

Linking microtopography with post-fire succession in bogs

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Abstract

Questions: Does post-fire plant succession in boreal bogs vary microtopographically and are successional patterns reproducible among similar microtopographic features? Does succession preserve microtopography post-fire?

Location: Boreal bog peatlands near Sinkhole Lake and Athabasca, Alberta, Canada.

Methods: We assessed microtopographic variation in post-fire plant community succession through stratigraphic macrofossil analysis of bog soil cores collected from high (hummock) and low (hollow) positions. We conducted vegetation surveys and collected soil cores from ten hummocks and hollows in each bog. Pre-fire microtopographic status was inferred based on floral composition and compared to current microtopography.

Results: Hollow vegetation was more variable than hummocks, both in present composition and post-fire succession. The successional trajectory of current hummocks was relatively uniform, showing relatively rapid shifts to *Sphagnum fuscum* dominance, but varied greatly in hollows. Hollows, although compositionally variable, were typically perpetuated following fire, while hummocks had an approximately equal chance of being perpetuated or becoming hollows.

Conclusions: Greater compositional variability at lower microtopographic positions, both spatially and temporally, is most likely due to the ability of hollows to support a wider range of species and greater susceptibility to severe disturbance. Likewise, spatial variability in fire severity appears to be responsible for perpetuation or change in microtopographic status, favouring the creation of hollows over maintenance of hummocks.

Keywords: Hollow; Hummock; Macrofossil analysis; Non-metric Multidimensional Scaling; *Sphagnum*.

Abbreviations: Ath = Athabasca; DSE = Distance from set elevation; Hol = Hollow; Hum = Hummock; MTF = Microtopographic feature; NMDS = Non-metric dimensional scaling; RCD = Relative charcoal distance; *R* = ANOSIM test statistic; SL = Sinkhole Lake.

Introduction

Floral composition of boreal, ombrotrophic bogs varies microtopographically between high, drier hummocks and lower, wetter hollows (lawns *sensu* Sjörs 1951) separated by up to 0.5 m in vertical position (Vitt & Slack 1984; Malmer 1986; Rydin 1986, 1993; Wallén & Malmer 1992). *Sphagnum* mosses dominate bogs due to their tolerance for the edaphic conditions (Vitt & Slack 1984; Rydin 1986, 1993). Particular *Sphagnum* species occur at different positions along the microtopographic gradient. Through competitive interactions and intolerance to flooding, *S. fuscum* is excluded from hollows and is restricted to its realized niche upon the tops of hummocks (Titus et al. 1983; Wagner & Titus 1984; Rydin 1986, 1993). Carpet and lawn species (e.g. *S. riparium* and *S. angustifolium*, respectively) are more prone to desiccation due to an inability of the moss community to retain water sufficiently and therefore are excluded from hummocks (Titus et al. 1983; Wagner & Titus 1984). Species that occupy intermediate positions (e.g. *S. magellanicum*) possess water relationships intermediate between hummock and lawn species.

Microtopographic compositional variation results in variation in peat accumulation because rates of production and decomposition are species-specific (Vitt & Slack 1984; Malmer 1986; Rochefort et al. 1990). *Sphagnum fuscum* has relatively low rates of production (Rochefort et al. 1990) but a high proportion of carbon in recalcitrant compounds, resulting in lower rates of decomposition compared to other bog species (Turetsky 2002). However, due to greater bulk densities of peat in hollows, hummocks and hollows may accumulate equivalent quantities of organic matter, despite differences in column depth (Benscoter et al. in press).

Fire has pronounced effects on local peatland processes (Mackey 1997). Carbon is lost directly through combustion of biomass, releasing 1–4 kg-C.m⁻² from affected boreal peatlands to the atmosphere (see Benscoter & Wieder 2003). Assuming 1470 ± 59 km² of peatland burns annually in boreal, western Canada (Turetsky et al. 2002), there is a direct loss of 3.1 ± 0.5 Tg-C.a⁻¹ from the affected peatlands in this region

(Benscoter & Wieder 2003). However, combustion is variable both within and between peatlands. In one bog fire, hummock vegetation resisted extensive combustion ($1.5 \pm 0.1 \text{ kg-C.m}^{-2}$ lost), while hollow vegetation burned to a greater degree ($2.8 \pm 0.3 \text{ kg-C.m}^{-2}$ lost; Benscoter & Wieder 2003), most likely due to greater water retention by hummock communities.

Fire resets the succession pattern of peatland vegetation as well, which further alters peatland C-cycling. Succession has the potential to influence bog microtopography, either by promoting the regeneration of the pre-fire microtopography or by causing changes due to shifts in vegetation. However, few studies have addressed the successional trajectory post-fire (Maltby et al. 1990; Kuhry 1994; Zoltai et al. 1998) and no studies of which we are aware have investigated microtopographic differences in vegetation succession or the effects of pre-fire microtopography thereon. The objective of this study is to compare vegetation composition and successional trajectory microtopographically and to assess the effects of succession and disturbance on the development and maintenance of microtopography post-fire for two representative continental western Canadian bogs.

Methods and Material

Site selection

Two historically burned bog sites were chosen: Sinkhole Lake and Athabasca. Sinkhole Lake ($53^{\circ}19' \text{ N}$, $115^{\circ}13' \text{ W}$) bog is bordered by a large non-patterned poor fen located ca. 120 km WSW of Edmonton, Alberta. According to historical fire records, this bog burned in a 1942 fire (Delisle & Hall 1987) that affected the entire bog land form, resulting in a dense, even-aged *Picea mariana* stand (48–51 years based on tree ring analysis). Test cores from hummocks showed a distinct charcoal layer around 25–30 cm from the surface, a depth consistent with ca. 60 years of post-fire peat accumulation (cf. Turetsky et al. 2000).

Athabasca ($54^{\circ}43' \text{ N}$, $113^{\circ}10' \text{ W}$) is a smaller bog also surrounded by a large non-patterned poor fen located ca. 5 km E of Athabasca, Alberta. Although records of a fire in this area are not available due to the small areal extent of the fire (< 200 ha), there was evidence that a fire occurred in this landform more recently than at Sinkhole Lake based on a younger (28–32 years based on tree rings), less dense *P. mariana* stand and a charcoal layer depth of around 15–20 cm, placing the time of fire ca. 40 years ago based on an expected 10-year post-fire re-establishment lag for *P. mariana* (Zoltai et al. 1998).

Experimental design

Present plant community and microtopographic relief

One transect was established through the centre of each bog site with 10 sampling points positioned randomly along each transect.

At each point, a $0.5 \text{ m} \times 0.5 \text{ m}$ plot was established on the nearest hummock and the nearest hollow and percent cover by species of the understorey (shrubs and herbaceous) and ground layer (bryophytes and lichens) was assessed for each plot. Epiphytic lichens present on stems of shrubs were also included, but ephemeral herbaceous species (e.g. *Smilacina trifolia*, *Rubus chamaemorus*) were absent due to timing of sampling. To quantify microtopographic relief, a reference line was established along the transect using a rotating laser level and measurements of deviation from this reference line to the vegetation surface were made for each plot (Distance from Set Elevation: DSE).

Non-metric multidimensional scaling (NMDS) was used to ordinate the plots based on their species composition (Minchin 1987) using DECODA v3.00 (Minchin 1998). The Bray-Curtis (Sørensen) dissimilarity index was used with standardized data to equalize the height of species response curves (Faith et al. 1987), with 20 different random starting configurations. Dimensionality of the final ordination was determined using a scree plot of number of dimensions vs. the minimum stress obtained and the axes were rescaled in half-change β -diversity units (McCune & Grace 2002).

Analysis of similarity (ANOSIM) was used to detect differences between *a-priori* groups of plots (i.e. hummocks vs. hollows, Sinkhole Lake vs. Athabasca; Clarke 1993). Using DECODA, groupings comparing sites and microtopographic features (hummocks and hollows) were tested. Vector fitting in DECODA was used to determine the degree of correlation of the plot positions in the ordination with variables describing the nature of the plot (site, microtopographic feature, relative vertical relief (DSE), and α diversity) and relativized based on their degree of correlation with the ordination. Monte Carlo simulations with 10 000 permutations were performed in DECODA to test the significance of the ANOSIM and vector fitting results.

To determine if the *a-priori* groups corresponded with patterns in vegetation composition between plots, hierarchical polythetic agglomerative clustering was performed using PC-ORD v4.0 (McCune & Mefford 1999). The average linkage fusion strategy was used based on Bray-Curtis (Sørensen) dissimilarities and summarized into five groups. Using these groups, indicator species analysis was used to identify species with high group fidelity and constancy.

Calculations of α , γ and β diversity using species richness were made for each site \times feature combination. Due to the constant size of the plots, the typical problems with using species richness can be avoided (McCune & Grace 2002). Alpha diversity (α) is the number of species within a plot. Beta diversity (β), which characterizes the rate of compositional turnover between plots (McCune & Grace 2002), was calculated as:

$$\beta = \gamma / \bar{\alpha} \tag{1}$$

where γ is the overall diversity of the site \times feature combination and $\bar{\alpha}$ is the mean diversity of the plots within each site \times feature combination.

Post-fire vegetation succession

Macrofossil analysis of stratigraphically deposited peat was used to assess post-fire compositional change. Intact peat cores were collected at random from each of the 20 plots at both sites by inserting a 50-cm long polyvinyl chloride (PVC) pipe 10 cm in diameter into the peat column. Each core was sectioned lengthwise into 1-cm depth increments continuously from the peat surface down to the charcoal layer to be used for macrofossil analysis.

Estimations of species abundance were made microscopically for subsamples of each depth increment as a percentage of the assessed subsample (App. 1a-b). Species were assigned to one of five functional groups based on taxonomy: *Sphagnum* Sect. *Acutifolia* (i.e. *S. fuscum*, *S. capillifolium*), *Sphagnum* Sect. *Cuspidata* (i.e. *S. angustifolium*, *S. riparium*), *Sphagnum* Sect. *Sphagnum* (i.e., *S. magellanicum*), true mosses (i.e., *Polytrichum strictum*, *Aulaacomnium palustre*, *Dicranum undulatum*), or lichen (i.e. *Cladina* spec., *Cladonia* spec.). Samples below the charcoal horizon were excluded from plant succession analyses, but were used to determine pre-fire microtopographic status (see below). The proportional composition of the five functional groups for each 1-cm depth increment were ordinated using NMDS as described above, followed by ANOSIM (grouped by site, microtopographic feature, and Relative Charcoal Distance, RCD), and vector fitting.

Calculations of α , γ and β diversity were made for each core, with α representing the diversity in an individual depth segment, γ representing the overall diversity of the core, and β representing the compositional change along the length of the core. Due to the grouping of species into functional classes and uncertainty as to the homogeneity of quantity of assessed subsample relative to the entire depth increment, the reciprocal of Simpson's dominance index

$$D_2 = \frac{1}{\sum_{i=1}^s p_i^2} \tag{2}$$

which measures the probability that two individuals chosen at random from a sampling unit will be different species, was used for calculating α and γ diversity.

Changes in microtopography

Pre-fire microtopographic position was inferred through macrofossil analysis of the vegetation remains found just below the most recent charcoal horizon. Dominance of characteristic species was used to infer hummock (*Sphagnum fuscum* or *Acutifolia* spp.), hollow (*S. angustifolium*, *Cuspidata*, spp., or lichens), or intermediate hummock (*S. magellanicum*) status. Hummocks and intermediate hummocks were combined for analytical purposes. Pre-fire status was compared to current microtopography to determine probabilities of persistence or change in microtopographic feature status for each site.

Results

Present vegetation community

For both sites, diversity (α and γ) and turnover were greater for hollows than hummocks (Table 1). Microtopographic feature, which is autocorrelated with vertical relief (DSE), is responsible for the greatest degree of variation in the NMDS, corresponding strongly with axis 1, which was rotated to the principal axis of variation (Fig. 1). ANOSIM indicated significant differences between sites and features ($p < 0.01$), although hummock points, regardless of site, were more tightly arranged than those for hollows. Cluster analysis supported the greater similarity of hummocks compared to hollows, placing all hummock plots in one group but dividing the hollow plots into the remaining four groups

Table 1. Diversity (species richness) calculations for present vegetation composition of hummocks and hollows from Sinkhole Lake and Athabasca bogs.

Site	Feature	γ Diversity	Mean α Diversity	β Diversity
Sinkhole Lake	Hollow	32	17.1	1.9
	Hummock	21	13	1.6
Athabasca	Hollow	32	15	2.1
	Hummock	19	11.2	1.7

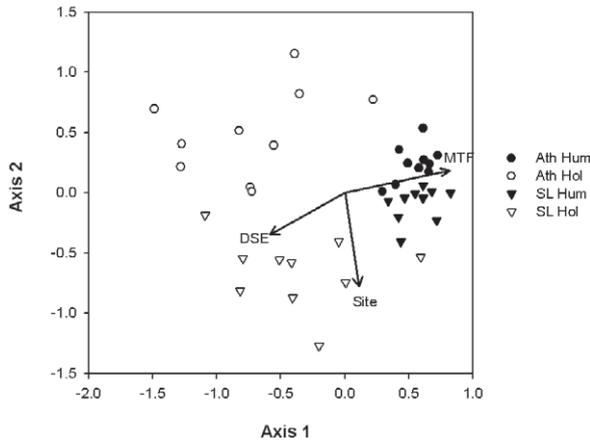


Fig. 1. NMDS ordination of vegetation cover data for ten hummock (solid) and ten hollow (open) plots in Athabasca and Sinkhole Lake bogs (stress = 0.1677). Significant fitted vectors for site Athabasca (Ath) vs. Sinkhole Lake (SL), microtopographic feature (MTF) hummock (hum) vs. hollow (hol), and vertical relief (DSE) scaled relative to their correlation coefficient; Site: $r = 0.77$; MTF: $r = 0.84$; DSE: $r = 0.67$.

(Apps. 2 and 3). Indicator species analysis showed *Sphagnum fuscum* to be highly indicative of the hummock group (indicator value = 95), with *Pleurozium schreberi* (indicator value = 83) and *S. angustifolium* (indicator value = 86), along with several *Cladonia* lichens, being indicative of groups 2 and 3, respectively.

Species scores were calculated as weighted averages along the DSE vector and used to make a condensed matrix of vegetation change along the vector (App. 4). Again, separation of hollows from hummocks along the vector was present, characterized by greater abundance of lichens at greater DSE with an abrupt shift to *S. fuscum* dominance on hummocks.

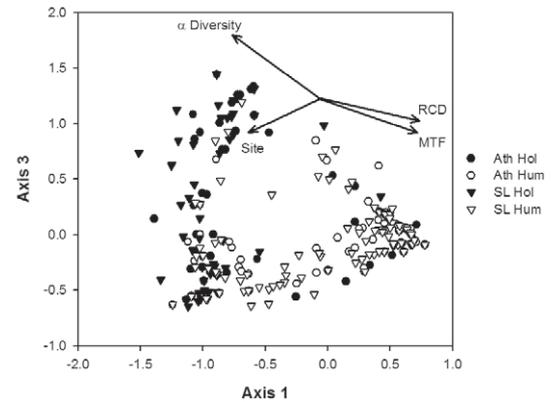
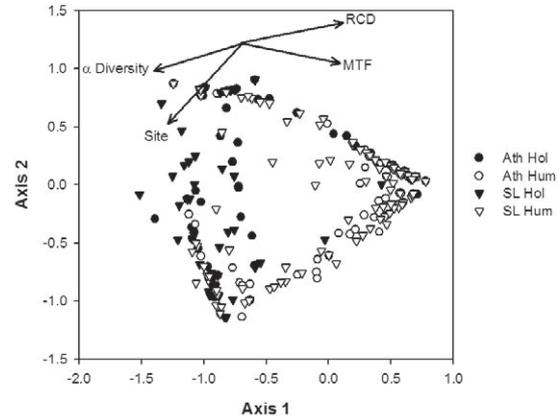


Fig. 2. Three-dimensional NMDS of macrofossil analysis data for 20 hummock (solid) and 20 hollow (open) cores from Athabasca and Sinkhole Lake bogs sectioned in 1-cm depth intervals (stress=0.0477). Significant fitted vectors for site (Athabasca [Ath] vs Sinkhole Lake [SL]), microtopographic feature (MTF; hummock [hum] vs hollow [hol]), and distance from the charcoal horizon (RCD) scaled relative to their correlation coefficient (Site: $r = 0.68$; MTF: $r = 0.74$; RCD: $r = 0.40$; α -diversity: $r = 0.31$).

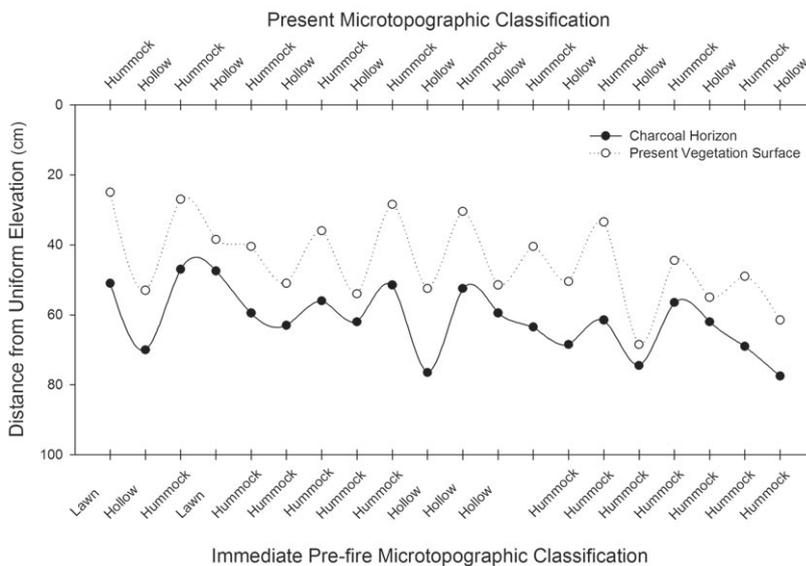


Fig. 3. Relative elevational positions of the present vegetation surface and charcoal horizon for plots in Athabasca bog ($n = 20$). Present microtopographic classification based on results of a vegetation survey of a 0.25-m² subplot from which the 10-cm diameter core was extracted. Immediate pre-fire classification based on interpretation of species composition results from macrofossil analysis of biomass remains just below the charcoal horizon. ‘Lawns’ are *Sphagnum magellanicum*-dominated intermediate hummocks. Data lacking a label did not have sufficient material below the charcoal horizon to make a confident determination of microtopographic status. Position on horizontal axis is arbitrary (not indicative of spatial distance).

Post-fire vegetation succession

Microtopographic position appears to be an important gradient determining vegetation compositional change (see Benschoter 2002 for detailed results; Fig. 2), with significant differences between sites ($R = 0.01, p = 0.003$) and features ($R = 0.55, p < 0.001$). Overall, hummock core composition, which is not significantly different between sites ($R < 0.01, p = 0.425$), seems to converge as RCD increases. Hummocks show abrupt shifts to *Acutifolia* (e.g. *S. fuscum*) dominance along the RCD vector, regardless of site (Table 2), supporting the convergence observed in the ordination.

Conversely, hollows showed a high degree of variability in post-fire compositional change, with significant differences between sites ($R = 0.05, p < 0.001$). Condensed community matrices show no clear trend in compositional change along the RCD vector (Table 2), supporting the sporadic ordination pattern for hollows.

While significant differences in γ and β -diversity were found between site \times feature combinations ($F = 5.82, df = 3,35, p = 0.003$; $F = 6.69, df = 3,35, p = 0.001$, respectively), no significant difference in α diversity was observed ($F = 1.08, df = 3,35, p = 0.370$). In general, hollows had greater β -diversity and only hummocks from Athabasca bog had lower γ -diversity (App. 5).

Changes in microtopography

A high degree of present-day and historic microtopographic variability was evident at both Athabasca (Fig. 4) and Sinkhole Lake bogs (Fig. 5). Hummocks were more prevalent before fire (80%) than hollows

Table 2. Condensed community matrix for macrofossil analysis data from 10 hummock and hollow cores in Athabasca and Sinkhole Lake bogs. Sample units condensed by distance from the charcoal horizon (RCD). Species categorized into group and group abundances standardized by group maximum and classified into ten cover classes (1 through 10[X]) by defined upper abundance limits (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, respectively). Plots sorted in ascending order by their scores on distance from the charcoal horizon (RCD) vector. Species sorted by their weighted abundance average along the RCD vector. Absences represented by (-).

Hummocks	
Athabasca	01234567891111111111222222 0123456789012345
SPHAGNUM	3X998762-1---21-----1242-
LICHEN	X331-----21-----1-----
CUSPIDATA	X5-2-----1-----1-----
TRUE MOSSES	9X743455212235322234462768
ACUTIFOLIA	5578898XXXXXXXXXXXXXXXX99X
Sinkhole Lake	01234567891111111111222222233 0123456789012345678901
CUSPIDATA	6X95---1-----1-----1-----
LICHEN	879X77555X94521----1-----
SPHAGNUM	X68866532122223332-24331231----
TRUE MOSSES	799899XX836544712231111-2---3---
ACUTIFOLIA	3434666788899999999XX99XXXXXXXXXX
Hollows	
Athabasca	012345678911111111112222 01234567890123
ACUTIFOLIA	147XX8X488432-----1-----
TRUE MOSSES	755557551--34547X8211-12
CUSPIDATA	-7XX97267----67--5---X-
LICHEN	X242223668X9989515-----5
SPHAGNUM	-4----22222222442XXXX86
Sinkhole Lake	0123456789111111111122 012345678901
SPHAGNUM	67XX867887662232-----
CUSPIDATA	583566531--1348X7XX---
LICHEN	75657899XX764137X83--
ACUTIFOLIA	-----3-278X9XX-----
TRUE MOSSES	21211111111345544-29XX

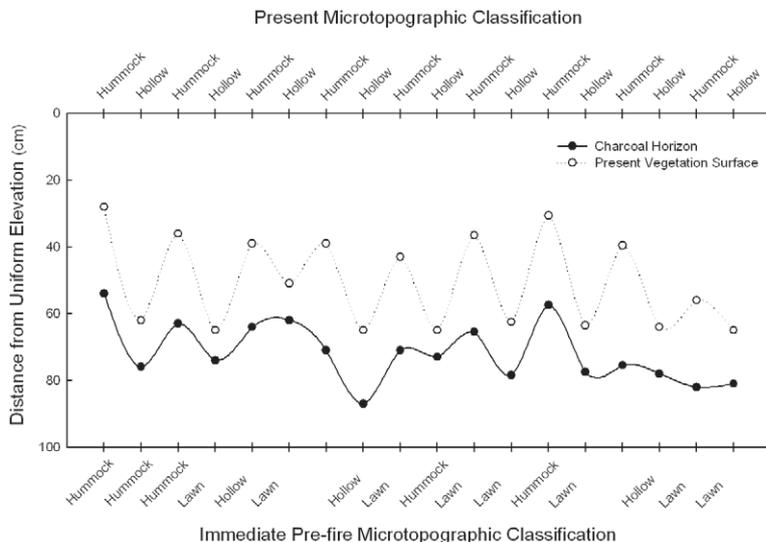


Fig. 4. Relative elevational positions of the present vegetation surface and charcoal horizon for plots in Sinkhole Lake bog ($n = 18$). Present microtopographic classification based on results of a vegetation survey of a 0.25-m² subplot from which the 10-cm diameter core was extracted. Immediate pre-fire classification based on interpretation of species composition results from macrofossil analysis of biomass remains just below the charcoal horizon. ‘Lawns’ are *Sphagnum magellanicum*-dominated intermediate hummocks. Data lacking a label did not have sufficient material below the charcoal horizon to make a confident determination of microtopographic status. Two cores (a hummock and hollow) were excluded because a reliable charcoal horizon was not identified. Position on horizontal axis is arbitrary (not indicative of spatial distance).

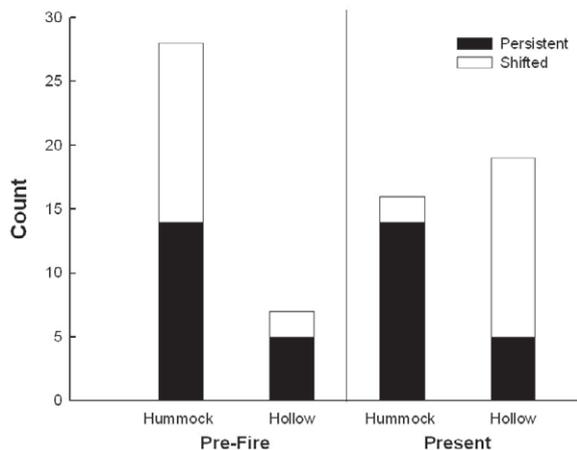


Fig. 5. Relative abundance of hummocks and hollows immediately pre-fire and at present. Shaded bars represent proportion of cores of each feature that remained consistent between both time points. Open bars represent proportion of cores where microtopographic feature shifts between time points were detected.

(20%), which varied from the almost equal distribution obtained by our sampling (46% and 54%, respectively). Present microtopographic position was predicted by pre-fire status more effectively for hollows than hummocks (Table 3). Of the cores inferred to have been hollows before the most recent fire, 71% are hollows at present. However, of the 19 hollows at present, only five were hollows before fire, whereas 87.5% of the current hummocks were hummocks before fire (Fig. 5). Pre-fire hummocks are more variable, with an equal probability of remaining hummocks or becoming hollows.

Table 3. Classification of 40 cores based on present and pre-fire microtopographic status for both sites (Athabasca = 20 and Sinkhole Lake = 20) combined. Present microtopographic status based on results of a vegetation survey of a 0.25-m² subplot from which the 10-cm diameter core was extracted. Immediate pre-fire status based on interpretation of species composition results from macrofossil analysis of biomass remains just below the charcoal horizon. ‘Lawns’ are *Sphagnum magellanicum*-dominated intermediate hummocks. Cores lacking a reliable charcoal horizon ($n = 2$) or sufficient material below the charcoal horizon to make a confident determination of microtopographic status ($n = 3$) were excluded.

		Pre-fire			Σ
		Hummock	lawn	Hollow	
Present	Hummock	10	4	2	16
	Hollow	8	6	5	19
Σ		18	10	7	35

Discussion

In general, post-fire bog succession appears to be an example of relay floristics (Clements 1916; Egler 1954), in which groups of species arrive, assume dominance, and are replaced in discrete waves, evidenced particularly in hummocks. Hollows also may follow this pattern, however the results of this study do not strongly support this hypothesis. Given a long enough time period, hollow species change may stabilize and show patterns similar to hummocks, but further study is required to investigate long-term (ca. 100 year or more) successional patterns in Canadian boreal bogs.

Several studies have shown that the microtopographic gradient is strongly correlated with spatial patterns in bog vegetation composition, due primarily to its autocorrelation with water table depth (Titus et al. 1983; Vitt & Slack 1984; Wagner & Titus 1984; Rydin & McDonald 1985; Rydin 1986, 1993; Vitt 1990; Gignac et al. 1991; Wallén & Malmer 1992; Thormann & Bayley 1997). The compositional patterns observed in this study support the importance of microtopographic position on species patterns, particularly with respect to *Sphagnum fuscum* dominance at higher microtopographic positions.

The results of this study suggest that by 40 years post-fire, hummocks are compositionally identical to those with 60 years of post-fire succession. The trajectories of change are uniform for the two sites examined in this study. There is also a concomitant decrease in α -diversity with greater vertical microtopographic position due to almost complete dominance of hummocks by *S. fuscum*. If hummocks are less extensively burned (Benscoter & Wieder 2003), as appears to be the case ca. 50% of the time in western Canadian bogs, they may be capable of regenerating faster from remaining fragments (Clymo & Duckett 1986) than hollows, promoting relatively rapid hummock re-establishment. However, if combustion is more severe, hummocks may become hollows due to reduced vertical elevation, preventing self-propagation of *S. fuscum* through absence of fragments or competitive displacement. Furthermore, reduced topography of severely combusted hummocks provides additional spatial opportunity for hollow establishment by creating moister conditions.

Hollows, however, are more variable, both within and between sites, supported by the greater β -diversity observed in hollows. No clear pattern of vegetation successional change was observed for hollows, which may be related to more extensive combustion in hollows. Areas experiencing more severe disturbance have a longer and more variable successional recovery because they have to begin from an earlier successional starting point, in some cases bare peat. This could result

in more species changes before returning to pre-fire composition, possibly with greater species residence times due to extended periods before environmental conditions change. Therefore, species diversity may be inversely proportional to community stability, as species diverse hollows have greater species turnover than hummocks.

Disturbed microtopographic features can respond in one of three ways: (1) return to their pre-disturbance state through regeneration; (2) hummocks can become hollows through combustion; or (3) hollows can become hummocks through succession. These responses occur at different rates and stages in the disturbance-recovery cycle, resulting in shifts in the relative abundance of features through the bog. Because hollows represent an early succession condition defined by low microtopographic position, it is not surprising that 71% of the pre-fire hollows persist as such at present. Likewise, it is not surprising that hollows are relatively more abundant at present than pre-fire because microtopographic hollows can be generated by combustion of hummocks, but not the reverse. Most likely the remaining 29% were not extensively burned, allowing them to reconvene their successional progression uninterrupted, culminating in their conversion to hummocks.

The results of this study emphasize the impact of disturbance and succession on bog microtopography. It has been suggested hummocks and hollows are self-propagating and maintained indefinitely (Tolonen 1971; Clymo 1983; Foster & King 1984; Madsen 1987; Nungesser 2003). While this may be the case in some instances and geographic areas, our study suggests a shifting mosaic pattern may be more appropriate, with disturbances such as fire, or perhaps even trampling, having the potential to drive changes in microtopographic state through variably altering both the physical properties of the peat (i.e. water saturation, shading, etc.) and the vegetation composition compared to pre-disturbance conditions. The frequency of fire occurrence in continental Canada, particularly compared to oceanic regions, makes disturbance a prominent and important feature controlling ecosystem composition and function, necessitating its incorporation into models of system processes. We hypothesize that maintenance of microtopography is disturbance-mediated, with disturbance severity and frequency controlling bog microtopography both directly and indirectly. However, further research is required to assess the mechanism of microtopographic maintenance.

Temporal changes of vegetation composition and microtopographic status are closely linked and may be linked to variability in bog function, most notably, carbon accumulation (Ohlson & Dahlberg 1991; Ohlson & Økland 1998; Benscoter et al. in press). Peatland suc-

cession is linked to fire severity, as in other ecosystems (Clark 1991; Schimmel & Granström 1996; Roberts 2004), resulting in structural (vegetation composition, microtopographical status) and functional (carbon accumulation) heterogeneity, both temporally and spatially, throughout bogs. Efforts to model bog function must take these dynamic interactions into account to more accurately assess bog C-cycling post-fire.

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