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An investigation of subfossil Scots pine (*Pinus sylvestris*) from Curlew Lane, Lancashire

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Abstract

This research presents the results of an investigation of subfossil trees from the Lancashire Coastal Plain that came to light in the facilitation of undergraduate final year projects at Manchester Metropolitan University. It details the field sampling and laboratory analyses utilising the techniques of dendrochronology and radiocarbon (^{14}C) dating and includes an illustration of best practices in the development of tree ring-width chronologies for the sensitive growth records of Scots pine trees that have previously grown on peat bogs. Results revealed that the Curlew Lane pine trees date from the early Holocene, a period when extensive boreal woodlands (including hazel trees and shrubs) grew in lowland areas in Lancashire and also in similar settings further to the south. The lack of pine macrofossil finds from Lancashire dating to the mid- to late-Holocene suggest that marine influences in the landscape were important factors not only in restricting this woodland type, but in creating an environment favouring bog oak woodland. The latter has provided an unparalleled resource for advances in dendrochronology (tree-ring dating) particularly since the 1980s.

Introduction

The Lancashire Coastal Plain covers over 395 miles^2 (1023 km^2), is underlain by Triassic and Carboniferous bedrock, and is also of international significance for over-wintering wildfowl and wading birds (Longworth, 1985; Natural England, 2014a). Its present-day landscape comprises gently undulating lowland farmland, former mosslands or peatlands, and coastal marshes and dunes, with topography developed in glacial and fluvioglacial outwash deposits and, particularly to the south of the River Ribble, 'subdued' by aeolian sands, marine and estuarine silts and peat accumulations (Taylor, 1967; Longworth, 1985; Natural England, 2014a). This relict landscape punctuated with meres (lakes) and mosses (peat bogs) has been an important source of palaeoecological information in the form of microfossils (e.g. pollen and diatoms) and macrofossils (e.g. tree stumps and trunks) preserved in these anaerobic wetland environments (e.g. Lageard & Ryan, 2013). Land drainage and ploughing mainly associated with the expansion of farming activities has taken place since the Medieval period and probably earlier, for instance in the case of Martin Mere, formerly the largest lake in England with an area of 7.6 miles^2 (1968 ha), still prone to flooding in the late nineteenth century (Hale and Coney, 2005: 1).

A relatively common sight in this area during the twentieth century were piles of tree roots, stumps and trunks, predominantly known as bog oaks (*Quercus* sp.), discarded at the edges of fields; these became important resources in the development of oak tree ring chronologies, particularly helping to span the English Neolithic archaeological period (Hillam *et al*., 1990; Brown and Baillie, 1992; Baillie, 1995: 40-44). Twenty-two sites with concentrations of bog oak, located between Southport and Ormskirk and to the north-west of Preston (see Atkinson *et al*., 1999), form the nucleus of the prehistoric English dendrochronological record that has enabled the dendrochronological dating of nationally important archaeological sites (e.g. the Sweet Track, Somerset Levels, Hillam *et al*., 1990) and more recent discoveries of prehistoric trees growing in more natural settings (both *in situ* and *ex situ* – Lageard and Ryan, 2013; Clarke, 2017; Hayles, 2017; Hayles and Lageard, 2017; Clarke and Lageard, 2018).

Increasing numbers of subfossil oak tree ring chronologies dated to calendar years have emerged since the 1980s in the UK, Ireland and elsewhere in continental Europe. These not only provide information on geographical occurrences and the age of these bog oak woodlands (ecosystems for which there are thought to be few if any modern analogues – Copini *et al*., 2016), but also give indications of past climate conditions. For instance, widespread mortality events in mire-rooting trees have been correlated with increasing climatic wetness (Leuschner *et al*., 2002; Eckstein *et al*., 2010; Edvardsson *et al*., 2016).

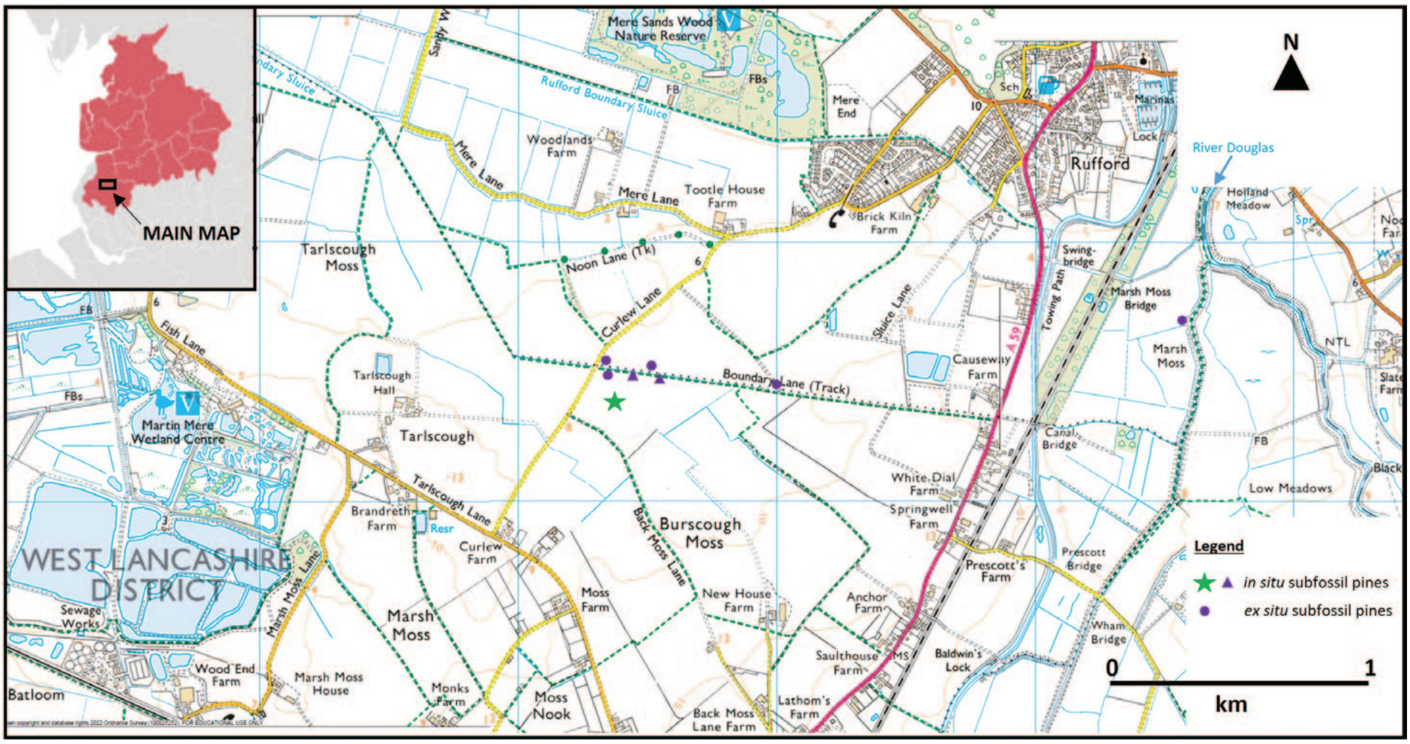

Figure 1: Origins of subfossil pine macrofossils sampled adjacent to Curlew Lane and Marsh Moss to the south-west and south of Rufford, Lancashire. Green star – origin of ex situ samples. Purple triangles – in situ fallen trunks (not sampled) visible in north facing ditch bank. Main map: © Crown copyright and database rights 2022 Ordnance Survey (100025252) FOR EDUCATIONAL USE ONLY. Inset map: Lancashire Tier 3 Lockdown Areas (Covid-19 Pandemic) October 2020 © iNews.

Subfossil or bog pines (Scots pine – *Pinus sylvestris*) have also grown widely on peatlands across Europe and they are generally well-preserved in peat deposits, although they have proved more challenging to date than bog oaks (Chambers *et al*., 1997). Often exposed during peat cutting activities, bog pines have been the subject of a significant amount of academic research in the UK, Ireland and further afield (Bennett, 1984; Pilcher *et al*., 1995; Lageard *et al*., 1999; Edvardsson *et al*., 2022; Margielewski *et al*., 2022), but notably not from sites in the Lancashire Coastal Plain, where their occurrence has been rare. The research reported here details an investigation of bog pines that emerged from a site to the south-west of Rufford, Lancashire. It demonstrates the process involved in creating and dating dendrochronological records from subfossil pines and also assesses the significance of these finds in the context of regional vegetation history.

Methods

Field sampling

Following previous sampling and successful dendrochronological analyses of subfossil oak trees uncovered at Martin Mere (Wetland and Wildfowl Trust – Clarke, 2017; Clarke & Lageard, 2018), enquiries were made at adjacent farms to see whether any similar finds had been made as a result of ploughing or drainage activities. Subfossil tree stumps and trunks had previously emerged from a field to the east of Curlew Lane (Figure 1). These had been initially piled in the farmyard at Curlew Farm and were later removed to another field to the south-east of Rufford (Marsh Moss – Figure 1). Some trunks also remained immediately to the north of the original finds area, either side of Boundary Lane (see Figure 1). Mechanised removal of the trees had resulted in some damage, but in many cases it was possible to sample trunks close to tree root crowns where there was better preservation of the wood, including in several cases the presence of bark. All the trees were identified as Scots pine (*Pinus sylvestris* L.) based on the cross-sectional structure of the wood and on the nature of the bark. Chainsaw sampling was undertaken from the two *ex situ* source areas mentioned previously, resulting in 30 disc samples (trunk/stump cross sections revealing growth increments or tree-rings).

Sample preparation and measurement

Sample discs were allowed to air-dry, before being prepared with a Bosch GBS 100A belt sander utilising progressively finer sandpaper grit sizes from P60 to P320 (particles of sand/

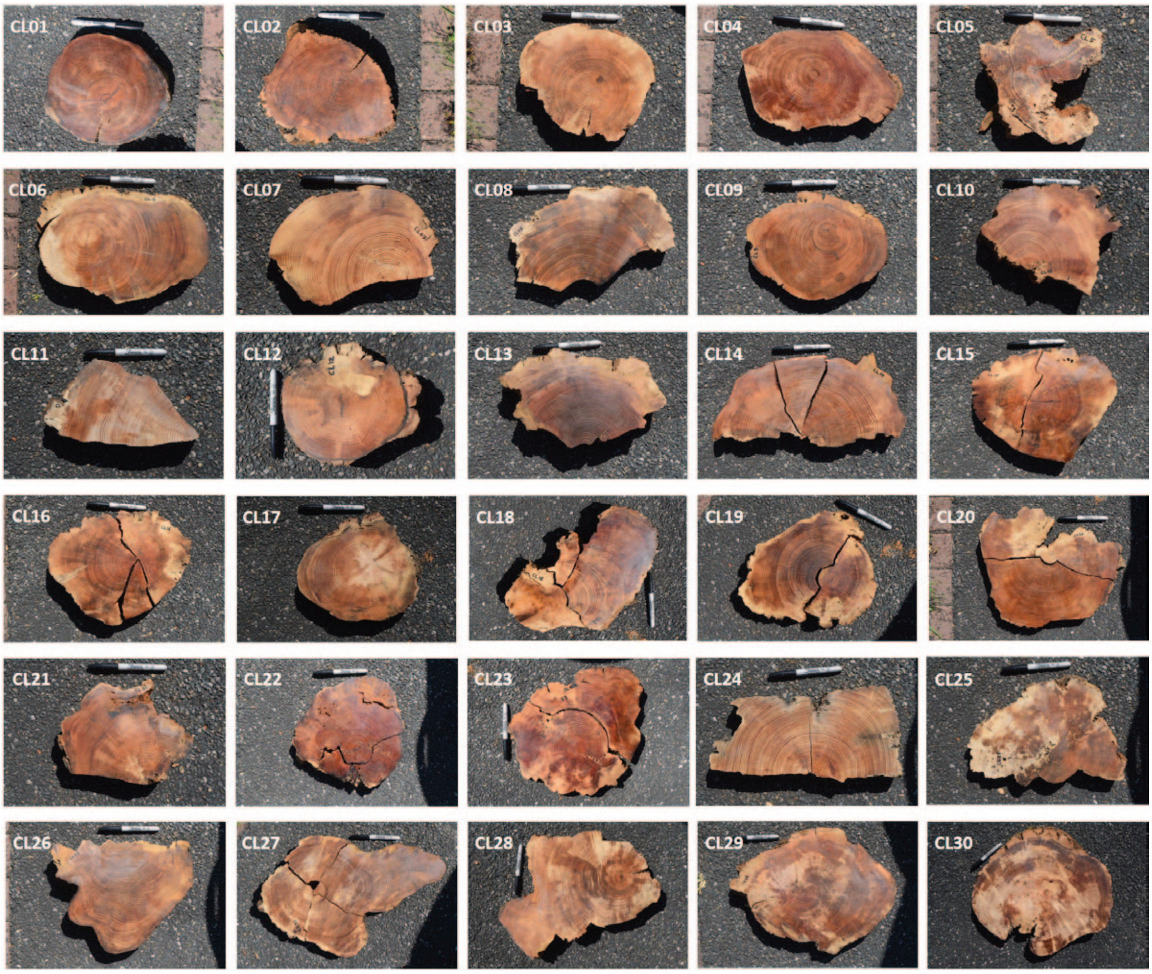

Figure 2: 30 subfossil pine disc samples retrieved from ex situ locations in the field (Figure 1). These were subsequently air-dried and prepared for ring-width measurements using a belt sander immediately prior to these photographic records (Marker pen scale length 13.7cm. Images: J. Lageard).

cm^2). This allowed samples to be smoothed and polished to allow the clear visual differentiation of tree-ring structures including their boundaries (see Figure 2).

Prepared disc samples were taken to the Dendrochronology Laboratory at Manchester Metropolitan University where their rings were measured to 0.01mm accuracy (using a binocular microscope, measuring stage/electronic measuring device and specialist computer software – *Input* and *Dendro* programs ©Tyers, 1999; Lageard *et al*., 1999). Measurements started at or near the centre of the tree (pith) and progressed towards the youngest ring, closest to the bark (see Figure 3).

Normally two measurement records were made for each disc, concentrating on areas where rings were clearly visible (see Figure 3). In four instances up to 4 radial measurements were necessary to obtain a consistent/precisely replicated mean growth record due to variable and eccentric growth patterns. These records were combined to form an averaged or mean growth record for the sample (see CL01M - Figure 4).

Chronology building

The ring-width records of all sample means and all individual radial measurements (e.g. CL01b and CL01c – Figure 4) were compared or crossmatched against each other to establish any similarity in their patterns. This was achieved using specialist computer software (Tyers, 1999) that utilises a *t* test statistical routine developed by Baillie and Pilcher (1973). Values of *t* in excess of 5.0 were investigated using visual alignment as possible indicators of correlations and therefore of contemporaneity. Ring-width records demonstrating good statistical and visual matches were combined to form an averaged growth record or tree-ring chronology. Initial chronologies were subsequently crossmatched against all remaining ring-width records until no further matches or additions to chronologies were

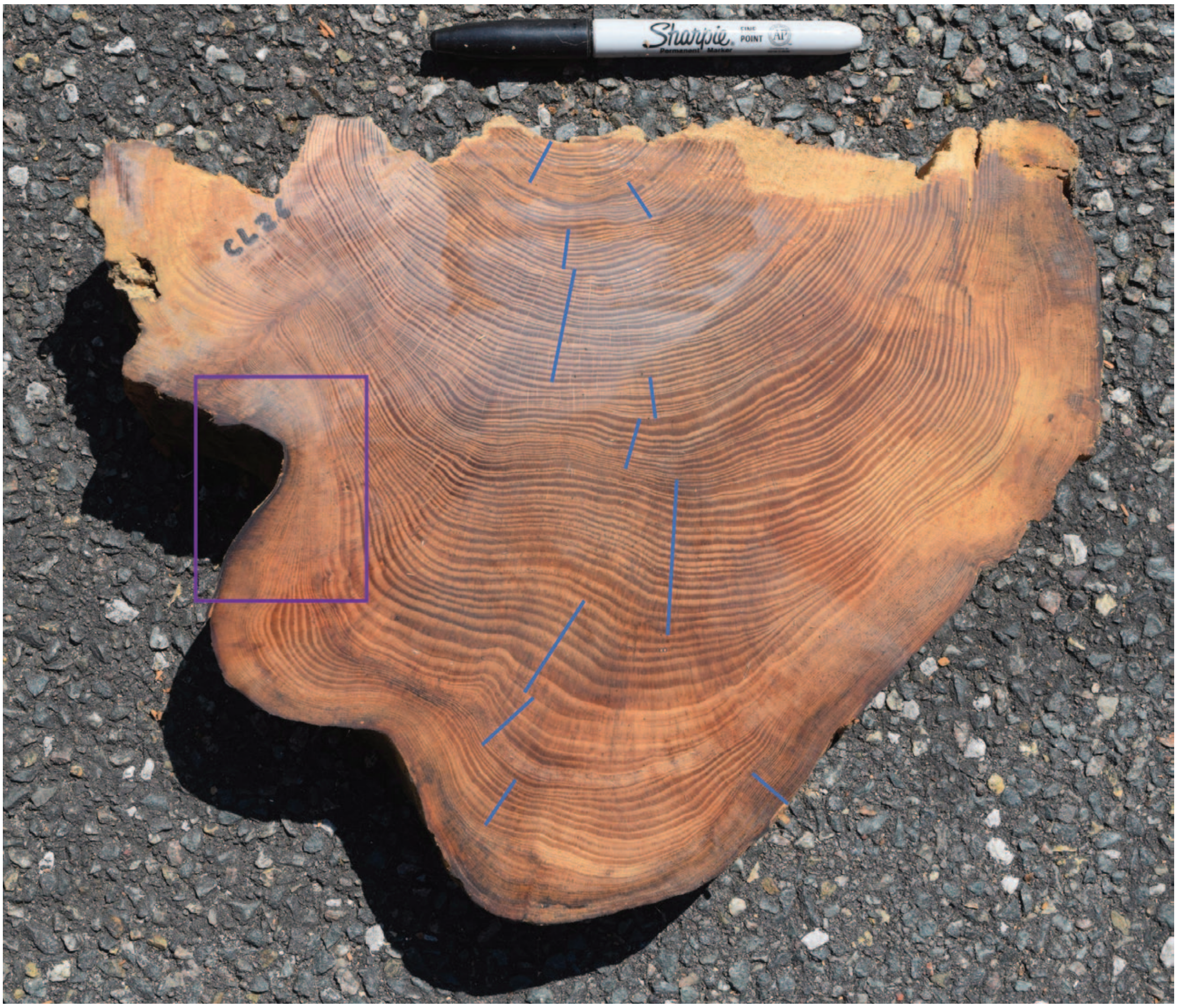

Figure 3: Disc CL026 following preparation using a belt sander. Blue lines represent a series of transects where ring-width measurement took place consecutively to create a growth record from the youngest ring (probably 10-20 rings from the pith which was missing in this sample) to the outer bark surface (bark no longer present following field sampling and subsequent preparation, but last ring well-preserved). Note that the transects traversed areas where the rings were 'stretched out'/fully visible and avoided areas that were 'constricted' or in 'zones de nécroise' (Munaut, 1966) – parts of the annual ring where cambial activity may have ceased due to the formation of trunk buttresses (purple rectangle). Transects should also be aligned at 90° to the ring boundaries to avoid inaccurate measurements (Image: J Lageard).

possible. Data from the final site chronologies were sent to the Dendrochronology Laboratory at Queen's University Belfast for comparison against their extensive database of bog oak and pine chronologies from the UK and Ireland. Separately all Curlew Lane pine data were compared with bog oak chronologies constructed from samples retrieved from the neighbouring wetlands of Martin Mere (Clarke, 2017; Lageard and Clarke, 2018).

Radiocarbon (^{14}C) dating

Wood samples comprising 10 annual rings were removed from disc samples representing the youngest ends of either site chronologies (see Figure 5), or in one case the youngest rings of an individual sample that demonstrated a possible crossmatch with a dated site chronology (oak) from Martin Mere (Figure 7). Sampling aimed to maximise the use of the 4 ^{14}C dates available by focussing on the site chronologies containing the largest number of tree-ring records thought to have come from separate trees, rather than from the same tree (*t* values exceeding 10.0 indicate ring-width series that are likely to have emanated from the same trunk – some individual trees could have been broken in to a number of pieces during extraction and transportation to the wood pile). The wood samples were carefully removed using a hammer and narrow-bladed chisel, taking care to avoid any poorly preserved wood and any contamination from

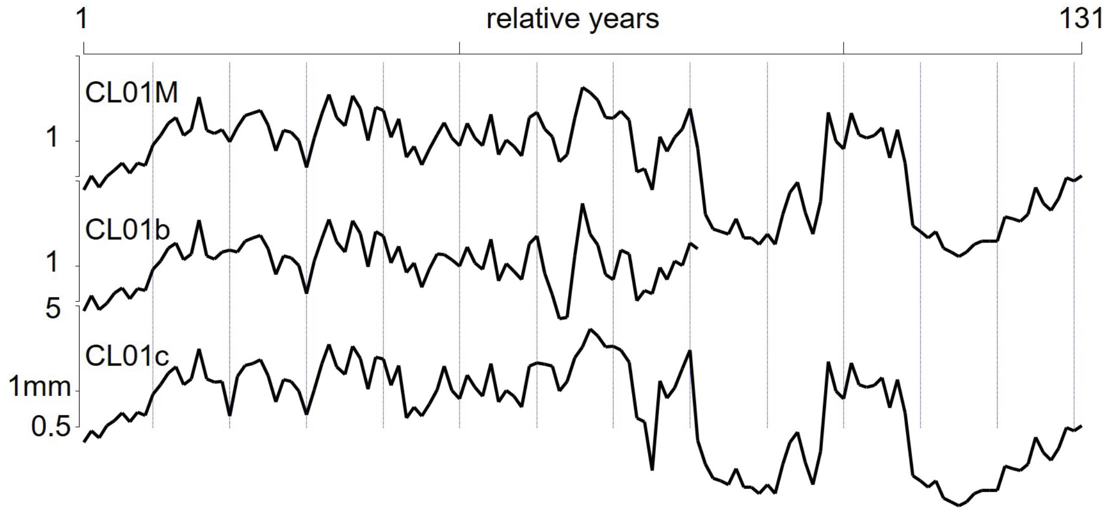

Figure 4: Ring-width records for subfossil pine disc CL01 – CL01b (radial transect measurement), CL01c (radial transect measurement), CL01M (mean growth record). Note that this sample had narrow ring series or reduced growth between rings 82-97 and 109-128.

residual peat or any sources of modern carbon (e.g. fine roots). Samples were then sealed in laboratory sample bags and sent to Beta Analytic (Miami, USA) for ^{14}C assay. Where the results of ^{14}C assays are written as '^{14}C years BP', this refers to years before AD 1950, a convention used in reporting ^{14}C 'dates' (Walker, 2005). In reality, ^{14}C dates are actually 'age estimates' due to uncertainties associated with the ^{14}C technique, and it is therefore essential that each is calibrated. Calibration was achieved using the OxCal software (Bronk Ramsey, 2021) and the calibration curve presented in InterCal 20 (Reimer *et al.*, 2020), providing an age range for each sample, within which the true calendar age hopefully lies (95% statistical confidence).

	CL01	CL02	CL03	CL04	CL05	CL06	CL07	CL08	CL09	CL10	CL11	CL12	CL13	CL14	CL15	CL16	CL17	CL18	CL19	CL20	CL21	CL22	CL23	CL24	CL25	CL26	CL27	CL28	CL29	CL30
CL01										5.4							5.1									5.5	5.44			
CL02				10.78						5.69																			5.36	
CL03				6.07																										
CL04																		5.23	5.65	5.68						5.57				
CL05										5.02																				
CL06																		6.23		5.07									5.17	
CL07																														
CL08																									8.89					
CL09																														
CL10																			5.32								5.55			
CL11														5.3								5.03	6.27	5.07				7.64	7.58	
CL12																5.19		5.4												
CL13																		5.01		5.15		5.02								5.39
CL14															6.07								5.56							
CL15																14.73														
CL16																												5.57		
CL17																														
CL18																										5.32			6.48	
CL19																						5.08		6.01		5.06			5.64	
CL20																						7.29	5.61		5.96				6.15	
CL21																								6.76						
CL22																							9.52	5.78	5.2					
CL23																											5.18			5.03
CL24																													5.4	
CL25																											5.32			
CL26																														
CL27																													6.49	
CL28																													6.91	
CL29																														
CL30																														

Table 1: Initial correlation matrix for Curlew Lane disc samples CL01 to CL30, showing t values exceeding 5.0. Site chronology correlations are distinguished using the following colours: CL1 – lime green, CL2 – pale green, CL3 – orange, CL4 – dark green [CL10 was added after crossmatching chronologies against previously undated records – bold cell outline], CL5 – yellow.

Results

Dendrochronology

Initial crossmatching identified five potential tree-ring chronologies (Table 1). Chronology building involved making mean records based on the strongest *t* value correlations to produce interim site chronologies. Subsequently, other ring-width records were compared with the interim chronologies and any records showing both *t* values exceeding 5.0 and a good visual match were added into the chronology. For site chronology CL4 for instance, individual records CL11M and CL29M (t = 7.58) were combined, with the later inclusion of CL10b, CL27b and CL28a (Figure 5). The latter three comprise single radial sample measurements that were terminated when sample disc ring-widths became very narrow (see narrow ring series Figure 4) and therefore representing hopefully unambiguous growth series (this is considered measurement good-practice when dealing with sensitive subfossil pine growth records).

Two interim site chronologies, CL3 (Figure 6) and CL5, comprised two ring-width records each and due to their high *t* value correlations (t = 10.78 and t = 14.78 respectively) it was concluded that these pairs of samples had been inadvertently sampled from different parts of the same tree (cf. English Heritage, 1998). With hindsight similarities can be seen in the images of sample discs CL02 – CL04 and CL15 – CL16 (see Figure 2).

Sixteen of the thirty Curlew Lane pine samples (53%) were successfully crossmatched and combined to form site chronologies including 101-277 tree-rings representing up to 277 years of subfossil woodland growth (Table 2). Individual growth records and the resultant site chronologies are measured in years relative to their individual components (relative years), but at this stage of the research these lacked any estimate of true calendar age.

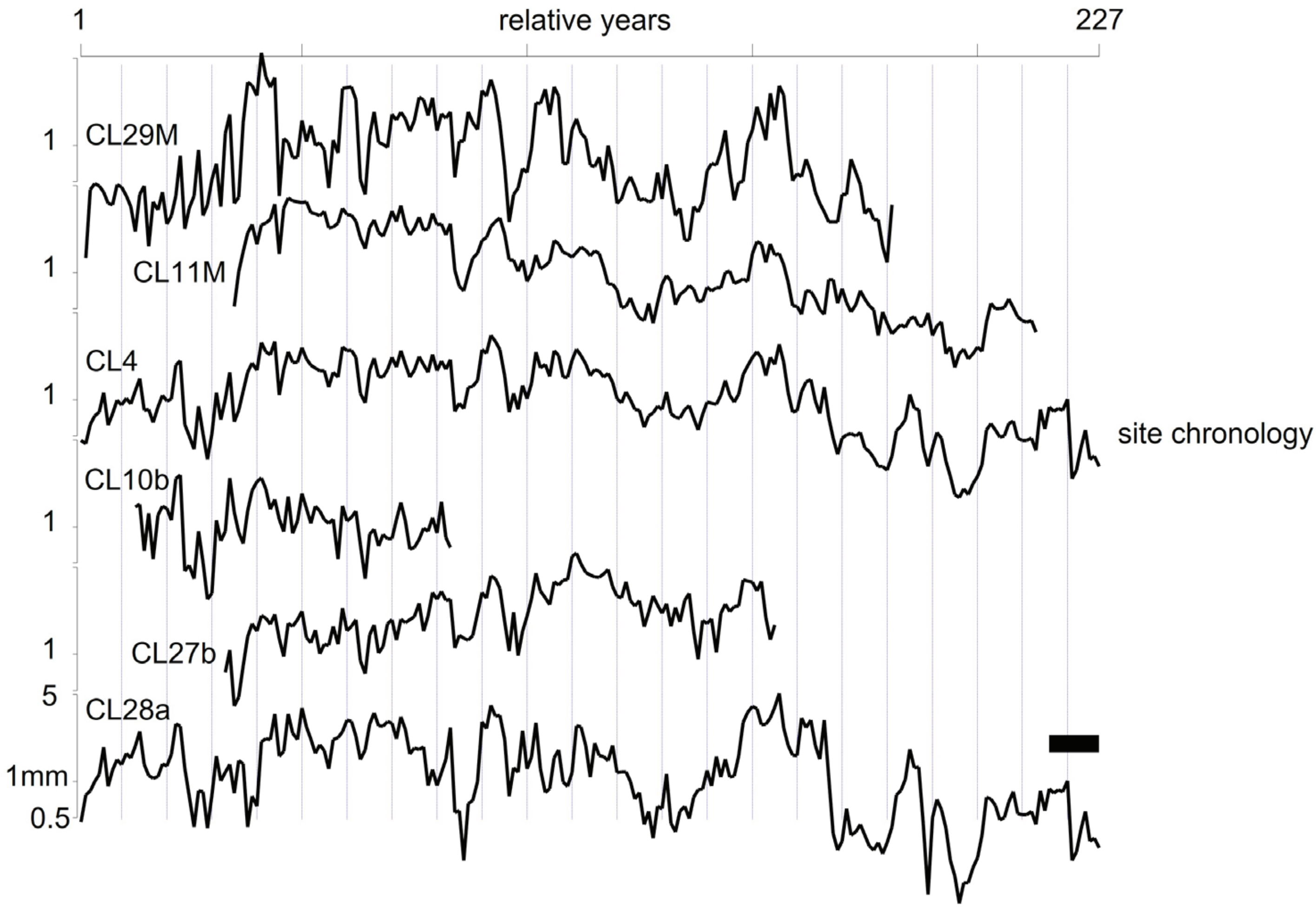

Figure 5: Subfossil pine ring-width records CL11M, CL29M, CL10b, CL27b, CL28a, all components of the overall site chronology CL4. Black rectangle represents 10 tree-rings removed from CL28a for radiocarbon assay.

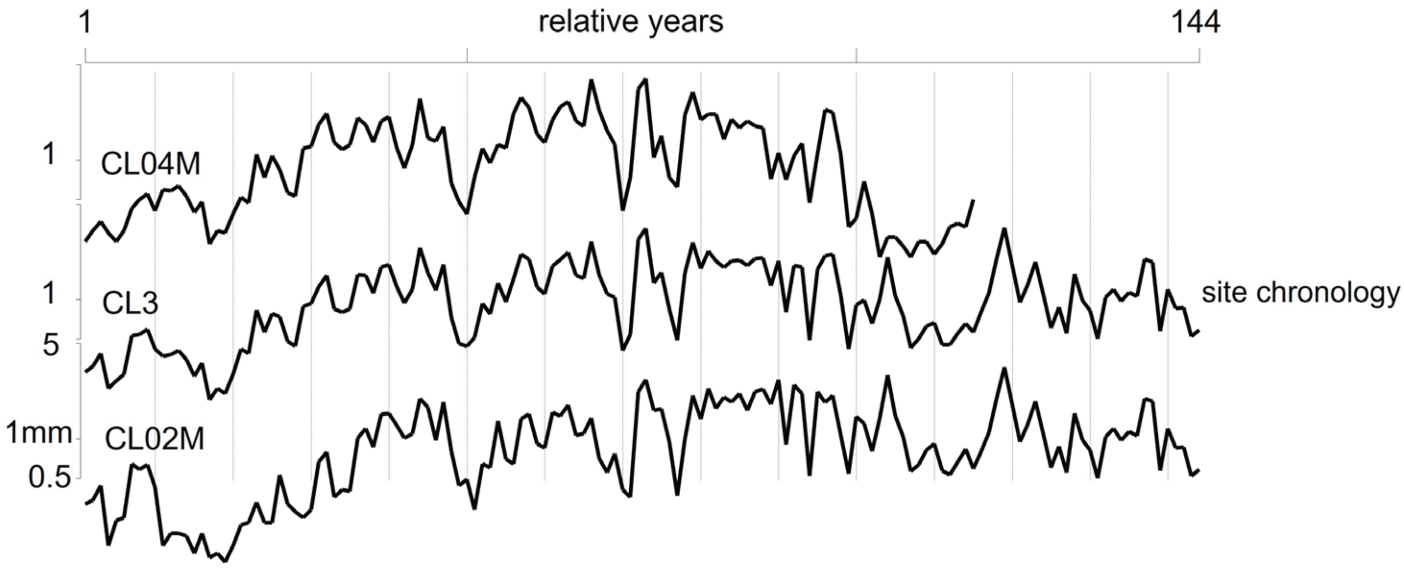

Figure 6: Subfossil pine ring-width records CL02M, CL04M combined to form site chronology CL3. A high statistical correlation (t = 10.78) and visual match between these two records suggests that these samples may have emanated from the same tree.

Table 2: Details of Curlew Lane 'floating' site ring-width chronologies including wood samples extracted for radiocarbon dating.

Chronology / Individual record	Initial components	Added	Length (yrs)	^{14}C sample
CL1	CL08M, CL25M	CL30a	277	CL08b
CL2	CL22M, CL23M	CL13M, CL20M	138	CL22a
CL3	CL02M, CL04M	–	144	
CL4	CL11M, CL29M	CL10b, CL27b, CL28a	227	CL28a
CL5	CL15M, CL16a	–	101	
CL12a	–	–	107	CL12a

Comparison of the Curlew Lane data with reference chronologies from further afield (UK and Ireland) resulted in a number of potential crossmatches. However, due to relatively low *t* value correlations (*t* ≤ 5.32 – David Brown pers. comm.) and the inter-species nature of these comparisons (bog oak – bog pine), dendrochronological wisdom and convention suggests that these results be viewed with considerable caution. Nevertheless, one crossmatch (t = 5.30) between CL12a and dated reference chronology Martin Mere 4_2 (4144 – 3993 BC – Clarke, 2017; Clarke & Lageard, 2018) comprising trees that had grown less than 2 km to the west of Curlew Lane (Figure 1) was intriguing, as there was also a good visual 'match' between the tree ring series (Figure 7). The youngest 10 tree-rings from CL12 were therefore removed for ^{14}C dating in order to test this possible contemporaneity.

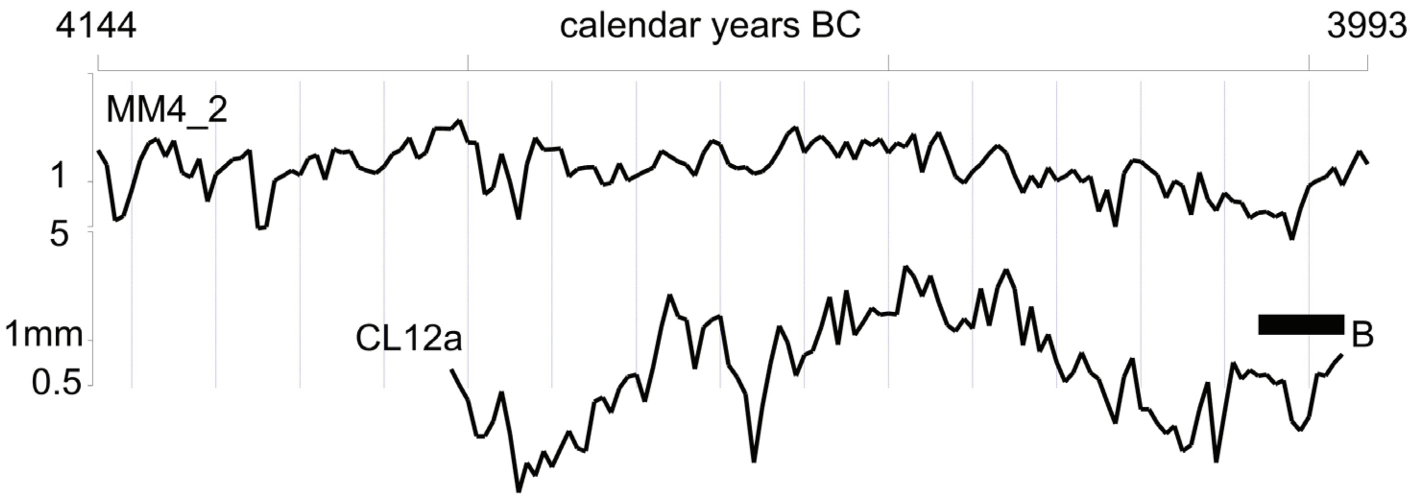

Figure 7: Potential cross-match (t = 5.30) between CL12a and Martin Mere subfossil oak chronology MM4_2 (Clarke, 2017). Note the more sensitive growth responses of the bog pine rings (CL12a) compared with the bog oaks (MM4_2), but also that both tree-ring series have apparently synchronous rising and falling growth trends, as well as precise synchroneity between key wide and narrow rings throughout the comparison. [This potential match was not supported by the ^{14}C assay (Beta – 625986 – Table 3), giving further credence to the standard dendrochronological practice of only confirming tree-ring dating where statistically significant cross-matching is corroborated by two or more reference chronologies, cf. Bernabei et al., 2010. Spurious correlations occur on occasions with shorter tree-ring series due to chance, but the similarities and correlation of key wide and narrow rings between CL12a and MM4_2 over a period exceeding 100 years is comparatively rare]. Black rectangle represents 10 tree-rings removed from CL12a for radiocarbon assay.

Radiocarbon (^{14}C) dating

Results of the four ^{14}C assays or age-estimates on Curlew Lane pine samples are presented in Table 3. These range from 8110 – 7420 ^{14}C years BP (calibrated age-range of 7179 – 6230 years BC).

Discussion

Regional palaeoecological context

An early study of regional vegetation history based on pollen analysis and ^{14}C dating of a peat core from Red Moss to the west of Horwich (21 km ESE from Curlew Lane), illustrated open Late-Glacial tundra-type plant communities dominated by herbs such as grasses, sedges, *Filipendula* species (e.g. meadowsweet), low-growing shrubs such as *Empetrum* (crowberry) and juniper up until around 9798 +/– 200 years BP (calibrated age range 9981–8639 cal. BC) (Hibbert *et al.*, 1971). Also present were isolated willow and birch (possibly including dwarf species such as *Salix herbacea* and *Betula nana*), and some Scots pine, although its representation at this time and hence local presence can be over-estimated (pine trees are wind-pollinated and prolific pollen producers, so long-distance transport of pine pollen should always be considered a possibility when interpreting pollen diagrams).

Table 3: Wood samples from Curlew Lane, their association with site tree-ring chronologies and radiocarbon age estimates.

Lab ID	Sample	Material	Rings	Site chronology	δ^{13}C (per mille)	Conventional radiocarbon age (years BP)	2 sigma calibrated age range (cal. years BC)
Beta - 625985	CL08b	wood	138-142	CL1	-24.8	8110 +/- 30	7179 - 7042
Beta - 625986	CL12a	wood	98-107	n/a	-26.8	7420 +/- 30	6383 - 6230
Beta - 625987	CL22a	wood	129-138	CL2	-25.8	7610 +/- 30	6502 - 6416
Beta - 625988	CL28a	wood	218-227	CL4	-25.1	7900 +/- 30	7028 - 6647

Subsequent climatic amelioration and further retreat of areas covered in ice permitted the northward expansion of the boreal forest, witnessed at Red Moss by sharp reductions in herb pollen from 9798 +/– 200 BP (9981–8639 cal. BC), high birch pollen up to 8790 +/– 170 BP (8292–7544 cal. BC), and a subsequent dramatic and sustained increase in hazel (*Corylus avellana*). Pine pollen rose more gradually peaking between 8196 +/– 170 and 7107 +/– 120 BP (7577–6699 to 6222–5745 cal. BC) (Hibbert *et al*., 1971 – see Figure 8), signalling the emergence of woodland in Lancashire, where Scots pine was an important component and lasting for possibly in excess of two millennia (between c 8000–6000 BC). Similar palynological evidence has also been forthcoming in Cheshire, where pine–birch–hazel woodland was dominant over an even longer period between 8625 +/– 50 and 5890 +/– 45 BP (7761–7564 to 4897–4616 cal. BC) (Lageard, 1992; Lageard *et al*., 1999; Hughes *et al*., 2000 – see Figure 8).

The Curlew Lane pine trees clearly date from this early Holocene period (Table 3; Figure 8) when plant communities in the Lancashire Coastal Plain can be characterised as components of a boreal forest or the Taiga type biome (western European maritime variant – including significant areas of hazel woodland) (Cox and Moore, 1985, pp.55-57). Macrofossils of similar age have also been found in Cheshire during road construction at Church Moss, Davenham. These included pine cones, pine and birch bark, as well as pine stumps and fallen trunks (less well-preserved than those from Curlew Lane due to a less anaerobic environmental setting), with two ^{14}C dates on the latter dating to 7810 +/– 80 BP and 7920 +/– 70 BP respectively (7031–6466 and 7042–6646 cal. BC) (Howard-Davies and Buxton, 1999).

Archaeologists attempted to find traces of Mesolithic human activity amongst the Davenham finds, such as worked wood or timbers or any alignment signifying a

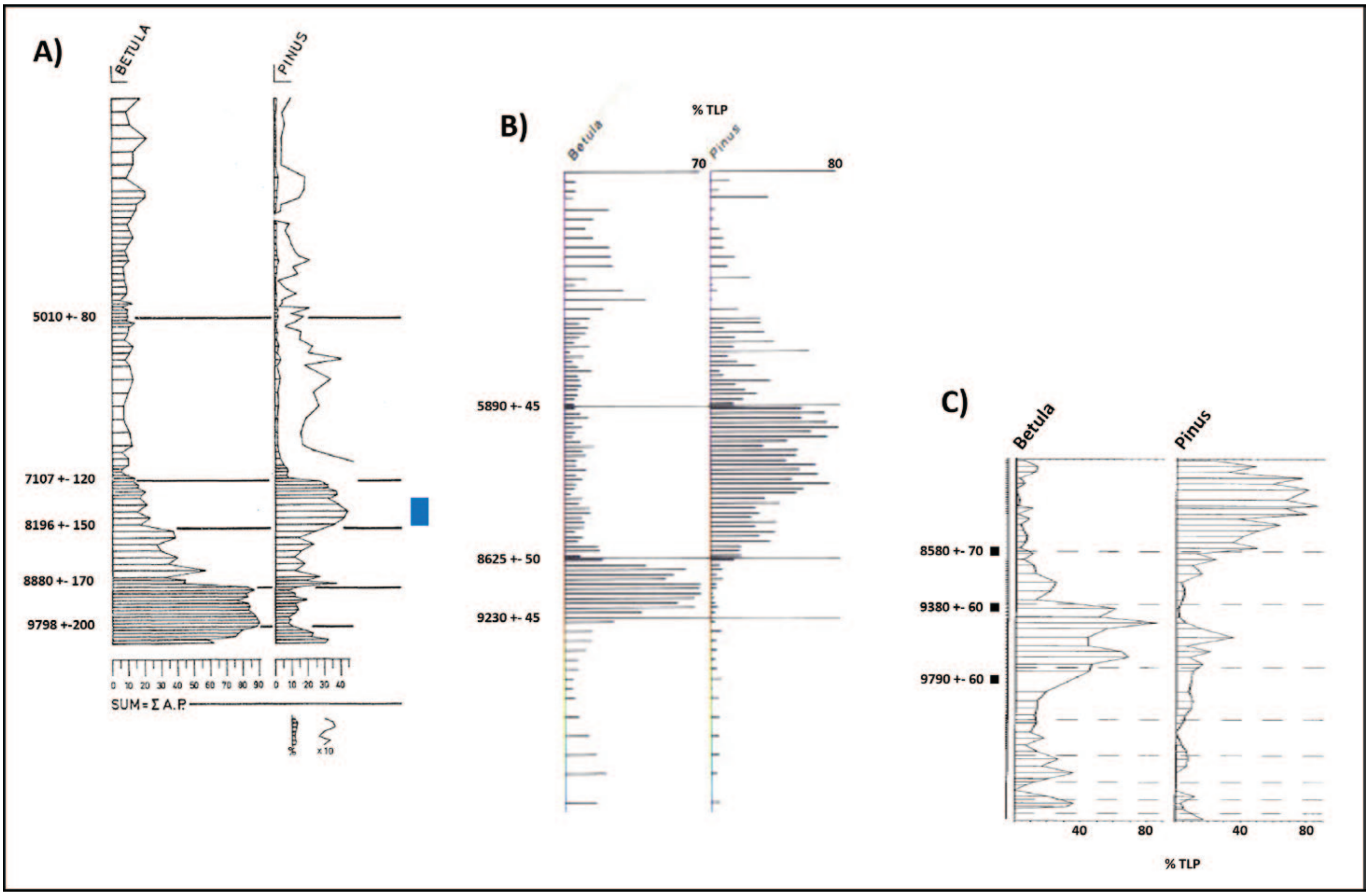

Figure 8: Comparison of mid-early Holocene pollen records for birch (Betula sp.) and Scots pine (Pinus sylvestris). Data selected from pollen diagrams for A) – Red Moss, Lancashire (Hibbert et al., 1971, p. 166; B) – White Moss, Cheshire (Lageard, 1992, p.82); C) – Church Moss, Cheshire (Hughes et al., 2000, p.700). Pollen data presented as % arboreal pollen (AP) in A) and % total land pollen (TLP) in B) and C). Blue bar – ^{14}C age of Curlew Lane pine samples plotted in relation to the Red Moss Pinus pollen record.

trackway across the bog, but concluded that the pine trees uncovered were most likely to have grown and died in natural circumstances. Interestingly the Davenham site also included fragments of hazelnuts, together with pine cones and charcoal/charred wood found in the northern part of the basin (Howard-Davies and Buxton, 1999, p.12). Whilst hazelnuts and evidence of burning could well be the result of natural processes (e.g. meteorological, natural weathering and decomposition, and/or animal predation) in the warm dry early-mid Holocene, hazelnut macrofossils tally with the assumed widespread presence of hazel as primary woodland or as an understorey component (see previous discussion and also Innes *et al*., 1999). There is now an extensive literature supporting not only the use of hazelnuts as a food source by early humans (Mesolithic hunter-gatherers), but also evidence of early woodland management (principally utilising fire) to proliferate this important subsistence crop throughout the UK/Ireland and elsewhere (Tallis, 1999; Holst, 2010).

Pine macrofossil absence (Mid-late Holocene)

There are clearly parallels in the early Holocene history of Scots pine in Lancashire and Cheshire with discoveries of pine micro- and macrofossils in both areas, but this complementarity appears to be lacking in the mid- to late-Holocene.

The Cheshire–Staffordshire–Shropshire Plain (known as the Meres and Mosses Region) is noted for its undulating landscape with numerous wetlands. Meres and mosses forming in low-lying depressions of glacial origin are an important characteristic of this region, and have assumed primary importance for many organisations interested today in cataloguing and safeguarding archaeological and natural environments, and overseeing land management, planning and development (Sinker, 1962; Leah *et al*., 1997; Leah *et al*., 1998; Natural England, 2014b; Meres and Mosses Landscape Partnership Scheme, 2018). These sites can range in size from a few hectares (e.g. Soss Moss, near Nether Alderley, Cheshire – c. 37 ha) to extensive areas such as Fenn's and Whixall Mosses NNR (966 ha or 9.66 km^2 straddling the English-Welsh border west of Whitchurch, Shropshire). Some larger sites have remained as lakes throughout the Holocene (e.g. Crose Mere, Shropshire), but many others have infilled naturally becoming at first marshes and then developing into raised peat bogs following the process of hydroseral succession (Lowe & Walker, 1997, pp.139-140). Before the widespread exploitation of bogs by humans in the later historical period, their surface vegetation reflected regional climate and local environmental conditions, and reconstructions of their vegetation history have demonstrated wetter and drier phases, the latter facilitating colonisation by Scots pine trees particularly in the mid- and late Holocene (e.g. Lindow and White Mosses, Cheshire – Lageard, 1998; Lageard *et al*., 1999).

Whilst the Meres and Mosses Region experienced uninterrupted wetland development during the Holocene, the Lancashire Coastal Plain in contrast experienced a different landscape trajectory with a number of significant marine incursions. Its early Holocene coast (The Hillhouse Coast – Gresswell, 1957) comprised extensive inter-tidal sand flats in the west, bordered by mudflats and salt marshes to the east (Plater *et al*., 1999). The dynamic nature of these sedimentary environments, a response to rapid post-glacial sea-level rise in the early-mid Holocene, lead to alternate phases of marine (e.g. silts, muds and sand) and terrestrial (e.g. peat) sedimentation, exemplified by the silt deposits intercalated with peats at Downholland Moss between 8000 and 6800 BP (Plater *et al*., 1999). The effects of sea level rise have been particularly noted at around 7000 BP (Tooley, 1985; Shennan & Horton, 2002) and prolonged waterlogging of low-lying coastal areas may well have caused widespread mortality of pre-existing pine woodland as evidenced by trees such as those uncovered at Curlew Lane.

These environmental disruptions may in part explain the shorter duration (vis à vis the Meres and Mosses Region) of early Holocene boreal woodland evident in the Red Moss pollen record. It is noticeable that pine pollen reduces to low (background) levels from 7107 +/– 120 BP (6222–5745 cal. BC), possibly signalling regional extinction or at least very significant reduction in pine woodland (Hibbert *et al*., 1971; Figure 8). This restriction of pine woodland also contrasts with the persistence of pine elsewhere into the late Holocene, for instance in Shropshire, western Ireland, Scotland and northern England (Sassoon *et al*., 2021; Lageard, 2022).

Marine transgressions therefore influenced landscape development, favouring the development and persistence of extensive wetland complexes such as Martin Mere into historic times. These unique fen-type environments developing in low-lying and often quite flat topography (a noticeable contrast to the hummocky Cheshire–Staffordshire–Shropshire Plain) were conducive to colonisation and sustained growth of oak trees (Baillie, 1995; Atkinson *et al*., 1999; Leuschner *et al*., 2002). Coney and Hale, commenting on the good quality of agricultural land resulting from the drainage of Martin Mere peats, also noted that 'few furrows can be ploughed without turning up giant bog oaks' (Coney and Hale, 2000:3) and the 20 bog oaks sampled recently for an undergraduate project (Clarke, 2017) from Martin Mere demonstrate the prolonged nature of bog oak woodlands through the mid- and into the late-Holocene (dendrochronologically-dated tree-ring chronologies: 4147–3954 BC, 4144–3993 BC, 3652–3505 BC and 1934–1738 BC – Clarke and Lageard, 2018).

The development of wetlands in the Lancashire Plain in the mid- to late-Holocene therefore favoured bog oaks rather than bog pines, not only explaining the rarity of macrofossil pine finds in the region, but also low pine pollen representation after 7107+/– 120 BP (6222–5745 cal. BC).

Conclusion

This research investigated a relatively rare find of Scots pine macrofossils uncovered during agricultural drainage of a field to the east of Curlew Lane in the central Lancashire Coastal Plain, dating them using a combination of dendrochronology and ^{14}C dating to the early Holocene. The Curlew Lane subfossil woodland correlates with existing regional pollen records that imply dominance of boreal forest-type vegetation between circa 8000 and 6000 years BC. The low representation or absence of pine micro- and macro-fossils in the mid-late Holocene in the Lancashire Coastal Plain appears to provide further evidence of the unique nature of wetland development in this area. Marine incursions and associated sedimentation governed both landscape and vegetation development (pre-eminence of bog oak woodlands), contrasting with the more hummocky topography of the Cheshire–Staffordshire–Shropshire Plain to the south, where Scots pine had a more prolonged presence.

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