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Replicability of data collected for empirical estimation of relative pollen productivity

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ABSTRACT

The effects of repeated survey and fieldwork timing on data derived from a recently proposed standard field methodology for empirical estimation of relative pollen productivity (RPP) have been tested. Seasonal variations in vegetation and associated pollen assemblages were studied in three contrasting cultural habitat types; semi-natural ancient woodlands, lowland heaths, and unimproved, traditionally managed hay meadows. Results show that in woodlands and heathlands the standard method generates vegetation data with a reasonable degree of similarity throughout the field season, though in some instances additional recording of woodland canopy cover should be undertaken, and differences were greater for woodland understorey taxa than for arboreal taxa. Large differences in vegetation cover were observed over the field season in the grassland community, and matching the phenological timing of surveys within and between studies is clearly important if RPP estimates from these sites are to be comparable. Pollen assemblages from closely co-located moss polsters collected on different visits are shown to be variable in all communities, to a greater degree than can be explained by the sampling error associated with pollen counting, and further study of moss polsters as pollen traps is recommended.

1. Introduction

In recent years attempts to quantitatively reconstruct past vegetation cover based on pollen data have become increasingly widespread. Current methods of quantitative reconstruction such as the Landscape Reconstruction Algorithm (LRA: Sugita, 2007a, 2007b) and the Multiple Scenario Approach (MSA: Bunting and Middleton, 2009) assume that properties such as the amount of pollen produced by a given taxon per unit area of vegetation, generally expressed as a relative pollen productivity (RPP) ratio, are constant in space and time.

A recent review (Broström et al., 2008) reported a wide range of RPP values for single taxa from different studies. Estimates of RPP are obtained by comparing modern pollen assemblages from moss polsters (e.g. Andersen, 1970; Hjelle, 1998; Broström et al., 2004; Bunting et al., 2005; Mazier et al., 2008; von Stedingk et al., 2008), pollen traps (e.g. Sugita et al., 2010; Mazier et al., 2012), or lake surface sediments (e.g. Soepboer et al., 2007; Poska et al., 2011; Hjelle and Sugita, 2012; Matthias et al., 2012) with the vegetation around the sampling point. The studies reviewed by Broström et al. (2008) used different methods of vegetation survey so it is unclear whether the assumption of constant RPP is in error or whether different methods lead to systematically different values. Bunting and Hjelle (2010) have shown that vegetation data collection method can have a marked effect on the RPP estimates obtained.

To allow the assumption of constant RPP to be tested, Bunting et al. (2013) presented a vegetation survey and moss collection protocol for RPP analysis which was developed through a practitioner workshop, and represented an agreed compromise between existing methods which, it was hoped, balanced efficiency and data quality. Three nested levels of vegetation survey are carried out around the sampled moss, defined by radial distances. The inner 10 m (zone A) is recorded using a standard array of 1 m^2 quadrats, 21 in total, oriented to compass bearings to reduce subjective bias in placement of the array. The 10–100 m zone (zone B) is first mapped in the field to identify the main communities present, then a small number of randomly located quadrats are recorded in each community (1 m^2 in open communities, 6 m radius circular quadrats in tall shrub and woodland communities). The vegetation in the area beyond 100 m (zone C) is quantified from existing data sources, such as published maps, aerial photography or remotely sensed data; the distribution of communities is digitised, and then community composition is defined where possible by extrapolation from the mapped zone B communities, by additional field recording, or from existing studies or databases.

Bunting et al. (2013) present an empirical test of the effects of different recording methods within zone A, which confirms that the array chosen produces statistically identical results to a more time-consuming complete survey using the 'ring method' (e.g. Broström et al., 2004), but did not investigate replicability of zones B and C. This

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paper presents a small-scale investigation of the possible effects of the timing of fieldwork on the datasets generated for zones A and B.

It is well known that the number of plant species that are recordable varies throughout the year, and some species show marked differences in their conspicuousness or abundance over the growing season (Hope-Simpson, 1940; Usher, 1980; Martínková et al., 2002). Estimates of percentage cover, upon which survey methods for RPP estimates rely heavily (e.g. Sugita et al., 1999; Broström et al., 2004; Räsänen et al., 2007; Mazier et al., 2008; von Stedingk et al., 2008; Abraham and Kozáková, 2012; Twiddle et al., 2012), vary throughout the growing season in hay meadows (Losvik, 1991; Martínková et al., 2002). In woodlands too there are large seasonal differences in the frequency with which some species are recorded, because they are either more abundant or more easily identified at a particular time of year (Kirby et al., 1986).

To test the assumption of constant RPP it is also necessary to apply a standardised method for collection of pollen data. Pollen trap studies show significant interannual variations in pollen production of individual species, in part caused by differences in seasonal temperature and precipitation (e.g. Andersen, 1974; Hicks, 2001; Autio and Hicks, 2004; Huusko and Hicks, 2009; Kuoppamaa et al., 2009; Nielsen et al., 2010; Donders et al., 2014). To avoid problems associated with this variation in the estimation of RPP, moss polsters are often used as pollen traps since they are generally thought to preserve and integrate several years of pollen rain (Andersen, 1970; Bradshaw, 1981; Caseldine, 1981; Mulder and Janssen, 1998, 1999), although some studies indicate that they represent little more than a single growing season (Räsänen et al., 2004; Pardoe et al., 2010). In the proposed standard protocol, a single moss polster is collected and defines the central point of the vegetation survey (Bunting et al., 2013).

Seasonal differences between pollen assemblages also occur and are closely linked to flowering times (Bonny, 1980; Cundill, 1985; Hicks, 1985; Ribeiro and Abreu, 2014; Tosunoglu and Bicacki, 2015), so it is necessary to ensure that the full year's assemblage is represented in order to reduce the risk of biasing in favour of early-flowering species. Strong seasonal variations have been recorded in pollen traps in Finland, with the majority of pollen being deposited in the summer when most plants were flowering. Autumn pollen assemblages comprised pollen from late-flowering plants, as well as redeposited pollen from the early-flowering taxa, and winter pollen assemblages consisted mainly of redeposited pollen along with some pollen from the earliest flowering taxa (Hicks, 1985). The source of the redeposited component is pollen moving through the trunk space, as well as that which has been filtered out by vegetation and later washed to the ground by precipitation (Tauber, 1965, 1967). Similar seasonal variations in pollen assemblages from Tauber traps have been recorded in Denmark (Andersen, 1974), Switzerland (Markgraf, 1980) and England (Bonny, 1980). Studies comparing moss polsters with other types of pollen trap such as Tauber traps, soils and lake surface sediments (Räsänen et al., 2004; Wilmshurst and McGlone, 2005; Pardoe et al., 2010; Lisitsyna et al., 2012) have found significant differences in their respective pollen assemblages, though they compare samples from two or more different traps taken at the same time and are therefore not useful for considering seasonal differences.

If the assumption that moss polsters preserve several years' worth of pollen rain proves to be false, pollen assemblages should ideally be collected at the end of the flowering season in order to avoid seasonal biases. The vegetation survey should be conducted at an earlier date so that the maximum possible number of species is recorded. The Crackles Bequest Project aims to compare estimates of RPP for common taxa from several sites in north-west Europe using the standard method proposed by Bunting et al. (2013). It was not possible within the confines of a 3-year research project to survey all sites at the optimum time for vegetation recording and to return to each location to collect the pollen assemblage at the end of the flowering season, therefore in this project pollen sampling was completed at the same time as vegetation survey, and fieldwork took place in early to mid summer whenever possible.

This paper presents a limited investigation of the possible effects of the timing of fieldwork on the datasets generated. Three sites were chosen to represent the three main cultural habitat types studied by the Crackles Bequest Project; semi-natural ancient woodlands, lowland heaths, and unimproved, traditionally managed hay meadows. Moss polsters were collected and vegetation surveys undertaken at each site in spring (May), summer (late June) and late summer/early autumn (September) in order to address the following research questions:

1) After the vegetation data have been processed for RPP analysis, do statistically distinct differences remain between repeat surveys at the same site? Can these differences be explained by seasonal variations in plant recordability?
2) Does the timing of moss polster collection systematically affect the pollen assemblage recovered from the moss, and if so do those differences reflect seasonal patterns?

2. Methods

2.1. Study sites

Site locations are shown on Fig. 1. North Cliffe Wood is a 35 ha woodland situated on postglacial lacustrine sands which overlie Mercia Muds. Soils are acidic, and the site lies at an altitude of approximately 7 m OD at the eastern edge of the Vale of York. Low-lying wetter areas are dominated by *Salix* spp. and *Betula pendula*, whilst drier areas support *Quercus robur*. Typical woodland species including *Hyacinthoides non-scripta*, *Primula vulgaris*, *Oxalis acetosella* and *Mercurialis perennis* are abundant within the ground flora. The centre of the survey was located at 53°49′26.10″N, 0°41′36.97″W.

Wheldrake Ings comprise *c.* 160 ha of unimproved, seasonally flooded, species-rich hay meadows under traditional management. The hay crop is cut in July, at the end of the flowering season, and the re-growth is grazed by livestock until late autumn. The meadows are then enriched with sediment during the winter floods and the hay crop begins to grow again during the spring. Typical species include *Filipendula ulmaria*, *Sanguisorba officinalis*, *Achillea ptarmica*, *Silaum silaus*, *Leucanthemum vulgare* and a wide range of grasses and sedges. The centre of the survey was located at 53°53′22.89″N, 0°56′22.19″W. This location was on slightly higher ground towards the margins of the Ings, which during a typical winter are not actually inundated, but experience a high soil water table. Within zone B a lower area of ground (apparently a palaeochannel) supports more hydrophilic taxa such as *Ranunculus flammula* and contains standing water during the winter. Because the moss sample location was not inundated, water-borne pollen is not considered to be a significant taphonomic component of the pollen assemblage.

Strensall Common is a 580 ha expanse of acidic lowland heath formed over glacial sands and supports a mosaic of wet and dry heath, mire, open water, woodland and acid grassland. Several typical heathland species are present, including *Calluna vulgaris*, *Erica tetralix*, *Molinia caerulea* and *Potentilla erecta*, as well as rarer species such as *Genista anglica* and *Drosera intermedia*. Trees present include *Pinus sylvestris*, *Quercus robur* and *Betula pendula*. The survey was centred on 54°2′54.00″N, 0°59′55.48″W.

2.2. Vegetation survey

A sampling point was selected on the first visit to each site and relocated on subsequent visits using handheld GPS, markers and photographs taken on the previous visit. At Strensall Common, it was possible to take subsamples from the same moss polster on each visit, so the location used was identical. At North Cliffe Wood and Wheldrake Ings, where moss was less abundant, samples were taken within 0.5 m of