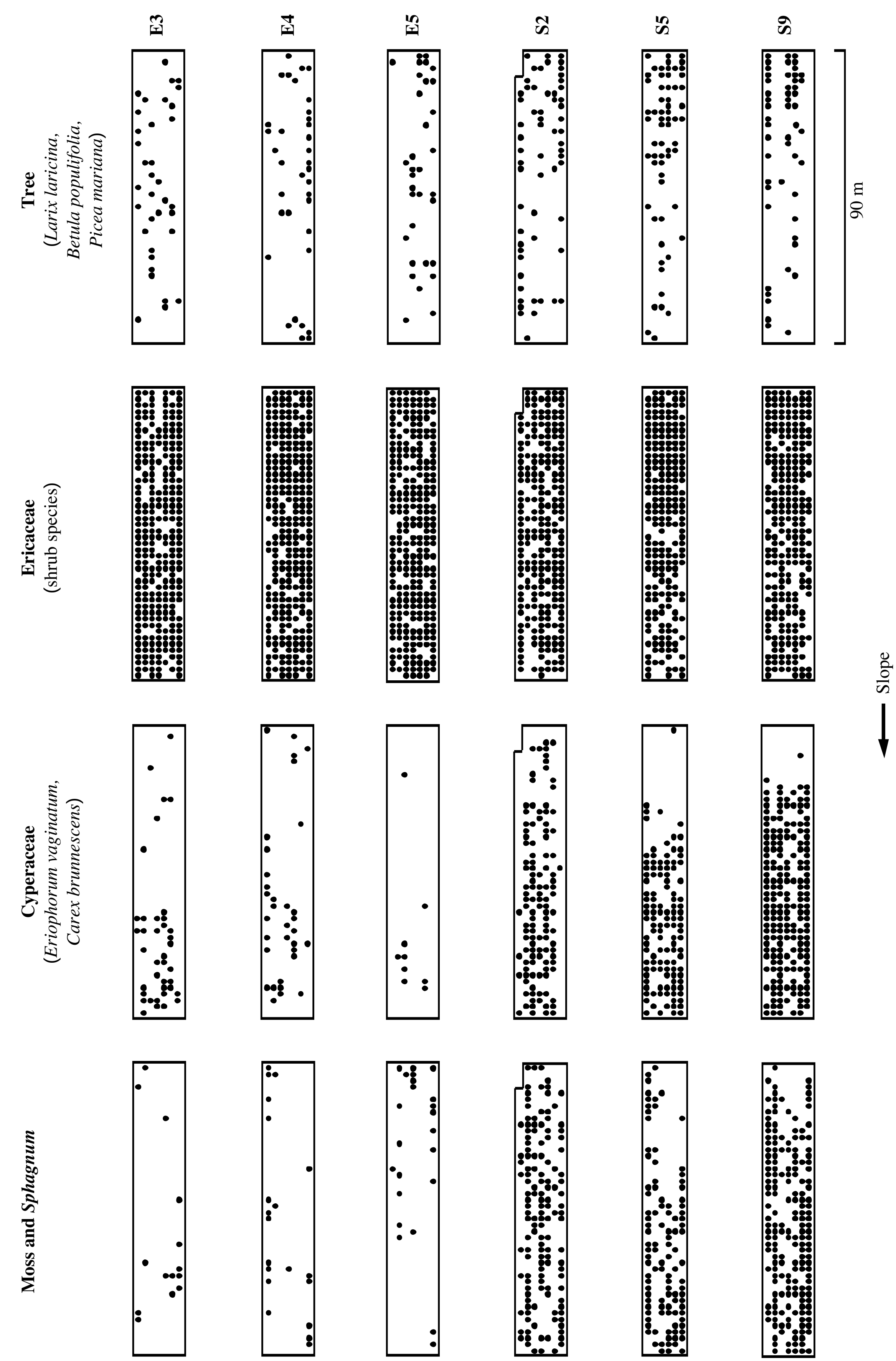

FIGURE 3. Spatial distribution of trees, ericaceous shrubs, sedges, cotton-grass, mosses, and *Sphagnum* in the ericaceous shrub (E) and *Sphagnum* (S) trenches. A taxon covering a sample point (located every 2 m along transects 2 m apart) is represented by a dot.

TABLE II. Percentage of sampling points having a given species in the ericaceous shrub trenches (E), *Sphagnum* trenches (S) and bulldozed unit (B) of the Cacouna-Station peatland

Trench or unit	E3	E4	E5	S2	S5	S9	B
Sampling points (N)	322	322	322	218	276	322	536
Points with vegetation (%)							
All species considered	92.5	95.3	90.7	98.7	99.3	99.7	47.6
Tree							
Larix laricina	7.5	6.2	5.9	14.8	17.8	13.7	0.2
Picea mariana	0.6	0.6	0.6	1.3	0.4	1.2	0.2
Betula populifolia	3.4	4.7	4.3	4.1	5.8	1.6	21.1
Ericaceae (shrub species)							
Andromeda glaucophylla	0.9		0.3	0.3			
Chamaedaphne calyculata	46.0	49.1	45.0	31.1	38.0	48.1	10.6
Kalmia angustifolia	22.0	15.8	26.4	14.2	15.2	6.5	0.9
Ledum groenlandicum	29.8	23.3	29.8	37.4	40.6	30.4	6.2
Rhododendron canadense	6.2	4.0	4.0	8.5	14.5	9.0	0.6
Vaccinium angustifolium	23.3	23.9	20.5	11.0	12.3	4.7	9.0
Cyperaceae							
Eriophorum vaginatum	12.1	10.2	2.8	35.5	37.3	39.1	6.9
Carex brunnescens				1.3	8.3	23.0	
Other vascular plants							
Osmunda cinnamomea						0.3	
Cypripedium acaule						0.3	
Drosera rotundifolia					0.4		
Prunus virginiana			0.3				0.2
Rubus chamaemorus	2.8	5.0	1.9	0.9			0.9
Nemopanthus mucronata		0.3					
Gaultheria hispidula	5.6	3.1	5.3	6.0	9.1	1.9	
Vaccinium oxycoccus				0.9	0.4	0.3	
Melampyrum lineare			0.3				
Moss and *Sphagnum*							
Polytrichum strictum	0.6	0.6	2.8	16.0	12.7	9.9	
Sphagnum capillifolium	2.8	2.5	2.8	17.0	12.0	6.2	
Sphagnum fallax	0.3	0.9	0.3	2.8	6.5	35.7	
Sphagnum fimbriatum						0.3	
Sphagnum fuscum	0.3	0.3		1.3	0.7	2.5	
Sphagnum magellanicum	0.3	0.6	0.9	9.7	8.3	3.7	
Sphagnum rubellum					0.4		
Sphagnum russowii		1.2	0.3	0.3	0.4	0.9	
Liverwort							
Mylia anomala	8.4	5.6	4.3	4.4	2.9	1.6	
Lichen							
Cladina mitis	0.3	0.6	0.6				
Cladonia cristatella	1.6	0.9	1.2				
Total number of species	20	21	22	21	21	22	11

drainage conditions (Bergeron, Bouchard & Leduc, 1988). *Betula populifolia* is usually not so abundant in natural peatlands but is often present after a disturbance such as drainage (Lévesque & Millette, 1977) or fire (Jean & Bouchard, 1987; Meilleur, Bouchard & Bergeron, 1994). It is noteworthy that the Cacouna-Station birch population is located 70 km north-east of the limit of natural distribution of the species (Rousseau, 1974). Large *Betula populifolia* populations were also observed in other abandoned peatlands of the region (Rivière-du-Loup, Le Parc, Coteau-du-Tuf, Isle-Verte [Rochefort & Lavoie, unpubl.]). Apparently, harvesting activities have favored the spread of this species north of its natural limit or the expansion of populations unnoticed by Rousseau (1974).

DENDROECOLOGICAL DATA

Figure 4 shows the age structure of *Larix laricina*, *Betula populifolia* and *Picea mariana* populations for the E, S and B sections. Because all trenches were abandoned at the same time, data were combined for each section. The age structure was established only when ≥ 10 individuals of the same species were sampled in a section. Trees were usually unable to grow in the peatland during the harvesting activities. However, in the E and S trenches, there was a sharp rise in the number of established *Larix laricina* only two years after abandonment (1975). It is unclear whether the 2-year lag between the abandonment and the rise in the number of established tamarack is due to the time required to make a good seedbed or the occurrence of a good seed year. However, additional rises in the number of tamarack are recorded in the age structure (1989-90), supporting the seed-year hypothesis. The population structure of *Betula populifolia* is not characterized by the rise and fall of established individuals, at least during the first 10 years after abandonment, probably because early successional birch species are known to produce numerous seeds on a regular

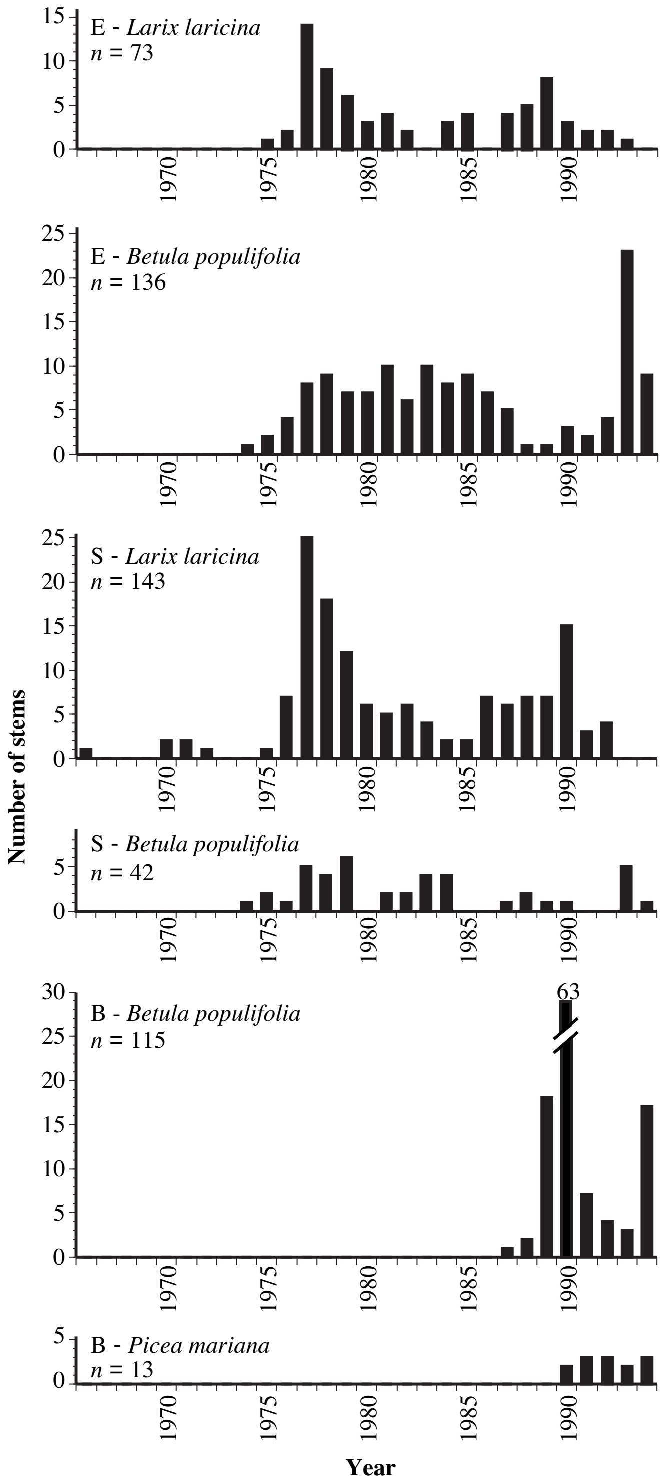

FIGURE 4. Age structure of tamarack, gray birch and black spruce populations of the ericaceous shrub (E), *Sphagnum* (S) and bulldozed (B) sections.

basis, *i.e.* almost every year (Fowells, 1965). In the B section, massive seedling establishment of birch occurred in 1990, *i.e.* one year after abandonment.

The relationship between the establishment year of a tree and total height and basal stem diameter was determined for tamarack and birch in the E and S sections (Figure 5). In most cases, the height and radial growth had a negative exponential pattern, particularly striking for *Larix laricina* (R^2: 0.46 to 0.85). Only tamaracks established during a 5-year period following the abandonment of the peatland were able to reach a total height of > 1 m, and a basal stem diameter of > 4 cm. This growth pattern is very similar to that observed following a fire in the boreal forest. The postfire cohort of trees light-suppresses the saplings established later (*i.e.* 10 years after the fire) (Bergeron & Charron, 1994). Although *Betula populifolia* and *Larix laricina* are shade intolerant species (Duncan, 1954; Fowells, 1965; Hosie, 1980; Gower & Richards, 1990), the tree population in the E and S sections is not dense enough to shade the saplings and prevent vertical and radial growth. Young birch and tamarack saplings were probably suppressed by established ericaceous shrubs. Tree height and diameter data thus suggest that ericaceous shrubs completely covered the trenches only 5 years after harvesting ceased.

Conclusion

Thickness of the peat deposit, surface water chemistry, and vascular plant species of the block-cut sections of the Cacouna-Station peatland are characteristic of the undrained bogs of the Rivière-du-Loup region. Revegetation of the E and S sections seemed to be very rapid; tamarack saplings were probably “choked” by a dense cover of ericaceous shrubs only five years after abandonment. Recolonizing processes of the Cacouna-Station peatland are not hampered by non-mire invasive species, which can be a problem for restoration in some abandoned European peatlands (B. D. Wheeler, pers. comm.). However, the scarcity of *Sphagnum* and mosses in most trenches, even 20-30 years after abandonment, suggests that the bog is not returning to a functional peatland ecosystem. Indeed, *Sphagnum* species or *Polytrichum strictum* seem to be essential for the formation of a new acrotelm, as observed in the S trenches. A post-harvesting acrotelm formed by ericaceous shrub remains (*sensu* Smart, Wheeler & Willis, 1989) was not observed in the E, S and B sections. Our study points to water level and harvesting methods as major factors controlling revegetation. For example, in the B section, additional drainage and the flat microtopography probably explain the slowness of revegetation and the presence of an important *Betula populifolia* population. Further investigations are needed to document special cases where natural revegetation failed even though sufficient moisture was available (Rochefort & Lavoie, unpubl.). The understanding of variable revegetation patterns will improve our knowledge of the recovery of highly disturbed peatlands.

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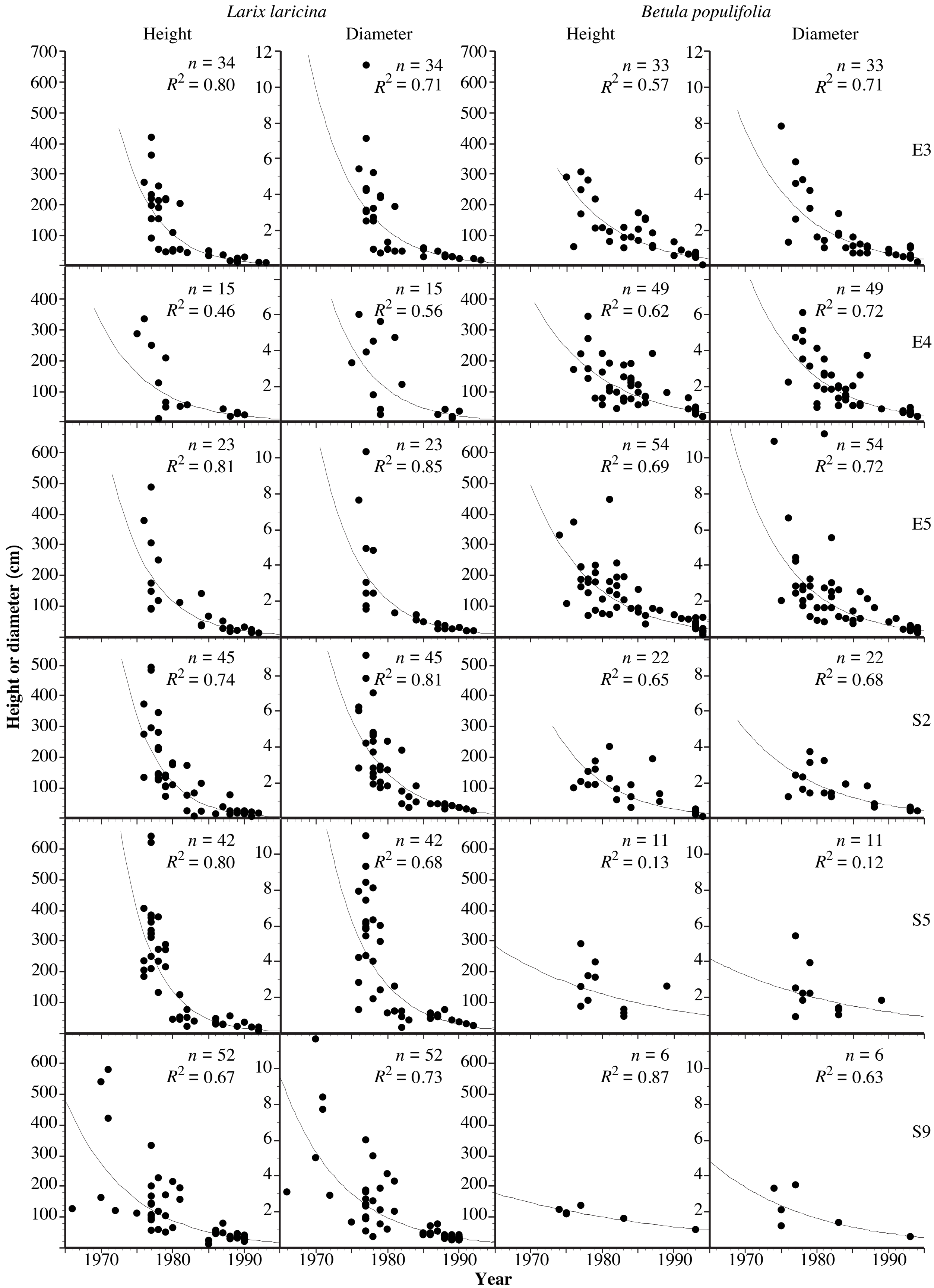

FIGURE 5. Relationship between time since establishment, height and basal stem diameter of tamarack and gray birch populations of the ericaceous shrub (E) and *Sphagnum* (S) trenches. R^2 were calculated using a negative exponential model.

of the Cacouna-Station peatland, S. Guay (Borealis Enr.) for field assistance and D. Bastien for help in *Sphagnum* identification. Comments of S. Campeau, G. Houle, N. G. Miller and an anonymous reviewer on an earlier draft were greatly appreciated.

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