



## Approaches to quantitative reconstruction of woody vegetation in managed woodlands from pollen records



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### ABSTRACT

There has been increasing interest in developing quantitative methods for reconstructing the dynamics of cultural landscapes over the last 15 years. This paper adds to this literature by using various approaches to reconstruct the vegetation of two woodlands subject to rotational coppicing (the periodic cutting of broadleaved trees and shrubs for wood products). Pollen deposition at ground level was determined at both sites using ‘Tauber’ traps placed near to the centre of 14 compartments of differing age in the coppice rotation. For the main woody taxa, Relative Pollen Productivity (RPP) estimates were derived using linear regression for pollen influx data and Extended R-value analysis for percentage data. The vegetation around three ponds was reconstructed by applying four methods (inverting the two RPP estimate approaches, the modern analogue technique and correction for pollen productivity using the linear regression estimated RPP values) to pollen data obtained from the uppermost sample of sediment from the ponds. To determine whether these methods gave better estimates of the vegetation composition than the original pollen proportions, the results were compared with the surveyed vegetation around each pond using the Bray–Curtis Index. Linear regression of pollen influx produced RPP values which are comparable with previous European studies, whilst for some taxa the Extended R-value analysis produced estimates which are orders of magnitude different both from values derived from the linear regression and previous work. No single approach performed equally well at reconstructing the vegetation around the ponds, and at two of the three locations the uncorrected pollen proportions were most similar to the surveyed vegetation. We conclude that applying quantitative reconstruction methods to individual small sites is, currently, not likely to be useful in complex cultural landscapes. In the context of coppiced woodland, deficiencies in our understanding of pollen taphonomy and the impact of the practice on pollen production first need to be rectified, and we identify strategies to address this situation.

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### 1. Introduction

Many parts of the world are dominated by cultural landscapes: those where the present day vegetation cover is the product of both natural environmental factors (such as climate, geology and local topography) and human activity, both direct and indirect, over long time scales. Pollen analysis of sediment cores offers evidence of changes in vegetation over time, which can then be translated into reconstructions of land cover and the impact of processes such as human activity assessed. Most translation is still qualitative yet questions related to the dynamics of cultural landscapes, such as the extent of woodland clearance, have driven many recent developments in the interpretation of pollen data, such as the PollLandCal Network’s activities (reviewed in Gaillard et al., 2008). More recently, the LANDCLIM project has demonstrated the

potential of using records from large sedimentary sites (>500–750 ha) or combining large numbers of small sites to reconstruct the relative abundance of the main plant taxa present in regional landscapes, allowing changes in the extent and distribution of woodland, heathland, pasture and crop land (Marquer et al., 2014; Trondman et al., 2015) to be mapped across areas measured in hundreds of square kilometres. Reconstructing cultural landscape processes at smaller, more ‘human’ scales in quantitative terms remains challenging, although various strategies have been proposed and are being explored (Sugita, 2007; Bunting and Middleton, 2009; Tipping et al., 2009; Sugita et al., 2010a).

All these reconstruction methods depend, implicitly or explicitly, on being able to quantify the amount of pollen contributed to a sedimentary pollen assemblage by different plant taxa. This varies depending on a range of factors concerning both the producing plant (such as reproductive strategy, plant height, vegetation structure) and the receiving sedimentary system (e.g. size, system type). In the vast majority of the literature, pollen productivity is assumed to be a constant, at least for

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a given taxon in a given region over a given time period. Estimates of pollen production are usually expressed as a ratio to a reference taxon, or Relative Pollen Productivity (RPP), and empirical estimations of abundance of the main taxa recorded in a region's pollen records, has been a fruitful area of recent research in Europe (e.g. Broström et al., 2008; Mazier et al., 2012a etc.) and beyond (e.g. Duffin and Bunting, 2008; Bunting et al., 2013a, 2013b; Li et al., 2015).

The assumption that a single RPP can be assigned to a taxon is clearly a simplification. At range limits, climate conditions are known to affect pollen production (e.g. Sugita et al., 2010a; Mazier et al., 2012b), and many plants vary investment in flowering facultatively in response to environmental stressors such as grazing or light availability. Using an ecological approach, Waller et al. (2012) showed that flowering rates, and therefore pollen production, vary over time as a result of the woodland management practice of coppicing, and used a simulation approach to explore the effect of those variations on the representation of tree taxa in pollen records from landscapes as the management practices changed. Similarly Baker (2012) has shown that heavy grazing can have a suppressive effect on Poaceae pollen production. This may explain some of the differences in pollen productivity estimated in different studies, for example Broström et al. (2004) report results from grazed meadows which show common forb pollen types to have higher productivity than grasses, whereas Hjelle (1998) found the opposite when analysing samples from hay meadows. Grazing suppression of Poaceae has also been used to support arguments that the pre-farming landscapes of north-west Europe included extensive grazed grasslands despite producing tree-dominated pollen records (Vera, 2000; Mitchell, 2005). In this paper, we present estimates of RPP from coppiced woodlands derived from modern pollen assemblages, rather than ecological methods, and consider the implications for reconstruction of past vegetation cover around small ponds in tree-rich habitats.

Coppicing was a common form of sustainable woodland management across northern Europe, with evidence for its practice going back into prehistory. Traditionally a means of controlling and maximising the production of timber, underwood and wood derivatives (e.g. charcoal) from woodlands, coppicing is recognised as a key factor in determining the characteristics of 'heritage' woodlands such as the extent of spring ground flora like *Hyacinthoides non-scripta* or provision of nesting sites for *Luscinia megarhynchos*, and is increasingly being reintroduced as a conservation measure. In coppiced woodland, some trees are allowed to grow to maturity with a single trunk (standards), but the majority of trees are cut back periodically, leading to regrowth of multiple stems from a near-ground-level base (the stool). Flowering of these coppiced plants will differ from standards, at least in the early years of regrowth. Differences will arise from a range of factors, including variations in the length of time branches of individual species take to reach sexual maturity, competition between regrowths and changing light conditions in the below-canopy growing environment related to the canopy type and density of the standards (Rackham, 1990).

Waller et al. (2012) explore the pollen signal from three coppiced woodlands with different species compositions, using a range of methods. Direct measurement showed that flowering response to coppicing varied widely by species. For the studied tree species *Tilia cordata* and *Alnus glutinosa*, the overall amount of pollen produced is substantially reduced even when there are long intervals between cutting events. In contrast, *Corylus avellana* regrowths flower within 1–2 years of coppicing. This species therefore produces pollen under the shortest of likely cutting regimes and pollen production during the early stages of regrowth appears to be higher than in later stages due to the reduction of competition for light from nearby stools. Records from the sediments of small ponds within these coppiced woods, sampled contiguously at high (annual to sub-annual thickness) resolution, showed patterns which could be interpreted in terms of known woodland history, but determining unambiguous markers of coppice management which could be

used in the interpretation of palaeoecological records was not possible. Zones of sediment inwash associated with local disturbance during winter cutting were probably the strongest single indicator observed. The differences between pollen assemblages collected in pollen traps placed in the middle of areas (compartments) of coppice of different age could not be simply explained as the result of years since cutting, probably due to local variations in vegetation composition and structure. The background pollen component, that sourced from beyond the compartment being studied (and therefore originating from compartments of different ages), appears to have been substantial. Using the information about flower production, estimates of relative pollen productivity from Southern Sweden (Sugita et al., 1999; Broström et al., 2008) were adjusted to give multiple values for each of the key coppiced taxa reflecting pollen production at different regrowth stages. These values were then used in simulations to explore the effects of landscape-scale changes in woodland management regime (proportion of landscape under coppicing, duration of coppice cycle) on the pollen assemblages deposited in small and large lakes and in a wooded peatland. These simulations supported inferences of coppicing from oscillations seen in Neolithic pollen records, especially in East Anglia and the northern Alpine Forelands, but the study as a whole suggested that the pollen signal from these complex cultural landscapes was likely to be highly variable and that simple, unambiguous signals of management could not be defined, even for pollen records from small basins with restricted source areas in landscapes which are believed to record woodland dynamics at the stand scale (Bradshaw, 1981a; Calcote, 1995).

The adjusted values used for modelling assumed that the overall RPP for the taxa in the managed woodlands, reflecting the pollen production of both canopy trees and coppice stools of all ages, was comparable to the estimates from southern Sweden presented by Sugita et al. (1999). In this paper we test that assumption by estimating RPP for the main woody taxa based on both percentage and influx pollen data from the Tauber trap records presented by Waller et al. (2012). These RPP values are then used to reconstruct vegetation cover around the small ponds studied by Waller et al. (2012) from the pollen assemblages in the uppermost year of sedimentation, to investigate whether simple (and simplistic) reconstruction approaches improve the interpretation of such assemblages significantly over a narrative interpretation based on the raw pollen assemblage. Comparing the different approaches and their assumptions with the actual vegetation allows us to identify ways forward to develop more realistic reconstructions of complex cultural landscapes with a multi-layered vegetation structure.

## 2. Field sites

Three woodlands in East Anglia, UK (Fig. 1), currently subject to coppice management, were selected for investigation by Waller et al. (2012). At Chalkney Wood (51°54'N 0°43'E; Fig. 1b) in central Essex, *Tilia cordata* is the main coppiced species but in some parts of the wood it is co-dominant with *Castanea sativa* and less commonly with *Carpinus betulus*, *Fraxinus excelsior*, *Acer campestre* or *Corylus avellana*. *Quercus robur* is the main standard species, though other species, including *Tilia cordata*, were recorded as 'maidens' (non-pollarded or coppiced trees) in 2007/8. The ground vegetation is dominated by *Hyacinthoides non-scripta* with *Rubus* spp. and *Pteridium aquilinum*. The site is cut on an approximately 25 year rotation.

At Bradfield Woods (52°09'N 0°06'W) in Suffolk (Fig. 1c), the coppiced stools consist predominantly of *Corylus avellana* and *Fraxinus excelsior*, with *Alnus glutinosa* co-dominant over an area of about 40 ha. *Primula elatior*, *Filipendula ulmaria* and *Mercurialis perennis* are common in the ground flora where the wood overlies boulder clay and *Rubus* spp., *Pteridium aquilinum* and *Hyacinthoides non-scripta* dominate in areas overlying sand. The standards are largely *Quercus robur*

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