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Middle Holocene environmental change and archaeology in coastal wetlands: further implications for our understanding of the history of *Taxus* woodland

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Abstract

A radiocarbon-dated multi-proxy palaeoenvironmental record from Beckton in the Lower Thames Valley, Southern England has permitted a detailed reconstruction of human activities and environmental change during the Middle Holocene. Peat accumulation occurred over river terrace gravels from *ca*. 7200-6600 until at least 3450-3240 cal BP and in the later period a trackway and platform structure provide unequivocal evidence for human exploitation of the floodplain environment during the Bronze Age. The site is unique in offering the first certain evidence of the utilisation of *Taxus* in in the construction of a wooden prehistoric platform. Across north-west Europe during the Middle Holocene, the colonisation of *Taxus* on peat is well-documented; at Beckton it occurred between *ca*. 5220-4940 to 4410-4220 cal BP. The research provides important insights into the former distribution of *Taxus*, and reasons for its expansion and decline during the Holocene, which has relevance to present day concerns over the conservation and management of *Taxus* woodland. Abandonment of the site occurred in response to environmental change to wetter conditions. The study employed multi-proxy analyses, including pollen, plant and wood macrofossils, and uniquely Coleoptera; Coleopteran analysis has significant potential to enhance understandings of environmental change and human-environment interactions in coastal wetland research.

Keywords

Archaeology, environmental change, relative sea level, *Taxus* (yew), vegetation history, tephra

1.0 Introduction

Today, *Taxus baccata* (L.) populations are relatively rare across its natural geographical range, and more significantly, are declining with a lack of natural regeneration (e.g. Thomas & Polwart, 2003; Deforce & Bastiaens, 2007; Ruprecht *et al.,* 2010; Linares, 2013; Iskulo *et al*., 2016). Protected areas and priority habitat status (EU Habitat Directive 92/43/EEC) have been established to conserve the natural distribution of the species (e.g. Svenning & Magärd, 1999; Thomas & Polwort, 2003; Mysterud & Østbye, 2004; Iskulo *et al*., 2016). The reduction in population is due to a combination of human pressures, grazing, temperature, competition (caused by excessive shade) and the dioecious nature of the species (e.g. Svenning & Magärd, 1999; Thomas & Polwort, 2003; Mysterud & Østbye, 2004; Iskulo *et al.*, 2012). Palaeoecological research can provide an important insight into the former distribution and pressures on *Taxus* populations, which is relevant to current concerns over declining levels and attempts to improve conservation and management of the species (Iskulo *et al*., 2016).

The presence of *Taxus* on the coastal wetlands of the Lower Thames Valley, Southern England and other parts of northwest Europe during the Middle Holocene is now well known (e.g. Beckett & Hibbert, 1979; Waller, 1994a; O'Connell & Molloy, 2001; Delahunty, 2002; Deforce & Bastiaens, 2007; Batchelor, 2009; Branch *et al*., 2012; Deforce *et al*., 2014; Waller & Early, 2015). Little is known however about the reason(s) for its colonisation, decline and former distribution on coastal wetlands. Branch *et al*., (2012) outlined the potential mechanisms involved, especially the importance of changes in peatland hydrology linked to relative sea level change. This new study examined in greater detail the interaction between vegetation succession and prehistoric human activities, thus permitting an evaluation of the role of human communities in the decline of *Taxus.*

The site at Beckton is located on the margins of the floodplain, adjacent to the geological and topographical boundary of the East Tilbury Marshes Gravel terrace (Gibbard, 1995), and approximately midway between the Lea and Roding tributaries. A detailed account of the archaeological findings is provided by Carew *et al*. (2009). Two trenches were excavated at the site

(Figure 1c), both containing a gravel surface overlain by approximately 2m of peat, capped by 1.5m of fine grained alluvium and top soil (Figure 2a). In Trench 1, abundant well-preserved wood was recorded towards the top of the peat including the wooden platform and brushwood trackway (Figure 2b). The platform lay on a peat surface radiocarbon dated 4230-3890 cal BP (-1.85 to -1.87m OD; Table 1), whilst three determinations on timbers from the structure itself (-1.85m to -1.79m OD) give a combined age range of 3980-3580 cal BP (early Bronze Age). The trackway was located on a peat surface dated 4240-3920 cal BP (-1.78 to -1.80m OD), with two dates from the structure itself giving a combined age range of 3550-3180 cal BP (late Bronze Age). A number of similar structures have been discovered along the floodplain of the Lower Thames Valley (e.g. Thomas and Rackham, 1996; Meddens, 1996; Divers, 1996; Figure 1a). With the exception of a Neolithic structure at Belmarsh West (Hart, 2010) and Silvertown Fort Street (Crockett *et al*., 2002), these date broadly to the Bronze Age between 4000 and 3000 cal BP, and are generally located towards the top of a thick horizon of terrestrial peat, which is overlain by fine-grained alluvium representative of flooding.

2.0 Methods

Due to the presence of the archaeological structures, Trench 1 was selected for detailed laboratory analysis. Column and bulk samples were taken through the sequence on the northern face of Trench 1 (Figure 2). Two separate columns were taken at the height of the trackway; one through it (<6>), and one on the western side (<4>). Lithostratigraphic analysis was carried out on both columns to establish the presence of any variations in the sequence caused by the trackway. The column samples were cleaned and described (Troels-Smith, 1955), and heights above mean sea level noted (British Ordnance Datum – m OD; Figure 2). The organic matter content was determined using the loss-on-ignition method (Bengtsson & Enell, 1986).

Pollen grains and spores were extracted following standard procedures (Branch *et al*., 2005a), and identified using type collections, keys and photographs (Moore *et al*., 1991; Reille, 1992). Poaceae grains were devided into wild or domesticated on the basis of grain size and annulus diameter (Andersen, 1979). The resultant Poaceae >40µm category combines all cereal types and wild grasses. A total of 300 pollen grains (excluding aquatics and spores) were recorded for each sample. The results are expressed as a percentage of total land pollen (trees, shrubs, herbs) prepared using

Tilia software (Grimm, 2004). The percentage pollen diagram was sub-divided into four local pollen assemblage zones (LPAZ) using numerical methods (CONISS). Pollen nomenclature follows Moore *et al*. (1991).

The plant macrofossils (seeds and fruits) were extracted from the bulk samples by sub-sampling a standard volume of sediment (250ml) and wet sieving them through 4mm, 2mm, 1mm and 300μm mesh sieves. The plant macrofossils were identified using type collections, keys and photographs (e.g. Berggren, 1981a, b; Anderberg, 1994). Waterlogged wood was extracted from separate samples associated with the archaeological structures. They consisted mostly of fragments of roundwood of various diameters. The wood was generally degraded and/or compressed, and in some instances it was not possible to provide a positive identification or accurate ring count. A minimum of 10 fragments were counted from each sample where available. Selection was based upon diameter (to represent roundwood from across the range) and morphology (to include fragments with several external characteristics). Thin sections were prepared using standard methods (Gale and Cutler, 2000), and the wood structure matched to reference slides. Plant nomenclature for wood and plant macrofossil remains follows the Flora Europaea as summarised in Stace (1997). Coleopteran remains were obtained from the bulk samples by wet sieving (1000-4000ml) over a 300μm mesh, concentrated by paraffin flotation (Atkinson *et al*., 1987).

Nine AMS radiocarbon determinations were made on plant macrofossils (seeds and wood) or bulk peat from the trackway and associated lithostratigraphic sequence, while a further five were undertaken on plant macrofossils from the platform (Figures 2, 3; Table 2). The radiocarbon determinations were calibrated using OxCal version 4.2.4 (Bronk-Ramsey, 1995, 2001, 2007) and Intcal13 (Reimer *et al*., 2013). The full calibrated age ranges (rounded to 10 years) are quoted as 'cal BP'.

An age model was generated within OxCal using a '*P-sequence'* algorithm and *k* factor of 100 (Bronk Ramsey, 2007; Blockley *et al*., 2007). The model placed boundaries at four key lithostratigraphic changes: (1) peat accumulating between -3.64m to -1.78m OD; (2) peat spanning the trackway (-1.78m to -1.67m OD); (3) peat accumulating during a significant decrease in organic matter content, immediately above the trackway (-1.67m to -1.53m OD; Figure 3), and (4) peat accumulating between -1.53m and -1.24m OD. Generation of the final model was an iterative process; when all of the radiocarbon dates were included, poor agreement was evident in the upper 5 radiocarbon dates (Beta-180310 to Wk-19034). The quality of individual samples was assessed. Where dates were from deposits representing mainly autochthonous material and stable depositional conditions they were considered likely to be more robust and retained, whilst dates originating from zones of human disturbance (e.g. the trackway) or where alluvial influence was prominent were considered more likely to suffer from complex transport and burial histories, and thus excluded from the final model (Table 1). While this procedure has the potential to be subjective, the date rejection criteria used relies on sound stratigraphic and sedimentological principles to independently assess each date. This procedure generated a model with high agreement indices and thus was used to interpolate age ranges at 10cm intervals through the peat and for each LPAZ boundary; the full calibrated age ranges (rounded to 10 years) are quoted in *italics* as ‘cal BP’. It is highlighted that the modelled ages become too imprecise for use above the trackway and the chronological inferences drawn from these intervals should be considered with this caveat in mind. The final model can be viewed in the Supplementary Data.

In order to assess the robustness of the final age model and to provide additional chronological information, the sequence was studied for its cryptotephra content using the methods outlined in Blockley *et al*. (2005). This identified low concentrations of both colourless and brown tephra shards in four broad zones: -3.60 to -3.50; -3.30 to -3.10; -3.00 to -2.90; and -2.30 to -2.10m OD. The upper two zones had shard concentrations of below 2 shards/cm^3 of sediment and were not pursued further, while the lower zones had higher concentrations (16 and 27 shards/cm^3 of sediment, respectively). The lower two intervals were prepared and analysed using WDS-EPMA chemical analysis. Diagnostic chemical data was only obtained on the upper peak (-2.99m OD) which indicated that the tephra was a sub-Alkali basalt derived from the Katla volcano in Iceland. However, the Katla volcano is highly productive with over 208 basaltic eruptions occurring during the Holocene, many with identical major and trace element chemical compositions (Larsen *et al*., 2001; Óladottir *et al*. 2008; Lane *et al*., 2012); hence the tephra was not useful in either testing or refining the chronology of the lithostratigraphic sequence at Beckton. Nevertheless, on the basis of the existing radiocarbon chronology the tephra can be broadly dated to between 7000 and 6000 cal BP, and significantly, represents the first example of middle Holocene tephra deposition in the Thames basin. The full findings will be reported elsewhere.

3.0 Lithological interpretation and results of the radiocarbon dating

Below -3.64m OD, gravel and sandy-clay deposits were recorded during the archaeological excavations (Figure 2). These sediments represent the upper surface of the Late Devensian Shepperton Gravel, which was deposited under high energy fluvial conditions in a braided river environment. This surface reduces in height from north to south across the site (*ca*. -3.60m to -6.00m OD) as would be expected from the position of the gravel terrace to the north (Carew *et al*., 2009).

Between -3.64 and -1.74m OD, the formation of wood peat represents the creation of semi-terrestrial conditions. The results of the radiocarbon dating and age-depth modelling suggest this transition took place around *7190-6620* cal BP (Figure 3; Table 1). This transition corresponds to a regional reduction in the rate of sea level rise from 2.6 to 0.8mm/yr from *ca*. 8000 cal BP, which caused widespread peat formation along the Lower Thames Valley between *ca*. 6800 and 5800 cal BP (Devoy, 1979, 1982; Sidell, 2003). During peat formation, the surface was prone to flooding, resulting in >20% input of mineral matter; between -2.84 and -2.24m OD (Unit 3; *ca*. *5740-5500* to *4860-4570* cal BP) inundation appears to have occurred more regularly.

The trackway is recorded in the sampled sequence between -1.74 and -1.67m OD on a surface of high organic matter content (75%; *4140-3900* cal BP), contemporaneously with the age upon which the platform was constructed (4230-3890 cal BP). Immediately above the trackway, the presence of clay and low organic-matter values indicate inundation between -1.67 and -1.50m OD, prior to a temporary return to drier conditions between -1.50m and -1.24m OD. Little variation in lithostratigraphy is recorded between columns <6> and <4> suggesting that the trackway had little impact upon peat accumulation (Figure 3). Above -1.24m OD to the top of the sequence, the deposition of clay, rich in detrital plant remains represents the transition to fluvial, possibly estuarine conditions at the site. Unfortunately, the chronology of events above the trackway (3460-3240 cal BP) is uncertain. However, the timing of final peat inundation is thought likely to be contemporaneous with other local sites around 2500 cal BP (Figure 1b): Beckton Nursery (2700-2180 cal BP; Divers, 1995), Beckton 3D

(2700-2150 cal BP; Meddens, 1996), Beckton Tollgate (2330-2000 cal BP; Tamblyn, 1994), East Beckton District Centre (2670-2150 cal BP; Jarrett, 1996) and East Ham FC (2300-2005 cal BP; Scaife, 2001). The results indicate that the entire peat sequence spans the late Mesolithic to late Bronze/early Iron Age cultural periods.

4.0 Results and interpretation of the palaeobotanical analyses

4.1 Pollen analysis

LPAZ GWB-1 indicates that between -3.64 and -2.46m OD (*7190-6620* to *5220-4940* cal BP) the dryland vegetation was dominated by mixed-*Quercus* dominated woodland with *Tilia*, *Ulmus*, *Corylus,* lesser quantities of *Fraxinus* and *Betula;* towards the end of the zone *Taxus* is recorded (Figure 4; Table 1). The most significant change in dryland vegetation was recorded around *7110-6560* cal BP (-3.60m OD), before which high percentage values of *Tilia* pollen suggest it was dominant or co-dominant with *Quercus*. In addition, whilst *Ulmus* was a minor component of the dryland vegetation, pollen percentage values decline to near absence indicating a population reduction between *ca*. *6150-6000* and *6030-5810* (-3.06 to -2.98m OD).

The decline in *Ulmus* pollen percentage values, occurs however around the time of an increase in taxa suggestive of improved light penetration to the ground surface (including Poaceae, *Plantago lanceolata*, *Chenopodium* type, Poaceae >40µm, *Hedera*) between *5890-5650* and *5570-5510* cal BP (-2.90 and -2.82m OD). At this time, during the early stages of paludification, the site was located much closer to the floodplain edge than the 150m distance currently indicated by British Geological Survey mapping (Figure 1a). As a consequence of this closer proximity, there is greater potential that the vegetation change occurred on the adjacent dryland (e.g. Hjelle, 1998; Bunting *et al*., 2004). However, due to taphonomic issues specific to coastal wetlands (including the difficulties of distinguishing the environment of origin of many herbaceous taxa (e.g. Waller, 1998; Waller *et al*., 2005) and of splitting cereal pollen from that of wetland grasses (Andersen, 1979; Waller & Grant, 2012; Perez *et al*., 2015)) it is possible some of these pollen taxa originated from plants growing on the floodplain. Furthermore, plants of the Chenopodiaceae family may be split into two broad groups, those associated with brackish and marine environments such as *Salsola kali*, and those commonly found in waste places and the edges of arable fields on dryland, such as *Chenopodium album*. Thus, the pollen values of *Chenopodium* type recorded may indicate the growth of saltmarsh plants (and therefore a brackish water influence) on the wetland rather than more open conditions on the dryland. It is also noteworthy that the decline of *Ulmus* occurred during a time of enhanced *Alnus* pollen values, and there is a possibility that the decline is the result of reciprocal changes in percentage pollen values.

The wetland was dominated by taxa analogous to that of present-day fen carr woodland, found in low-lying areas that are waterlogged for much of the year (e.g. Wheeler, 1980). The woodland was dominated by *Alnus glutinosa* with some *Salix*, both of which are common to these wetland ecosystems. *Fraxinus*, *Betula* and *Corylus* may also have occupied the wetland, together with *Rosa*, *Prunus* and *Lonicera periclymenum*. The ground flora would have consisted of the following herbs, aquatics and ferns: Poaceae, Cyperaceae, Apiaceae, *Ranunculus*, *Menyanthes trifoliata*, *Sparganium* and *Typha latifolia*, *Dryopteris* and *Polypodium vulgare*.

The transition to LPAZ GWB-2 is defined by rising percentages of *Taxus* pollen, representing its colonisation of the peat surface from 5220-4940 cal BP (-2.46m OD). The pollen record indicates that *Taxus* became an important component of the wetland woodland dominated by *Alnus*. Otherwise, much of the woodland composition remained unchanged from LPAZ GWB-1, with the exception of the expansion of *Fraxinus* with *Taxus*, and a decline in the number of herbaceous pollen taxa recorded. Neither of these findings is unexpected; *Taxus* and *Fraxinus* have been recorded as separate sub-communities in former *Alnus* dominated woodland on the nearby Erith foreshore (Seel, 2001), whilst the field layer beneath *Taxus* is known to be sparse due to the dense shade produced by its canopy (Seel, 2001; Thomas and Polwart, 2003). The presence of *Taxus* suggests that the peat surface was drier during this period since it is unlikely to have grown on unconsolidated very wet peat (Thomas and Polwort, 2003); an interpretation supported by a reduction in aquatic pollen.

The dryland continued to be dominated by mixed deciduous woodland through much of LPAZ GWB-2. However, towards the top of the zone, changes in vegetation composition are recorded on both the wetland and dryland. *Taxus* undergoes a long-term decline from *4410-4220* cal BP on the wetland, towards the end of which *Quercus* and *Tilia* decline on the dryland from *4160-3930* cal BP. The decline of *Taxus* resulted in an apparent return to a wetland woodland canopy dominated by *Alnus* with *Salix*. Minimal values of Poaceae, Cyperaceae and aquatic taxa do not suggest this occurred as a consequence of wetter conditions, although the possibility of paludification cannot be discarded as a possible causal factor (e.g. Waller, 1994b; Grant *et al*., 2011). However, the age of the platform (4240-3890 cal BP) and later trackway (3460-3240 cal BP) do provide unequivocal evidence for the presence and impact of human activity within the immediate area of the site at this time.

LPAZ GWB-3 commences immediately above the trackway structure (sometime after 3460-3270 cal BP) and is characterised by significant changes in pollen stratigraphy: (1) the decline of *Alnus*; (2) an increase in the number of herbs and ferns indicating more open conditions (e.g. Poaceae, *Plantago lanceolata* and *Pteridium aquilinum*); (3) an increase in pollen of light demanding shrubs (e.g. *Hedera*), and (4) an increase in pollen taxa indicative of aquatic vegetation communities (e.g. *Sparganium,* Cyperaceae and most likely Poaceae). The pollen-data provides unequivocal evidence that the vegetation community on the peat immediately overlying the trackway was significantly different to that beneath: the decrease of *Alnus* together with increasing Cyperaceae, *Sparganium* and most likely Poaceae (e.g. *Phragmites australis*) indicates retrogressive succession in response to wetter conditions. Increasing pollen values of *Chenopodium* type may also indicate that local environmental conditions were becoming more brackish rather than exclusively freshwater. Of particular importance here is the interpretation of the Poaceae >40µm pollen grains which might be used to infer nearby arable cultivation. However, as highlighted above, this group includes both cereals and wild grasses (Andersen, 1979); previous studies have indicated the association of these grains with other wetland herbaceous and aquatic taxa (e.g. Poaceae, Cyperaceae, *Sparganium*) means that at least a large proportion of them represent wild grasses found in wetland habitats (e.g. *Glyceria* sp.) (Waller & Grant, 2012; Perez *et al*., 2015). Furthermore, due to the poor dispersal characteristics of cereal pollen grains, the >5% pollen values recorded would require substantial cultivation proximal to the site.

Midway through the zone (-1.50 to -1.38m OD), an increase in *Alnus* and decline of herbaceous and aquatic taxa suggests a re-expansion of woodland on the wetland. This period is short-lived with a second, permanent decline in *Alnus* occurring at the transition into LPAZ GWB-4 (which also coincides with the transition from peat to clay). The decline of *Alnus* woodland is accompanied by the same increase of shrub, herbaceous and aquatic taxa as that recorded at the beginning of LPAZ GWB-3. However, in this case, the presence of *Armeria maritima* with higher values of *Chenopodium* type provides stronger evidence for brackish water conditions. In addition, *Pteridium aquilinum* and *Pinus* are recorded in high quantities; these palynomorphs are commonly over-represented within the sediments of such environments due to their ability to travel long distances (by fluvial and/or aeolian means; Campbell, 1999).

4.2 Plant macrofossil and wood analyses

Plants commonly found within fen carr woodlands dominate the plant macrofossil record (Figure 5). Although some samples had no macrofossil preservation, the common occurrence of *Alnus glutinosa* and *Rubus* sp. with sporadic *Betula pendula/pubescens*, *Corylus avellana*, *Vaccinium* sp., *Sambucus nigra* and *Prunus* indicates a mosaic of woodland with an understorey of shrubs. Similarly, a wide range of herbaceous taxa are recorded including *Ranunculus* sp., *Solanum dulcamara,* Apiaceae cf *Oenanthe* sp. and various Cyperaceae. The only noticeable change in assemblage occurs between -1.78 and -1.39m OD (from *4140-3900* cal BP; level with and above the trackway) in which an increase in herb and aquatic taxa suggest wetter conditions (including *Sparganium* sp., *Eleocharis palustris* and *Polygonum hydropiper*). Another notable occurrence is the presence of *Atriplex/Sueada* sp. seeds at -2.56 to -2.35m OD (*ca*. *5430-4830* cal BP) indicating the growth of saline plants or disturbed ground taxa. The wood macrofossil data (Figure 2b; Carew *et al*., 2009) confirm the predominant growth of *Alnus glutinosa* on the wetland with *Taxus*, *Fraxinus* excelsior, and *Betula* sp.

5.0 Results and interpretation of the coleopteran analysis

Three local coleopteran assemblage zones (LCAZ-1 to 3) have been defined (Table 2; Figure 6). Throughout the sequence, pools of stagnant, vegetation-rich water were present at or near to the site. This is indicated by the presence of a diverse range of species, such as the water scavenger beetles *Cercyon ustulatus, Hydrobius fuscipes, Octhebius minimus* and *Hydraena testacea*. Predaceous diving beetles such as *Colymbetes fuscus* suggest that some vegetation-free stretches of open water must always have been available for colonisation (Friday, 1988; Koch, 1989). This in turn indicates that some of the local aquatic habitats consisted of larger, more permanent ponds and not temporary pools.

During LCAZ-1 (*ca*. *6920-6440* to *6030-5810* cal BP; -3.54 to -2.96m OD), the site was located in richly vegetated deciduous ancient woodland, including *Quercus*, *Tilia*, *Ulmus*, *Betula* and *Acer*. This is indicated by the presence of bark beetles such as *Scolytus multistriatus, Scolytus mali, Kissophagus hederae, Dryocoetinus villosus, Ernoporus caucasicus*. The presence of dead standing deciduous wood is indicated by the throscid beetle *Trixagus dermestoides* whose larvae develop in wood, the silvanid beetle *Silvanus unidentatus* that lives under *Quercus* bark, and weevils *Rhyncolus punctulatus* and *Coeliodes erythroleucos* that live in *Quercus*. This picture is atypical of other floodplain sites where the ground is usually too damp to support mature tree species.

The transition into LCAZ-2 (*ca*. *6030-5810* to *4160-3930* cal BP; -2.96 to -1.78m OD) is characterised by the reduction of dryland woodland and appearance of wetland habitats. This is consistent with evidence for ongoing paludification and is supported by the development of *Alnus* carr throughout this interval. There is evidence for the development of *Alnus* carr through this interval. Leaf beetles such as *Chrysomela aenea* and *Plagiodera versicolora* provide evidence for the presence of *Alnus* and *Salix*, whilst the growth of *Phragmites*, Cyperaceae and *Oenanthe* is indicated by aquatic plant-feeding beetles *Plateumaris braccata* and *Prasocuris phellandrii*. *Lemna minor* is indicated by the aquatic weevil *Tanysphyrus lemnae*.

After *4160-3930* cal BP (-1.78 to -1.01m OD; LCAZ-3), woodland appears to recede, with evidence for the expansion of grassland and open, sunny areas indicated by species such as *Trechus quadristriatus*, *Pterostichus nigrita* and *Bembidion guttula* (Koch, 1989; Lindroth, 1974). This corresponds to a large increase in mineral sediment input at -1.78m OD, which suggests widespread flooding at the site. The evidence for a change to more open woodland is supported by the appearance of the weevil *Bagous argillaceous* in the upper part of the sequence, which feeds on Poaceae (Alexander, 1994). LCAZ-3 is also characterized by the appearance of the long-toed water beetle *Esolus parallelopipedus*, a river and stream species which prefers clean stones and low silt conditions (Koch, 1989).

6.0 Discussion

6.1 Dryland environmental change in the Lower Thames Valley

The close proximity of the site to the wetland edge has permitted reconstruction of the prehistoric vegetation on the dryland. The palaeobotanical records strongly suggest that dryland woodland, dominated by *Tilia* and *Quercus* with *Ulmus* and *Corylus* initially occupied the site prior to peat formation, as indicated by very high percentage values of *Tilia* pollen (which is entomophillous) and insects monophagous to *Tilia* and *Quercus*. These pollen and insect indicators rapidly reduce signifying the retreat of dryland woodland in response to peat formation (paludification). The cause(s) of the middle Holocene *Tilia* decline in the UK have been comprehensively reviewed by Grant *et al*. (2011), and the cause of this early event at Beckton is a clear example of paludification Type II: a rapid decline associated with a transition from dryland to peat formation (see also Waller, 1994b).

The low percentages of *Ulmus* suggest that it was a minor component of the woodland cover. However, due to the dense cover of wetland and dryland woodland, the under-representation of *Ulmus* might be related to pollen filtration. Despite this, a reduction in *Ulmus* pollen is recorded between *ca. 6150-6000* and *6030-5810*. The event is considered significant because it coincides with the well-documented '*Ulmus* decline' in NW European pollen records (Parker *et al*., 2002) and the Lower Thames Valley (e.g. Devoy, 1979; Wilkinson, 1988; Wilkinson *et al*., 2000; Batchelor *et al*., 2014). The reasons for this decline have been of some debate with the following hypotheses proposed: (1) climate change to cooler conditions (e.g. Smith, 1981); (2) soil deterioration (Peglar and Birks, 1993); (3) competitive exclusion (e.g. Huntley and Birks, 1983; Peglar and Birks, 1993); (4) human interference with natural vegetation (e.g. Scaife, 1988; Lamb and Thompson, 2005), (5) disease (e.g. Perry and Moore, 1987; Girling, 1988; Waller, 2013), and (6) multiple causes (e.g. Parker *et al*., 2002; Batchelor *et al*., 2014).

The event at Beckton is preceded by occurrences of the elm bark beetle *Scolytus multistriatus*. In modern contexts, *S. scolytus* and *S. multistriatus* are the beetles responsible for carrying the fungus *Ceratocystis* (*Ophiostoma*) *ulmi* that causes disease. Whilst not monophagous on *Ulmus* and considered the less reliable indicator, the presence of *Scolytus multistriatus* prior to, and during the decline may therefore represent potential evidence for a disease-caused decline, especially when combined with further similarly dated insect records of *S*. *scolytus* in London at Hampstead Heath

(Girling, 1988), Old Seager Distillery, in Kent at Horton Kirby Paper Mill (Batchelor *et al*., 2014), and further afield at Red Moss of Candyglirach, Aberdeen (Clark & Edwards, 2004). However, it is also argued that the occurrence of *S*. *scolytus* / *multistriatus* only demonstrates the presence of a suitable habitat, and evidence for the growth of *Ulmus*, either dead, or growing under stressed conditions; not for the presence of disease itself (Bevan, 1987; Robinson, 2000; Waller, 2013).

An increase in the number of light-loving herbs and shrubs (including Poaceae, *Plantago lanceolata*, Poaceae >40µm and *Hedera*) occurs immediately after the decline between *5890-5650* and *5570-5510* cal BP, suggestive of Neolithic temporary land clearance for agricultural purposes. This interpretation is supported by unequivocal archaeological evidence approximately 200m to the north-east of the site on dryland, where a scatter of pottery, struck and burnt flint and a considerable quantity of carbonised processed grain (*Triticum dicoccon* and possibly *T*. *monococcum*) dated to 5890-5320 cal BP were recorded (Stafford *et al*., 2012).

The evidence from Beckton therefore contributes to the multi-causal model for the *Ulmus* decline. However, simply referring to this model does not take into account the precise relationships between the different causal factors at individual sites (e.g. primary / secondary causes and consequences), that led to the decline (see Waller, 2013; Batchelor *et al*., 2014). Due to the significant number of palaeoenvironmental records in the Lower Thames Valley, a classification system was recently proposed enabling such a categorisation (Batchelor *et al*., 2014). Within this system, Beckton and Hampstead Heath were placed within the same category as they both contain evidence for *Ulmus* growing under stressed conditions (possibly suffering the effects of disease) due to the presence of *S. scolytus/multistriatus*, prior to its decline from the local environment, with, or followed by archaeological/palaeoecological evidence for human activity. At Hampstead Heath, *S*. *scolytus* predates the decline, although the precise temporal relationship is uncertain, whilst the decline itself occurs with and is post-dated by coleopteran and palynological evidence for human activity (Girling & Grieg, 1985; Girling, 1988; Parker *et al*., 2002).

After the decline of *Ulmus*, it is considered likely that *Taxus* colonised the dryland prior to expanding onto the peat surface (see 6.2) for the following reasons: (1) the very low concentrations of pollen recorded may suggest distal growth; (2) the present-day preference of *Taxus* is for dry and well drained soils, and (3) openings produced within the woodland by the reduction of *Ulmus* would have represented opportunities for the colonisation of *Taxus* which is recognised as a pioneer species (Tittensor, 1980). Support for this argument also comes from a number of Irish records that show *Taxus* pollen percentages increasing shortly after episodes of temporary land clearance associated with an *Ulmus* decline (e.g. O'Connell *et al*, 1988; Mitchell, 1990; O'Connell and Molloy, 2001; Huang, 2002; Molloy and O'Connell, 2004; Lamb and Thompson, 2005). If this is the case, it suggests that the initial colonisation of *Taxus* may have been influenced by human activity at Beckton.

At Beckton, the decline of dryland woodland is indicated by the synchronous decline of *Tilia* and *Quercus* shortly after *4160-3930* cal BP. The date of this decline is consistent with that recorded at other sites in the Lower Thames Valley (e.g. Thomas & Rackham, 1996; Wilkinson *et al*., 2000; Branch *et al*., 2012) and UK (Grant *et al*., 2011), occurring between *ca*. 5000 and 3000 cal BP. The decline is contemporaneous with evidence of human activity and a change in vegetation on the floodplain; initially *Alnus* dominated and was succeeded by a large expansion of herbs and aquatics indicative of wetter conditions. Waller & Grant (2012) argue that such abrupt, simultaneous changes in pollen stratigraphy (which are a common feature in pollen diagrams from the Lower Thames Valley) are not good indicators for a reduction in the abundance of *Tilia*. This is because, prior to vegetation change on the floodplain, any evidence for dryland clearance will be masked by the fen woodland, whilst difficulties in determining the environment of origin of many herbs (including Poaceae >40µm) hinders the identification of such events after the decline. Higher resolution pollen analysis through this part of the sequence may have enabled the causes of the *Tilia* decline to be considered further, but it is categorised here as an example of wetland processes and a reciprocal change in pollen representation (Grant *et al*., 2011).

6.2 The history of Taxus woodland in the Lower Thames Valley

The pollen-stratigraphic record indicates that the main expansion of *Taxus* woodland occurred on the peat surface at Beckton around *5220-4940* cal BP (-2.46m OD). Waterlogged wood identifications were not carried out on the main sequence, and macrofossil and insect remains are absent, most likely as a consequence of factors specific to *Taxus* including: (1) that there are no known insect taxa exclusively associated with *Taxus* (Lattin, 1998; Daniewski *et al*., 1998; Hageneder, 2007), and (2) that the late sexual maturity and dioecious nature of the tree may have reduced the number of seeds produced (Thomas & Polwart, 2003). However, the high pollen percentage values recorded at the site in tandem with the identification of trees in the peat at Beckton Nursery (Divers, 1995), A13 Woolwich Manor Way (Gifford and Partners, 2001), Beckton Alp (Truckle and Sabel, 1994), Beckton Tollgate (Tamblyn, 1994), East Beckton District Centre (Jarrett 1996) and East Ham Football Club (Scaife, 2001; Figure 1) indicate that *Taxus* formed a mixed wetland woodland community with *Alnus* for which there are few comparable palaeobotanical records across north-western Europe (e.g. Godwin, 1975; Beckett and Hibbert, 1979; Orme and Coles, 1989; Waller, 1994a; O'Connell and Molloy, 2001; Delahunty, 2002; Deforce and Bastiaens, 2007; Deforce *et al*., 2014; Waller and Early, 2015) and, significantly, for which there is no known modern analogue in the UK (Seel, 2001).

Taxus is now known to have been an important component of the *Alnus* dominated woodland on the peat surface of the Lower Thames Valley, spanning from at least the East India Docks (Pepys, 1665) in the west to Aveley Parish and Erith Forest in the east (Wilkinson and Murphy, 1995; Seel, 2001), according to multi-proxy palaeoenvironmental investigations. The importance of increasing knowledge and understanding of the timing and causes of this colonisation and decline have recently been highlighted by Branch *et al*. (2012) who propose five possible mechanisms: (1) variations in peat surface hydrology; (2) variations in the rate of relative sea level rise; (3) human activity; (4) climatic change, and (5) genetic variability.

At Beckton, the expansion of *Taxus* appears to occur during a period of drying peat surface conditions as indicated by rising organic matter values and a decrease in clay content (Figure 3). The expansion of *Taxus* at the site is analogous in date and nature to that of Hornchurch Marshes to the east (Branch *et al*., 2012), suggesting that regional factor(s) influenced this event either by driving changes in peat hydrology (e.g. relative sea level change) or upon *Taxus* directly (climatic change). However, it is of note that at Beckton the same drier hydrological conditions were present during the early stages of peat formation, when *Taxus* was not.

Taxus underwent a long-term decline at Beckton commencing from *4400-4230* cal BP, and continuing until shortly after *4160-3930* cal BP. The age of the platform structure (3980-3580 cal BP), and use of *Taxus* in its construction provides the first unequivocal evidence for its direct use by prehistoric people in the Lower Thames Valley. However, even with a lack of artefact remains of *Taxus* elsewhere, the impact of humans upon its decline should not be underestimated. Many palaeoenvironmental and archaeological records indicate that the wetland had a role in the rearing of domesticated animals. These include the presence of a cow's tooth at Beckton, domesticated animal bone at Atlas Wharf (Lakin, 1998), East Beckton District Centre (Jarrett, 1996) and Tesco's Swedish Wharf (Chew, 1994; Meddens, 1996), dung beetles at Beckton, St Paul's Academy (Hawkins, 2005), Bridge Road Rainham (Grattan 1991), and Bellot Street (Branch *et al.*, 2005b), and a causeway at Hays Storage, Dagenham. Ecological evidence demonstrates that these animals can become tolerant to the toxicity of *Taxus,* and that the tree is highly susceptible to, and disadvantaged by such browsing (Kelly, 1981; Mitchell, 1988; Hannon and Bradshaw, 1989; Mitchell, 1990; Tittensor, 1980; Mysterud and Østbye, 2004; Hageneder, 2007). The new results from Beckton indicate that the decline in *Taxus* may have been more closely linked to human activity, rather than changes in peat hydrology (linked to relative sea level) (see Branch *et al*., 2012).

6.3 The causes of trackway construction and abandonment

At Beckton, the late Neolithic/Early Bronze Age wooden platform and trackway were both constructed on the peat surface at approximately the same depth and date, as seeds from the peat immediately below both structures provide statistically the same age (4230-3890 and 4240-3920 cal BP respectively), although wood from the structures themselves indicate different ages: the maximum age range of wood from the platform is 3980-3580 cal BP, and the younger trackway is 3550-3180 cal BP. Despite the chronological difference, the palaeoenvironmental results, in combination with the stratigraphic position of the structures indicate that both the platform and trackway were built upon a peat surface that had been relatively dry since *5220-4940* cal BP. However, the peat overlying the trackway exhibits an entirely different hydrological signature, with evidence of increased inundation and retrogressive succession suggesting abandonment in response to wetter conditions. Further evidence for this change in environment was recorded in Trench 2, in which a substantial quantity of natural waterlogged wood was recorded at the same horizon. At Beckton there appears to have been a temporary reversal in this transition towards wetter conditions, with a return to peat formation and *Alnus* dominated wetland woodland, prior to eventual inundation, most likely between 2700 and 2000 cal BP. The transition towards wetter conditions and inundation was almost certainly driven by estuarine expansion during the late Holocene; the potential causes of which are the subject of much discussion elsewhere (e.g. Sidell, 2000; Shennan *et al*., 2006; Horton & Shennan, 2009; Baeteman *et al*., 2011; Bradley *et al*., 2011; Shennan *et al*., 2012).

The results from Beckton would therefore appear to suggest that the structures were built in response to cultural imperatives (for example: maintaining networks and providing access to specific resources; e.g. Meddens, 1996; Plunkett *et al*., 2013), and abandoned as consequence of environmental change (wetter conditions consequent of increased inundation). However, at other trackway sites where pollen analysis has been undertaken in the Lower Thames Valley, the evidence is less clear. Waller & Grant (2012) argue that at only Fort Street, Silvertown (Crockett et al., 2002) does the structure pre-date the change in pollen stratigraphy; at three other sites, the occurrences are reversed. In some studies, only the last (surviving) phase of construction has been radiocarbon dated, so the initial phase/s is unknown (Meddens, 1996; Waller & Grant, 2012). This only enhances an issue raised by Plunkett et al. (2013) based on the study of Irish peatland wooden structures, that on the basis of chronology alone, it can be difficult to positively identify causal relationships between environmental change and the use of peatland structures, and the mechanisms by which environmental change can influence their use are complex.

7.0 Conclusions

The new radiocarbon-dated palaeoenvironmental record from Beckton indicates that peat formation commenced at *7190-6620* cal BP and ceased sometime after 3460-3240 cal BP (estimated to be between 2700 and 2000 cal BP). During the period of peat formation, various important environmental changes were recorded in the following chronological order:

1. *Quercus* and *Tilia* dominated dryland woodland retreated from the site following submersion by peat and the growth of *Alnus* carr woodland.
2. *Ulmus* declined from the dryland woodland during the Neolithic between *ca*. *6150-6000* and *6030-5810*. Multiple causes are indicated with *Ulmus* growing under stressed conditions (possibly

suffering the effects of disease) prior to its decline from the local environment, followed by archaeological and palaeoecological evidence of human activity.

3. *Taxus* first appeared in the pollen record from *5740-5500*, potentially facilitated by openings created in the dryland woodland following temporary land clearance. However, from *5220-4940* cal BP, it underwent an expansion representing its migration onto the peat surface to form mixed carr woodland with *Alnus*. This colonisation appears to have been dependent upon a dry peat surface linked to a lower rate of relative sea level rise, or possibly favourable climatic conditions. *Taxus* declined from the wetland between *ca*. *4410-4220* and *4160-3930* cal BP, an event that was at least partially linked to its use in trackway construction during the Bronze Age.
4. Dryland woodland declined from *4160-3930* cal BP. The cause of the decline appears to be multi-causal with unequivocal contemporaneous evidence of activity on the wetland demonstrating interference with the vegetation succession, and an increase in *Alnus* pollen potentially suggesting the expansion of fen woodland onto areas of former dryland.
5. A platform and trackway appear to have been constructed contemporaneously on the peat surface (4230-3890 cal BP), although the wood used for construction was older in the platform (3980-3580 cal BP) than trackway structure (3550-3180 cal BP). The surface on which construction took place was dry suggesting that construction was not in response to a change in environmental conditions. However, abandonment clearly was, with a transition to wetter conditions eventually culminating in estuarine inundation later in the sequence.

The new investigations at Beckton have therefore provided a significant contribution to our understanding of the interactions between vegetation change and human activity in coastal wetlands. Ongoing research into the history of *Taxus*, *Ulmus* and *Tilia* will continue to improve knowledge and understanding of the timing, duration and causes of vegetation change across the area, as well as comparison with records from other parts of the UK and Europe. The study has also demonstrated the importance of undertaking high resolution multi-proxy palaeoenvironmental investigations proximal to wetland structures in order to elucidate whether construction has taken place in response to environmental change, and the potential for tephrochronological studies in the Lower Thames Valley.

The research has provided an important contribution to our understanding of the former distribution of *Taxus* in NW Europe. Its growth on coastal wetlands as part of mixed deciduous woodland has no known modern analogue in the UK, and clearly indicates that its distribution was far more widespread in the past. The study indicates that *Taxus* was able to grow in a wider range of habitats but is sensitive to the pressures of both environmental change and human activities. Thus, given current concerns over declining population levels, improved measures to conserve and manage *Taxus* woodland in the UK and many parts of Europe are urgently required to ensure its long-term sustainability.

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