Figure 5.4: BAR 1 pollen data (peatland taxa) (reproduced from O'Brien 2009)

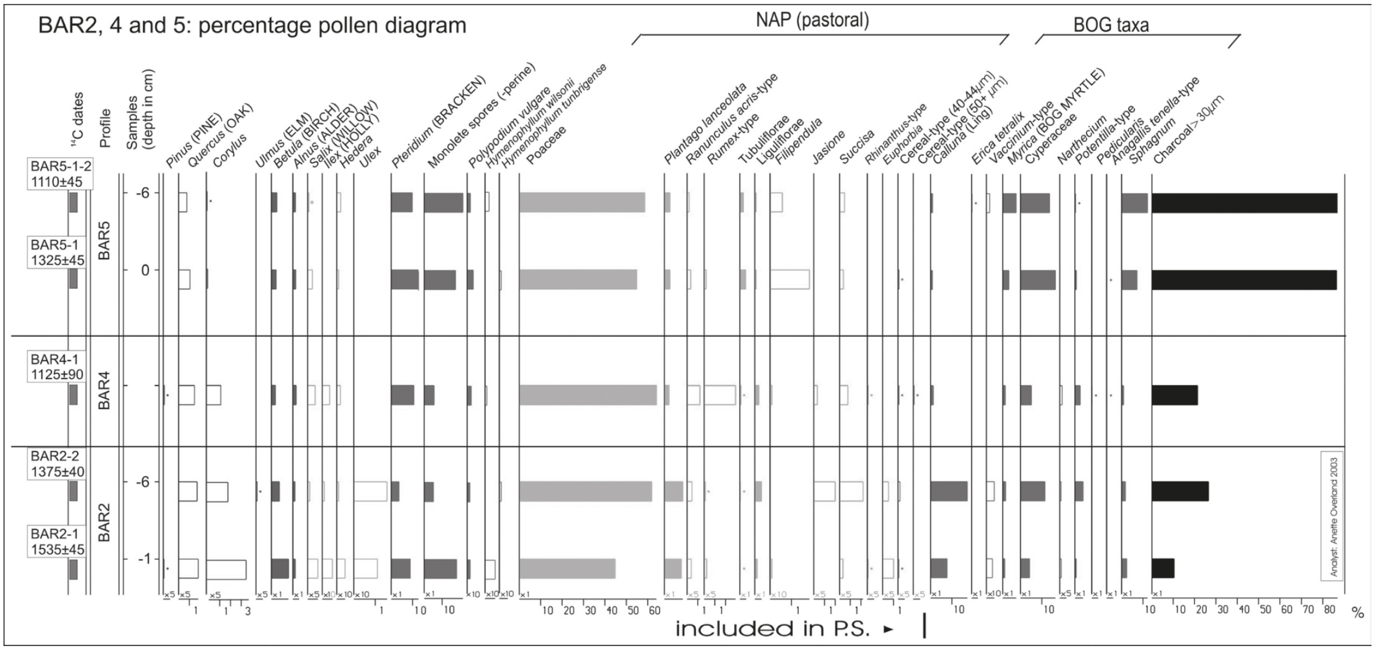

Figure 5.5: BAR 2, 4 and 5 pollen data (reproduced from O'Brien 2009)

The pollen record reflects vegetation that was growing very close to the sampling site (see Chapter 4), within a maximum of tens of metres, with some contribution from plants growing further away. These data show the development of the upland vegetation from prehistory to the 18th century. The presence of taxa associated with open grassland/pasture, and comparatively low percentages of tree/shrub pollen, shows the landscape was largely open, and probably grazed, from the beginning of peat accumulation. The relationship between the timing and nature of vegetation change, human activity/land use and blanket peat inception (as introduced in Chapter 1), is an important theme we will consider further in Chapter 6.

Case study: Hidden Landscape Archaeology? Modelling peatlands in four dimensions: Hatfield Moors

The second case study focuses on Hatfield Moors bordering South Yorkshire and North Lincolnshire, which along with Thorne Moors to the north (collectively known as the Humberhead peatlands), form the largest area of former raised bog in England (Fig. 5.6). We continue some of the themes from the previous case study, not least the question of understanding the development of peatlands through time and space, and associated implications for past human activity and the archaeological record.

Background, geographical context and circumstances to the work

The Humberhead peatlands have been the focus of archaeological and palaeoenvironmental research for many years (see Chapter 1). In this case study we will consider the study by Chapman and Gearey (2013), funded by English Heritage (now Historic England). The original project had various aims and outcomes, but here we will focus specifically on the question of modelling pre-peat landscapes, peatland growth and spread and implications for understanding human activity and the interpretation of a particular archaeological site.

Hatfield and Thorne Moors to the north, were ombrotrophic peatlands, forming part of a once extensive area of alluvial wetlands known as the Humberhead Levels, which has been subjected to extensive drainage and land reclamation since the 17th century (see Van de Noort 2004; also Chapter 2). The present extent (Hatfield Moors: 1360 ha and Thorne Moors: 1760 ha) is a result of these processes – historic mapping (see below) indicates that Hatfield was once much more extensive and merged with the floodplains of the Rivers Torne and Idle to the south and east. The pre-peat deposits at Hatfield consist of coversands (that is, sands that were deposited by wind action, probably in the early Holocene). Lindholme Island in the centre of the moors, consists of gravels, probably deposited during the last glaciation. In their intact state, the raised mires apparently had classic 'domed' profiles. An account from 1920 describes Thorne Moors as around 10 km across, with a dome rising between 7–10 m above the surrounding plain (Chapman and Gearey 2013, 17). Peat cutting peaked during the early 20th century, and was followed by large scale mechanical extraction from the 1950s with the introduction of 'surface milling' in the 1980s. Peat extraction ceased and the moors were acquired by Natural England in the early 2000s, with a programme of re-wetting and rehabilitation. Despite antiquarian reports of bog bodies and other finds (see Chapter 2), only two archaeological sites have been investigated: a probable Bronze Age timber trackway on Thorne Moors and a Neolithic timber trackway and platform on Hatfield Moors (Plate 5), discussed further below.

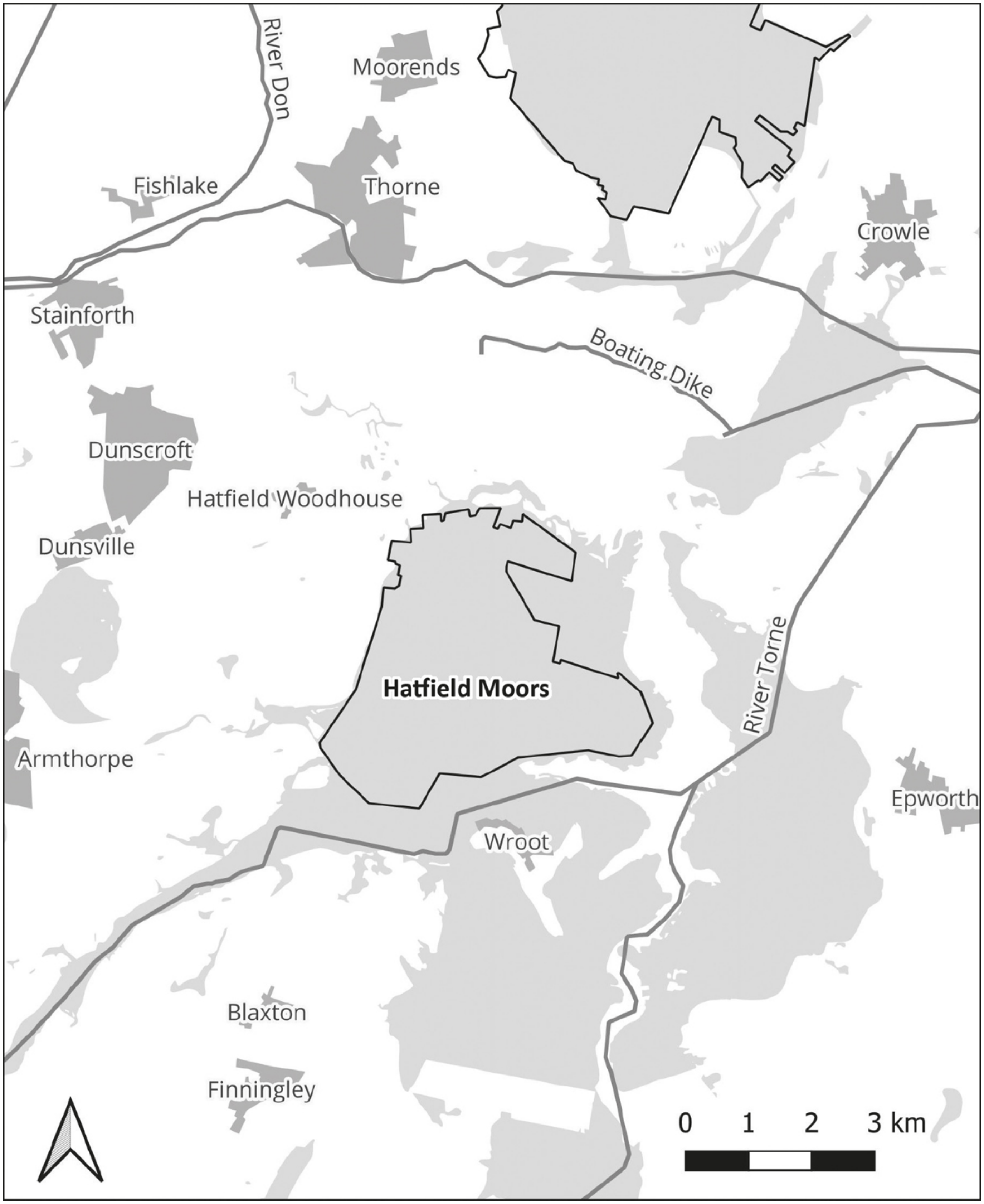

Figure 5.6: Hatfield Moors location map. Light grey shading indicates extent of wetlands

Approaches and methods adopted

We focus predominantly on the approach to reconstructing the pre-peat landscape, modelling the spatial and chronological patterns of peat across Hatfield Moors. This was inspired in part by the

Lisheen Mine Project (see Chapter 2 and also below), but without the significant resources that facilitated the creation of the 4-D models of landscape for the latter site. This would have been a forlorn attempt without the considerable body of data from previous palaeoecological studies that were available (see Chapter 2), including palynological, palaeoentomological and associated radiocarbon and dendrochronological dates. These provided extensive information on the timing and nature of peat inception and spread in certain parts of the peatland. The aim was to utilise data from these previous studies, augmented by additional analyses, to model patterns of peat inception and spread across Hatfield Moors using GIS.

A second aim was to assess the surviving depth and extent of peat (following the end of peat extraction) and to establish what these remaining deposits equated to in terms of a 'chronological envelope': in other words, the relative depth and dates associated with the base (inception) and top (cut-over surface of peat). The significance of this relates to exploring the archaeological *potential* of the surviving peat across the study area (see below).

The general approach utilised archive data, alongside targeted fieldwork and integration using a Geographical Information System (GIS) to generate models of peatland growth. During the initial stages of the project, the chance discovery of an archaeological site in the form of a Neolithic timber trackway (see Box 7), provided an opportunity to excavate and investigate the relationship of this structure to the development of the peatland. The overall approach can be split into the following stages:

1. *Collation of palaeoenvironmental data* and other relevant information from Hatfield Moors. This allowed an assessment of the distribution of data from the study area. The palaeoenvironmental records also provided information concerning the timing and character of vegetation and environmental processes during peat inception and growth. In addition, topographic and mapping data (LiDAR, geological and historic) were collected during this stage of desk-based assessment.
4. *Ground Penetrating Radar Survey*: The previous landowners (the peat extractors) of Hatfield Moors had used Ground Penetrating Radar (GPR; see Chapter 3) to determine the depth of peat across part of the study area. These data, augmented with peat-depth measurements from boreholes,, could be utilised to model the morphology of the pre-peat landscape (Fig. 5.7)
5. *Borehole Survey and Sampling*: the above data were not available for all the study area and hence it was necessary to collect further information concerning the depth of the peat and the underlying surface. This was also informed in part by the results of stage 1. This was implemented using a 'sampling' approach for selected parts of Hatfield Moors and the excavation of a series of cores in grids (Fig. 5.8, see Chapter 3) to establish the depth and character of the surviving peat. Excavation of a Neolithic archaeological site (see below) discovered just after the start of the project was carried out in this phase.

Figure 5.7: The various datasets used for modelling the pre-peat topography of Hatfield Moors. This included Ground Penetrating Radar (GPR) data (left), depth and peat thickness data from borehole transects (centre) and borehole grids (right)

6. *Radiocarbon dating*: selected samples from the base and top of the peat at various locations were collected during the previous stage and submitted for radiocarbon dating. The samples were selected to represent an altitudinal range of basal elevations (mOD) with other samples collected from the top of the cutover surface.

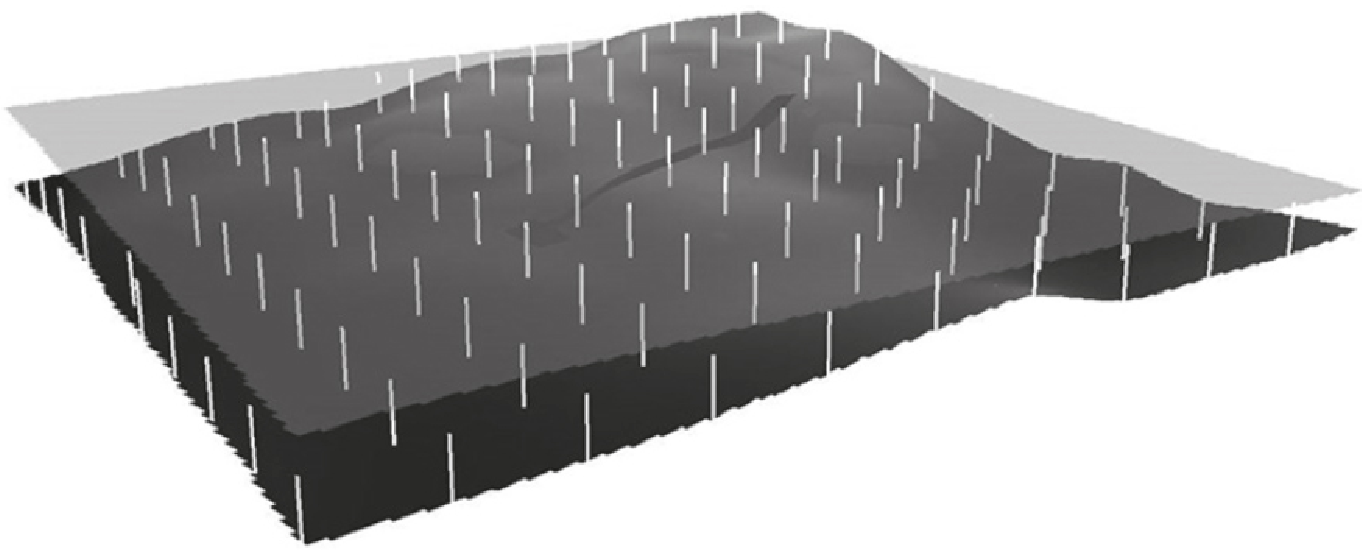

Figure 5.8: Example of a borehole grid showing both the pre-peat topography and the top of existing (cut-over) peat. This model shows the area around the Neolithic trackway and platform

7. *GIS Data analyses*: the various topographical data sets (GPR, coring and other associated information) were collated and manipulated to generate a model of peat depth and the morphology of the pre-peat landscape (Fig. 5.9). The radiocarbon dates from stage 4 and previous chronological data (stage 1) for peat inception could then be interrogated with respect to the topography of this underlying surface. Radiocarbon dates from the surface of the cutover peat could also be related to the height of the surviving surface, derived from the LiDAR dataset.
8. *GIS Modelling*: the integration of spatial and chronological data on pre-peat topography, peat inception and growth established that peat inception was related strongly to the morphology of the underlying landscape. The modelled relationship between the timing and the location of peat

inception was used to generate models of the growth of the peat across the study area. A similar process was employed to model the date of the surviving cutover surface of the peat.

Overview of the results

TIMING AND CAUSES OF PEAT INCEPTION ON HATFIELD MOORS (STAGE 1)

It had been proposed on the basis of previous research that inception across Hatfield Moors was via paludification (see Chapter 1). The basal deposits indicated peat accumulation directly over a dryland surface of windblown sands, with no intervening water-lain deposits. Previous palaeoenvironmental study included three sequences with radiocarbon dates from the base of the peat, which indicated this process commenced *c.* 3000 BCE in the central part of the moor, but later from *c.* 1500 BCE closer to the current edges of the area. Both pollen and beetle data were available from various sampling locations across the study area.

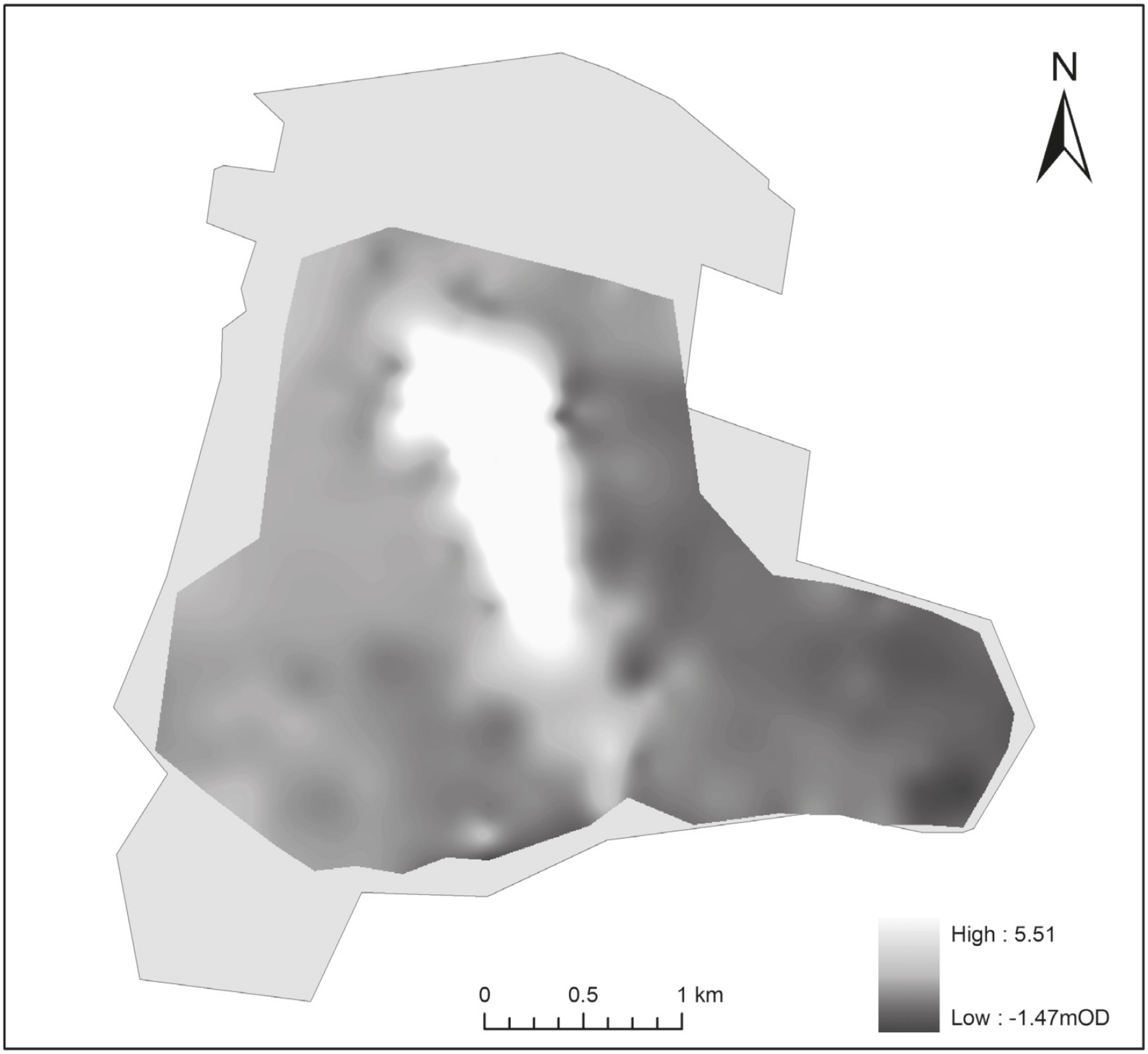

Figure 5.9: GIS model of the topography of the pre-peat landscape on Hatfield Moors, incorporating the datasets presented in Fig. 5.7

The pollen analyses indicated the pre-peat landscape was at least partially wooded with oak, birch and alder in wetter places, but with Scots pine and associated heath present; the beetle fauna also included species typical of the latter environment. Peat cutting exposed numerous trunks and stumps of pine rooted in the pre-peat land surface of windblown sands (see above). Dendrochronological study of pine sub-fossils from the western edge of Hatfield produced a chronology of 2916–2475 BCE and a single sample of oak dated to 3777–3017 BCE, indicating increased wetness, peatland spread and the death of the woodland during the 4th to 3rd millennium. The environment during initial peat inception was relatively dry, as indicated by the minerogenic, highly humified character of the peat, the presence of *Eriophorum* macrofossils in these deposits and abundance of heather in the associated pollen record.

Evidence for variation in peat inception is apparent in the palaeoentomological data from the southwest corner of Hatfield Moors, which indicated a sequence (see Chapter 1) from eutrophic to mesotrophic and finally ombrotrophic peat formation. Charcoal was identified in some basal peats, whilst a few of the pine and oak trees referred to above, also appeared to have been burnt at or around the time of their death. Conditions must have been relatively dry, seasonally at least and despite the accumulation of peat, to permit ignition of the vegetation. It is unclear whether this burning was a result of human activity, or natural causes (e.g. lightning strikes). The Scots pine dominated woodland would have died back as watertables rose (as indicated by the dendrochronological record) and the peatland system became further isolated from the influence of groundwater. Mesotrophic acid heath, dominated by heather and *Eriophorum* preceded the development of full ombrotrophic *Sphagnum* dominated raised bog from *c.* 1700–1000 BCE.

Modelling peat inception and spread

The basal pre-peat topography was modelled using the data collected in Stages 1 to 3 (see above). The radiocarbon dates from the base of the organic deposits obtained by previous research (referred to in part above) and the new dates acquired in Stage 4 were analysed with respect to the morphology of the pre-peat landscape. The results indicate there was no simple relationship between land surface elevation and the timing of peat accumulation. For example, the Porters Drain area, in the southwest of the peatland, is one of the lowest parts of Hatfield Moors (–1.5 m OD) produced a basal date of 2460–2135 BCE. This can be compared to the earliest date obtained, from just to the North of Lindholme Island, 5470–5220 BCE from a height of –0.11 m OD. The overall range of radiocarbon dates for peat inception ranged from the latter, through to the youngest date of 1690–1500 BCE from the southern edge of the study area.

The earliest (recorded) wetland development (above; 5470–5220 BCE) was close to the (later) location of the Neolithic trackway (see Box 7), where organic muds were deposited in a shallow, possibly discontinuous pool, to the north of Lindholme Island from *c.* 5470–5220 BCE, spreading south to reach the edge of the island itself by 2920-–2760 BCE. This water body infilled with organic sediment, through hydroseral succession (see Chapter 1) prior to subsequent ombrotrophic mire development. The chronology of the transition to the latter is unclear due to the removal of the upper deposits by later peat cutting. Palaeoentomological analyses of the deposits infilling this pool identified *Bembidion humerale,* a lowland 'peat specialist' species of beetle, the presence of which may indicate ombrotrophic peat growth had begun earlier than *c.* 1700–1000 BCE (see above). Saproxylic beetles imply trees were present nearby during the infilling of the pool: *Rhyncolus sculpturatus* (Fig. 5.10) was recorded, an 'old forest' or 'wildwood' species, associated with Scots pine in particular, a tree whose local presence is also indicated by the remains of subfossil wood towards the base of the peat (see above).

Box 7: The Later Neolithic Hatfield Trackway and Platform

The Hatfield trackway and platform is the only archaeological site to have been identified and fully excavated on Hatfield Moors. The site was discovered by a local man, Mick Oliver during one of his forays across the peatland. It would appear that the structure had been exposed for some time, and had only survived at all because it was located very close to the base of the peatland and the peat extraction machinery had not milled it away completely. As it was, there was significant damage to parts of the site, through peat cutting, the excavation of a drainage ditch and subaerial exposure. Excavation of the surviving sections demonstrated the structure consisted of a corduroy trackway, built of logs of *Pinus sylvestris* (Scots pine; sourced locally) and running for some 45 m to a platform (*c.* 4.5 × 10 m), built in the same manner, although it seemed that the logs had been disturbed by the peat cutting. Radiocarbon dating of the timbers produced an estimate of 2730–2450 BCE. There were few other structural elements preserved, aside from a poorly preserved peg, with the faint marks of a stone tool. Strips of *Betula* (birch) bark seemed to have been deliberately laid down below the 'sleepers' of the trackway in three places.

Another apparently deliberate, but rather odd feature of the site, was the trackway had a slight but marked 'dogleg' plan, where it seemed to avoid a slightly higher area of the pre-peat landsurface. The trackway also narrowed significantly along its length: it was 3 m at the southern end, but *c.* 1 m where it met the platform. The southern end of the trackway marked the northern end of Lindholme Island during the later Neolithic; at that time the wetland that it crossed into was a shallow pool (see below). Gearey and Chapman (2011) suggest the landscape context of the structure and the unusual architectural features imply that the trackway and platform were not intended for crossing the shallow open water, nor for other practical purposes such as hunting. Instead, the monument might have been an 'arena' for religious or ritual performances, linked to the transformation of the landscape from dry- to wetland: 'Perhaps it was hoped that the rituals performed at the very edge of this wetland would be sufficient to reverse the inexorable rise of the waters and establish the 'natural' order of the past' (Gearey and Chapman 2011, 28–29).

The site was subsequently 'scheduled' (see Chapter 7) and the surviving sections re-buried beneath a mound of peat in an attempt at preservation *in situ*. The 'Community of Builders' Project later built a scale replica of the site (see also Chapter 7).

Hence, peat inception began at different times – from the 6th millennium BCE, through to the mid-2nd millennium BCE – but proceeded through different 'pathways' (see Chapter 1): paludification as well as terrestrialisation/infilling. The timing of peat inception seems to have been related in part to the topography of the pre-peat landscape. Locations prone to accumulate water, such as depressions and shallow basins in the basal sands, produced the earliest radiocarbon dates, with peat later subsuming the higher (water shedding) slopes and ridges. The tendency of a specific location to accumulate or shed water was apparently more significant, in the initial stages of peat inception at least, than the absolute height (relative to mOD) of particular locations. The visualisation of the pre-peat landscape as a three dimensional surface, upon which certain points were more or less prone to waterlogging and hence peat inception, formed the basis for a subsequent GIS model of peat growth and spread, that we consider next.

Figure 5.10: The beetle Rhyncolus sculpturatus, found in deadwood of coniferous trees (credit: AfroBrazilian – Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76455845)

GIS MODELLING: PEAT INCEPTION

The analyses summarised above therefore demonstrated peat growth and spread across the pre-peat landscape of Hatfield Moors was not only time transgressive, but was seemingly controlled at least in part by localised topographic variations. To produce a 4-dimensional model of this process, it was necessary to extrapolate continuous 'surfaces' (isochrones) from the chronological 'point' data (the collated radiocarbon dates) for peat inception at the sampled locations across the pre-peat landscape. The technical GIS based methodology for this process is described by Chapman and Gearey (2013) and will not be discussed in great detail here.

The model (Fig. 5.11) shows the output as the estimated date of peat inception in five 'time slices': Late Mesolithic (pre–4000 BCE), early Neolithic (4000–3300 BCE), Late Neolithic (3200–2500 BCE), early Bronze Age (2500–1500 BCE) and later Bronze Age (1500–700 BCE). As outlined above, the nature of peat inception varied across the landscape, but this is not shown in the model. This model can be used to 'visualise' the process of landscape change and to contextualise prehistoric human activity and the construction of the trackway during the later Neolithic (see below).

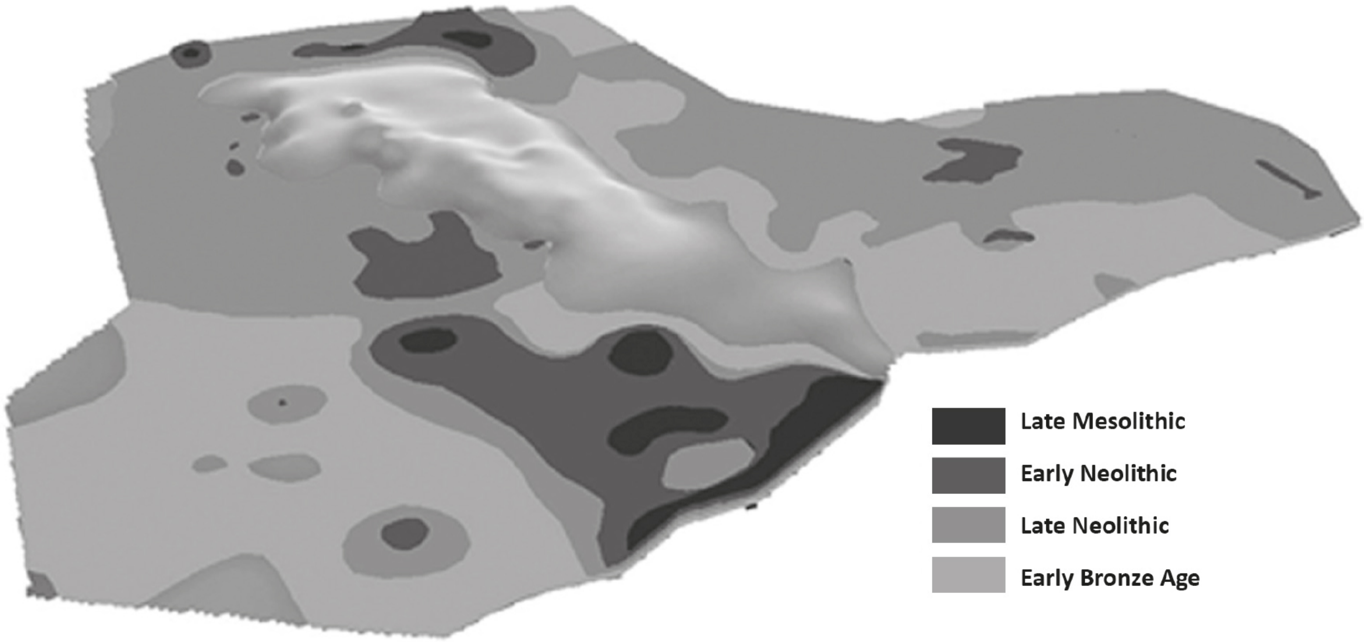

Figure 5.11: GIS model of peat inception and spread across Hatfield Moors

GIS MODELLING: SURVIVING PEAT DEPTH AND AGE

The remaining depth of peat (following the cessation of peat cutting) was modelled using topographic data sets representing the pre-peat landscape (base of the peat) and the contemporary surface of the peatland (derived from LiDAR data). The model (Plate 6) shows that aside from a discrete area at the southern edge of the study area, peat depth is generally less than 1 m; the mean depth is 1.02 m. Interpolation of the age of this cutover surface from the radiocarbon dating programme indicates that the *youngest* surviving deposits date to the medieval period, but that the majority of the surviving surface is Bronze Age. In some areas, peat cutting has removed these leaving Neolithic peats exposed. Of course, any archaeological material that was preserved in these deposits has been lost.

Summary and Themes

The Hatfield Moors case study demonstrates the application of GIS-based approaches for modelling hidden pre-peat land surfaces and processes of peatland inception and growth, using a range of legacy and bespoke datasets: cartographic, topographic, geophysical, palaeoenvironmental and radiocarbon dating. The 4-D models should perhaps be regarded as 'data representations' rather than literal 'visualisations' of the spatial and chronological pattern of peat growth. The models also provide a landscape context for the intra-peat Neolithic trackway and platform which can help inform interpretation; we will consider this further in Chapter 6. Stratigraphic and palaeoenvironmental data demonstrate that peat inception was not only time-transgressive, but that there were different pathways to ombrotrophic mire growth in different parts of the landscape, with paludification of the pre-peat land surface as well as hydroseral succession/infilling. Finally, the models of surviving peat depth and estimated age of the cutover surface, provides information concerning the loss of peat and any associated archaeological remains, potentially useful from a heritage management perspective (see Chapter 7).

Intra-peat archaeology

Overview