Extended abstract No. 57

LATE HOLOCENE FIRE HISTORY AND VEGETATION RECOVERY IN TWO RAISED BOGS AND A GLANCE TO MODERN BOG FIRE PATTERN

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SUMMARY

Macroscopic charcoal, plant macrofossils and radiocarbon dating were used to examine one bog section from Finland and one from Estonia. During the last 5000 years, both peatlands have experienced several fire events. A typical pre-fire vegetation community consisted of hummock *Sphagna*, often accompanied by *Calluna vulgaris*. Only the most severe fires resulted in a dramatic change in the vegetation composition. The recovery time of dry microtopes following severe combustion sometimes took up to 350 years. The results suggest that fires have been a regular phenomenon in boreal bogs. In order to better understand bog fire dynamics we surveyed modern fire pattern on a boreal bog that contained drainage-affected and unmanaged parts. Throughout the bog, dry hummock surfaces provided spreading routes for fire while hollows stayed intact. The drained part was combusted more severely than the pristine part. Our conclusion is that artificially lowered water levels increased the impact of fire. Possible implication for future is that in a warmer climate with prolonged extreme dry seasons, bogs are likely to become more vulnerable to fires.

KEY WORDS: bog, fire, vegetation recovery

INTRODUCTION

Because mires store huge quantities of carbon as peat, any large-scale change in peat accumulation pattern can initiate additional and unpredictable climate feedback (Zoltai *et al.*, 1998). Fires are an important natural disturbance element throughout the boreal zone and can directly release carbon from ecosystems into the atmosphere (Benscoter and Wieder, 2003). Total peat combustion in North America is estimated to be nearly 10 Tg C $year^{-1}$ (Zoltai *et al.*,1998) while in an individual peatland carbon loss can be of the order of 3 kg C m^{-2} per fire event (Pitkänen *et al.*, 1999; Benscoter and Wieder, 2003). Following a fire event, peatlands can act as a net carbon source for around the next ten years, i.e. until the vegetation recovery process returns the peatland to a net carbon sink state (Wieder *et al.*, 2009). Warm and dry weather conditions and abundant fire fuel availability, i.e. dry or dead plant material, favour fire occurrence (Reinhardt and Holsinger, 2010). Typically fires spread along dry lichen-*Calluna*-dominated fringes while wet depressions remain intact (Wein, 1983; Turetsky *et al.*, 2004), yet contradictive patters have also been reported (Benscoter and Wieder, 2003). Modern mire fire patterns and the subsequent vegetation recovery have been widely studied in

boreal Canada (e.g. Turetsky *et al.*, 2002; Benscoter *et al.*, 2005; Benscoter, 2006, Wieder *et al.*, 2009). However, with a modern ecological approach it is not possible to assess the fire frequency and pattern of post-fire disturbance successions under a changing climate over millennial time-scales. Furthermore, studies that compare fire patterns between natural and drained mire conditions are scarce. Here we approach bog fire theme from two different angles. Firstly, we aim to define bog fire patterns and frequencies during the history of two bogs in relation to paleoclimate and to determine the nature and time-scale of post-fire vegetation succession. Secondly, we compare modern fire patterns on an unmanaged bog surface *vs.* a drainage-affected bog surface We hypothesize that drainage increases fire intensity through an altered water table level and consequent change in vegetation. As drainage can simulate possible future changes in vegetation caused by changes in effective moisture conditions (Strack *et al.*, 2004, Riutta *et al.*, 2007, Laine A. *et al.*, 2009) our results can be used to speculate the impact of a warming climate on fire intensity.

MATERIAL AND METHODS

We present late-Holocene bog fire data derived from two boreal bogs, one in Finland (Kontolanrahka) and one in Estonia (Männikjärve). These bog sections have exceptionally robust chronologies that enable precise dating of each fire event and enable us to provide temporal estimates of post-fire recovery processes. Only ombrotrophic peat sections were included to this study. In order to define the fire patterns and frequencies and the initiated disturbance successions during the bog history we focused on the occurrence of macroscopic charcoal particles, as evidence of local fire events. To focus on changes in microtopography (hydrology) we divided *Sphagnum* species into three functional species groups: hollow *Sphagna* (mainly *S. balticum*), lawn *Sphagna* (mainly *S. magellanicum*) and hummock *Sphagna* (mainly *S. fuscum* and *S. rubellum*. To identify and test the links between fire and vegetation composition we applied constrained ordination methods (DCA and RDA) for the data from both sites separately.

The modern fire study site was located in western central Finland. The studied peatland was a patterned raised bog. The southern side of the peatland complex was under peat extraction. Adjacent to the studied area was a ditch with a peat bank which was located between the extraction area and the unmanaged area. In May 2009, a human induced fire spread out to the surrounding forest, peat extraction field, and to the unmanaged part of the raised bog. We conducted the vegetation survey in August 2009.

RESULTS

Palaeofires

Several layers with macroscopic charcoal were detected from both peat sections (Sillasoo *et al.*, 2011). It seems that the fire frequency interval has been less than 300 years through the late Holocene period. Pre-fire communities where typically characterized by hummock *Sphagna* often accompanied by *Calluna vulgaris*. Sometimes the post-fire vegetation community revealed a clear wet-shift, where the preceding hummock community was replaced by lawn/hollow community. In Kontolanrahka the ordination analyses suggest that *Eriophorum vaginatum* and *Calluna vulgaris* were associated with large (> 1 mm) charcoal particles showing them to have their highest abundance just before or after the fire. The abundance of hollow and lawn *Sphagnum* increased with increase in time since fire (TSF)

variable, indicating that fire initially favoured wetter communities. In contrast, hummock *Sphagnum* was associated with time before fire (TBF) variable in that their high abundance preceded fire events. In Männikjärve the abundance of lawn *Sphagnum* increased with TSF. The highest abundance of *Calluna vulgaris*, *Eriophorum vaginatum* and hummock *Sphagnum* were associated with smallest time to or from the fire event, i.e. those were either favouring the occurrence of fire or were favoured by fire.

In this study many of the detected fire events seem not to have had a long-lasting dramatic influence on the original habitat. However, often a fire event resulted in a dip in the amount of hummock forming *Sphagna* proportions, after which the community rapidly starts to recover and usually reaches its pre-fire proportional level within the next tens of years. After the most severe fire events, when a dry species community is replaced by hollow species community, the recovery took longer, up to 200-250 years.

Fire events were relatively evenly dispersed over the studied period in both bogs, although in Kontolanrahka the severe fire events were concentrated to the time period before 2500 cal. yr BP while in Männikjärve the fire frequency has increased towards the modern times. Männikjärve and Kontolanrahka fire history records indicate no direct link to the regional palaeoclimate.

Modern fire

The fire damage frequency was higher in the drained than in the unmanaged area (Ronkainen *et al.*, in press). The hummock vegetation covering the drainage-affected area suffered most from the fire: over 60% of the ground and field layers were burned. In addition to the completely burned area, about a third of the field and ground layers were scorched. No unburned field layer surfaces remained and only 8% of the ground layer remained unburned. In contrast to the drainage-affected area, ca. 40% of hummock vegetation remained unburned in the unmanaged part of the peatland. Of the hummocks that were impacted by fire, around 30% were burned and around 30% scorched. Only a minority of lawns were impacted by fire; 2% of the lawn vegetation was burned, but the scorched area varied between 24% (field layer) and 10% (ground layer). Vegetation in the hollows remained unburned throughout.

CONCLUSIONS

The two northern boreal bog records suggest that fires have been a frequent natural ecosystem disturbance component through the late-Holocene period in this rather sparsely populated area Dry hummock surfaces have burned repeatedly with a time interval less than 300 years. Only the most severe fires had a long-lasting effect on the habitat and a wet shift occurred. In these cases the vegetation recovery took up to 350 years but typically the post-fire recovery and re-establishment of a dry habitat begun immediately and was completed within next ten(s) of years.

Drainage had promoted a vegetation succession gradient that had led to the dominance of hummock vegetation close to the drained area. The peatland fire proceeded along dry surfaces, and wet depressions remained intact. Consequently drainage succession favoured the spread of fire, and lowered water levels also increased the impact of fire. In the future, more extreme and prolonged seasonal droughts and/or human-induced peatland drainage may result in more severe and frequent fires in boreal regions.

ACKNOWLEDGEMENTS

Palaeofire work refines the results of the ACCROTELM-project, supported by the European Commission under the Fifth Framework Programme Contract No. EVK2-CT-2002-00166, and is part of the project no. SF0280009s07 ‘‘Impact of disturbances on wetland ecosystems in Estonia’’ target financed by the Estonian Ministry of Education and Science. Funding from the Academy of Finland (codes 131409, 218101, 201321 and 1133515) is acknowledged.

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