Sweet chestnut (*Castanea sativa* Mill.) in Britain: a multi-proxy approach to determine its origins and cultural significance

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Abstract

Sweet chestnut *Castanea sativa* has been regarded as a Roman archaeophyte in Britain since the eighteenth-century AD. This research re-examined that thesis, collecting new evidence from genetic, dendrochronological, archaeological and historical analyses, using archived specimens, published reports, peer review and novel fieldwork. The main research and original fieldwork focused on England and Wales, within a British, Irish and continental European context. Sweet chestnut landscapes were identified as ancient inclosures, ancient coppice woods, historic boundaries, historic gardens, historic deer parks and designed parklands, historic formal avenues, and more recent high forest and production coppice. Genetic analysis determined that the oldest British sweet chestnut trees/stools derived from parts of France, Spain, Portugal, Italy and Romania. Some of these sources were refugia during the Last Glacial Maximum for sweet chestnut and other nut-bearing trees (oak, hazel, beech). Innovative clonal analysis verified individual tree and stool antiquity for the first time. Modern (post-AD 1800) trees and coppice in Britain were genetically differentiated from ancient trees and coppice; historic garden trees (from the 12th.–13th. centuries AD) originated in N Portugal and N Spain; and Welsh sites differentiated from Irish and English sites. Dendrochronological analysis discovered that sweet chestnut tree ring series replicate oak reference chronologies, so archaeological specimens of sweet chestnut wood can now be precisely dated. Several iconic ancient trees were dated accurately for the first time, the oldest from AD 1640. Archived specimens purported as 'Roman' 'sweet chestnut' were re-examined and rejected as neither. No pre-AD 650 sweet chestnut finds could be verified as grown in Britain. The earliest written record of sweet chestnut growing in Britain was from AD 1113. Other 12th. century AD records evinced nut growing and coppicing: these sites pre-date their written record, possibly by several centuries. Overall, no evidence was found for the 'Roman introduction' thesis. Further research should focus on finding sweet chestnut pollen and wood specimens amenable to dating.

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

Signed … ……Date ……03 May 2019…….

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This doctoral dissertation consists of a summary report, six academic journal papers (four published, one accepted for publication, and one submitted under review, as at 03 May 2019), and one published research technical report. Additional published, unpublished and supplementary information is also presented.

[Since initial submission of this thesis, the two unpublished papers have been published – their details are appended below – Appendix F and Appendix G].

List of published/accepted/submitted journal papers and research report (topical order):

Archaeological evidence.

Appendix A

Jarman, R., Hazell, Z., Campbell, G., Webb, J., Chambers, F.M. (2019). Sweet chestnut (*Castanea sativa* Mill.) in Britain: re-assessment of its status as a Roman archaeophyte. *Britannia*, 50, pp. 49-74. DOI: 10.1017/S0068113X19000011. https://www.cambridge.org/core/journals/britannia/article/sweet-chestnut-castanea-sativa-mill-in-britain-reassessment-of-its-status-as-a-roman-archaeophyte/73CB0575C77B991B3BE64D84F96EFE9C/share/7ed1e7b1ee0878edffdd27d6cdbe58e292144fa9

Appendix B

Jarman, R., Marshall, P., Allaby, R., Davies, J., Bronk Ramsey, C., Dunbar, E., Reimer, P., and Chambers, F.M. (2018). *Sweet chestnut nut fragments from Romano-British sites at Castle Street, Carlisle and Great Holts Farm, Boreham, Essex – a new assessment*. Research Report Series 78-2017, pp.1-25. Portsmouth: Historic England. ISSN 2059-4453 (Online). https://research.historicengland.org.uk/Report.aspx?i=15952&ru=%2fResults.aspx%3fp%3d1%26n%3d10%26a%3d5077%26ns%3d1.

Dendrochronology.

Appendix C

Jarman, R., Moir, A.K., Webb, J., Chambers, F.M. (2017). Sweet chestnut (*Castanea sativa* Mill.) in Britain: its dendrochronological potential. *Arboricultural Journal*, 39(2), pp.100-124. DOI:10.1080/03071375.2017.1339478 http://www.tandfonline.com/eprint/gAigMIAkvIFtcw3ADRVX/full

Appendix D

Jarman, R., Moir, A.K., Webb, J., Chambers, F.M., and Russell, K. (2018). Dendrochronological assessment of British veteran sweet chestnut (*Castanea sativa*) trees: successful cross-matching, and cross-dating with British and French oak (*Quercus*) chronologies. *Dendrochronologia*, 15, pp.10-21. DOI:10.1016/j.dendro.2018.07.001. https://www.sciencedirect.com/science/article/pii/S1125786518300821?via%3Dihub

Genetics evidence.

Appendix E

Mattioni, C., Martin M.A., Chiocchini, F., Cherubini, M., Gaudet, M., Pollegioni, P., Velichkov, I., Jarman, R., Chambers, F.M., Paule, L., Damian, V.L., Crainic, G.C., and Villani, F. (2017). Landscape genetics structure of European sweet chestnut (*Castanea sativa* Mill): indications for conservation priorities. *Tree Genetics and Genomes*, 13, pp.39-53. doi.org/10.1007/s11295-017-1123-2.

http://www.readcube.com/articles/10.1007/s11295-017-1123-2?author_access_token=CplDv7PaN-JN1N57sp_upve4RwlQNchNByi7wbcMAY40lo03QtDqFDr_vnQppUc1dHVF0hy8D7hJ1lxveCYz7KP9O9lS3oHhqiL50qumnK_8vJJ7-5_smJGhy9W9LlmnqwpmTMBuVv17GPM8QzwQaA%3D%3D

Appendix F

Jarman, R., Mattioni, C., Russell, K., Chambers, F.M., Bartlett, D., Martin, M.A., Cherubini, M., Villani, F. and Webb, J. (2019). DNA analysis of *Castanea sativa* (sweet chestnut) in Britain and Ireland: elucidating European origins and genepool diversity. *PLoS ONE*, 14(9), pp. 1-26. DOI:10.1371/journal.pone.0222936. Open access https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0222936.

Historical ecology.

Appendix G

Jarman, R., Chambers, F.M., Webb, J. (2019). Landscapes of sweet chestnut (*Castanea sativa*) in Britain – their ancient origins. *Landscape History*, 40(2), pp.5-40. doi:10.1080/01433768.2020.1676040 https://www.tandfonline.com/doi/10.1080/01433768.2020.1676040.

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Contents

1. Introduction

Conventional research into the post-Glacial vegetation history of Britain, as reconstructed from pollen analysis and macroplant remains, has allowed the identification of tree species that are assumed 'indigenous' (i.e., taxa that spread to Britain apparently without human intervention), and those that are assumed to be 'introduced', either deliberately or accidentally by human agency (Godwin, 1975; Huntley and Birks, 1983). Palaeoecological research has identified the chronology of post-Glacial spread of the major woodland 'natives', such as birch, pine, hazel, oak, elm, lime, alder, ash; and those that apparently assumed importance in British (mainly English) woodlands later in the Holocene, such as hornbeam and beech. Traditionally, these are accorded a different status from those species that are *known* introductions (such as horse chestnut *Aesculus hippocastanum*), and from other species that are *assumed* introductions (such as sweet chestnut *Castanea sativa*) (Preston et al., 2002 and 2004). The case of sweet chestnut is particularly interesting in light of research elsewhere that has resulted in a change to its status in parts of continental Europe.

Sweet chestnut is now deemed indigenous in several parts of continental Europe, although previously considered to have been introduced by Greeks and Romans from Turkey and the Caucasus: it is understood to have survived during the Last Glacial Maximum (LGM) in disjunct refugia in northern Iberia, southern France and Italy, as well as in Greece and Turkey (Huntley and Birks, 1983; Krebs et al., 2004 and 2019; Mattioni et al., 2013 and 2017; Roces-Díaz et al., 2018). It is conventionally thought that sweet chestnut did not spread naturally to Britain after the LGM, unlike other plants and animals that are regarded as 'indigenous' species in Britain. Sweet chestnut is regarded as an 'introduced' species, purported to have been brought to Britain by the Romans sometime before the 5th. century AD (Godwin, 1975; Rackham, 1980 et seq.; Preston et al., 2004; Van der Veen et al., 2008; Witcher, 2013; Stace and Crawley, 2015).

The ‘Roman introduction to Britain’ thesis merits re-examination, as the original work on which present authors (*inter alia, supra*) base their presumption dates from Godwin (1956 and 1975): none of them re-assessed Godwin’s cited sweet chestnut examples, nor provided new evidence for Roman period growth of sweet chestnut in Britain. Questioning the origins of sweet chestnut in Europe has an ancient genesis: even in the Roman period, there were discussions by *inter alia* Virgil, Plato, Columella and Pliny on sweet chestnut’s names, its origins, its propagation and cultivation. They described its uses as wood (such as for vineyard stakes) and as food (such as how to graft varieties to improve eating nuts); and speculated on the translocation of the tree by Greeks and Romans across Europe (Conedera et al., 2004; Squatriti, 2013). In Britain, sweet chestnut has long-attracted inquiry: John Gerard reflected on its use and origins in his *Herball* (1597); and John Evelyn in his *Sylva* (1664 and 1706) postulated that species like sweet chestnut, walnut and sycamore were not native to Britain. Referencing Pliny’s recommendations for sweet chestnut varieties and planting techniques, Evelyn proposed that sweet chestnut was introduced to Britain by Caesar: ‘Pliny, Lib. xv. Cap. xxiii… concludes them to be excellent Food; and doubtless Caesar thought so, when he transported them from Sardis first into Italy, whence they were propagated into France, and thence among us’ (1706, p.55). In 1769–71 a debate took place in the Royal Society’s journal on whether sweet chestnut was indigenous in Britain, with presentation of detailed evidence and suppositions (Barrington, 1769; Ducarel, 1771; Thorpe, 1771; Hasted, 1771). The conclusion was that sweet chestnut seemed to have been introduced, probably in Roman times, and this notion has persisted to the present, with modern accounts of the British Flora reciting the thesis (such as Preston et al., 2002 and 2004; Stace and Crawley, 2015). Godwin (1956 and 1975) had cited published archaeological reports of sweet chestnut (wood and charcoal) found in dated contexts up to the medieval period, and determined that sweet chestnut first appeared in Britain in the Roman period. Godwin did not report any finds of pollen, nor of nut remains; he also warned against assuming that sweet chestnut was grown in Britain by the Romans.

Whilst considering sweet chestnut as a Roman introduction and archaeophyte, workers ‘post-Godwin’ have also given it the status of an ‘honorary native’, first by Rackham (1980), then Peterken (1981). From widespread and detailed surveys of woodlands

across Britain, they judged sweet chestnut to behave as a well-established member of semi-natural woodland and wood-pasture communities, which were of considerable antiquity: they considered sweet chestnut to form a habitat in its own right within some ancient woodland types. Rackham (1980 and 2003) described three specific woodland types that accommodated sweet chestnut: 'Chestnut-Lime', 'Chestnut-Oak' and 'Chestnut-Hornbeam'. Peterken classified sweet chestnut into 'chestnut forms' of five native woodland types, whilst describing it as a 'doubtfully native' but 'very long-established' species that 'arguably… should be recognised as a separate stand group' (1981, p. 177). The National Vegetation Classification in Britain (Hall et al., 2004) incorporated sweet chestnut as a typical associate into three of its native woodland types. Some of Britain's most ancient and important trees for cultural and ecological heritage are sweet chestnuts, inhabiting historic parklands and pasture-woodlands (ATI, 2018). Nevertheless, some woodland management plans have used sweet chestnut's 'alien' status to justify its removal to benefit 'native woodland' habitats (Buckley and Howell, 2004); Lim et al. (2014) described it as an introduced and invasive species with 'high invasive impact'.

There is evidently a confused attitude towards the species, regarding it as non-indigenous to Britain, but also highly valued as an ecological and cultural resource, as if it were indigenous. Clarifying the underlying reasons for this confusion becomes critical when threats to the species arise, such as the present threat from chestnut blight *Cryphonectria parasitica.* Sweet chestnut populations across mainland Europe have been devastated by this disease during the twentieth century, since it was introduced from eastern Asia. Britain was free of it until 2011, when the first outbreak was reported in Warwickshire, with subsequent outbreaks in Devon and in SE England up to 2018. The response to chestnut blight can be quite different if sweet chestnut is regarded as an 'alien', 'problematic' species rather than as an important component of semi-natural woodland and historic cultural landscapes.

The concept of 'naturalness' underlies this dilemma and the present research viz. whether a species is indigenous or non-indigenous, and whether its habitat is natural or semi-natural or artificial. This concept is especially relevant for nature conservation in

regions like the British Isles, where the last glacial maximum (LGM) left a very impoverished flora and fauna, subsequently restocked over millennia by plants and animals spreading from refugia across continental Europe (Preston et al., 2002). Britain's 'natural' complement of resident breeding terrestrial and freshwater species was 'fixed' at *c.* 7000 years BP (Godwin, 1975; Gibbard, 2007), when land connections with continental Europe became permanently flooded. The post-LGM recolonisation was essentially a 'natural' process up to that time, but humans evidently assisted some species, either through deliberately translocating plants or animals to live with and live off, or accidentally bringing them (Preston et al., 2004). This 'human assistance' strengthened as trade and migration between continental Europe and Britain developed, during the Neolithic and especially during the Roman occupation, when some exotic plants and animals were first introduced and grown in Britain – described as 'archaeophytes', as distinct from 'neophytes' (species introduced post-AD 1500) (Preston et al., 2004; Van der Veen et al., 2008; Witcher, 2013). Sweet chestnut had functional value to people, not just as a nutritious food source but for its production of fibre, livestock forage and timber, grown in a wide range of environments and socio-economic contexts. It has been identified as part of human civilisation in Europe (from Iberia in the west through the Mediterranean region to Turkey in the east and the Balkans in the north) since the Bronze Age (Conedera et al., 2004; Squatriti, 2013). There is evidence for sweet chestnut occurrence and usage in the archaeological and historic records, from prehistory through to contemporary history, as buried plant material and artefacts and in archival forms such as maps and charters, place names and language.

In contemporary society, plants and animals are considered for their 'conservation' values as well as for their 'functional' values – they can be deemed important enough 'in their own right' that they 'merit' protection or stewardship (Mabey, 1997; Goodenough and Hart, 2017). Parameters have been developed (The Nature Conservation Review [NCR] – Ratcliffe, 1977) to describe and define the 'importance' of a particular species of plant or animal, to ascertain on what grounds it ought to be protected, such as on account of its key function in an ecosystem, its rarity, or its vulnerability. 'Naturalness' was one of these parameters, defined by the NCR as

whether a species belongs to a particular geographical location because it arrived there 'naturally', or does not belong there because it was introduced by human intervention – direct or indirect. Naturalness is a problematic concept in practice, as it can be difficult to determine the point at which human influence on the movement (dispersal or migration) of plants or animals makes it 'unnatural' (through deliberate or accidental translocation); furthermore, the timescale over which change can occur can become 'enforced' rather than 'natural'. The development of genetics analysis now illustrates how some genotypes within a species can be spread anthropogenically, selectively, even though the overall spread of the species may be considered 'natural'. For example, in direct comparison with sweet chestnut, the oak species *Quercus robur* and *Q. petraea* have been presumed indigenous to Britain, owing to pollen and archaeological evidence indicating their presence since soon after the LGM, presumed to pre-date human intervention (Godwin, 1975; Huntley and Birks, 1983; Birks, 1989; Stace, 2019). However, studies of oak using genetic analysis (Petit et al., 2002; Cottrell et al., 2002; Lowe et al., 2005; Kremer, 2015) have indicated that different genotypes/haplotypes of oak arrived in Britain at different times from different genepools/LGM refugia in continental Europe; and they appear to be mixed in a way that evinces anthropogenic translocation, such that oak genepools in Britain could now be considered an admixture of indigenous and introduced genotypes.

The approach taken for this study of sweet chestnut is determined by the nature of the species: it can grow as an isolated plant within a variety of environments, such as an open-grown tree within wood-pasture, parkland or farmed land; or as a community of plants, such as a wood, or an orchard. As an angiosperm belonging to the Fagaceae, sweet chestnut possesses several key characteristics (Tutin et al., 1993; Stace, 2019), exhibited in living specimens and dead plant material: it has male and female flowering parts; produces pollen that is wind and insect dispersed; reproduces sexually by fruiting (although called 'nuts', the sweet chestnut nut is not a true nut); regenerates vegetatively (asexually) from dormant buds by sprouting and from rooted layers; has an extensive root system; develops sapwood and heartwood, with distinctive wood anatomy, only similar to, but usually distinguishable from, *Quercus robur* and *Q. petraea* (Schweingruber, 1990; Hather, 2000). Sweet chestnut has the potential to be

very long-lived – as living material (both above ground and below ground) and as dead material (pollen, wood and nuts, preserved in various states and environments) (Gale and Cutler, 2000). It is amenable to DNA analysis of individuals and communities of sweet chestnut plants, including living material and, potentially, dead material, which can describe genetic relationships between individual sweet chestnut plants in the same location; and to associate sweet chestnut plants between one location and another (Buck et al., 2003; Mattioni et al., 2013). One of the oldest living trees in Europe is a sweet chestnut growing on the slopes of Mount Etna ('*Il Castagno dei cento cavalli* '), purported to be at least 2000 years, possibly even 4000 years old (Pereira-Lorenzo et al., 2019); and one of the oldest living trees in Britain is a sweet chestnut – at Tortworth, Glos., purported to be over 1000 years old *infra*. The technical challenges for this study are to be able to determine the age and ancestry of a living sweet chestnut plant; and to verify from dead plant material and written reports where, and when, sweet chestnut has grown in specifiable places in the past.

The genesis of this research evolved over some thirty years of personal experience working on conservation of ancient trees and woodlands, where sweet chestnut was sometimes found as a significant tree or woodland community, apparently not compatible with its conventional 'non-indigenous' status. Working with Oliver Rackham and Francis Rose from 1971 onwards gave historical ecological and biogeographical insights into British ancient semi-natural woodlands and wood pastures and also into continental European plant communities, where sweet chestnut was deemed indigenous and which appeared similar to its British habitats. Survey work with Oliver Rackham in Welshbury Wood and Chestnuts Wood, in the Forest of Dean, identified the possibility of sweet chestnut being long-established in those sites (Rackham and Jarman, 1995; Rackham Archive): the present research study was 'mentally' initiated at that time. Rackham continued to provide personal insights into the 'sweet chestnut as a Roman archaeophyte' question up to his death in 2015.

1.1. **Aim**

This research study examines the history and ecology of sweet chestnut in Britain – to investigate when it first spread to Britain, and whence, after the Last Glacial Maximum in Europe.

The overall aim of the research is to use multi-proxy methods to ascertain the ecological and historical status of sweet chestnut growing in Britain, in semi-natural woodland and as ancient trees, and specifically to test the conventional view that it is a Roman archaeophyte.

The research study was designed to answer the following questions:

- when is the earliest verified date for sweet chestnut growing in Britain?
- whence do the longest-established British sweet chestnut trees derive?
- does new evidence for antiquity and origins alter the ecological and cultural significance of sweet chestnut in Britain?

The research was published through a series of academic journal papers: introductions to the papers (Appendices A–G) present more detailed rationales and contexts for specific aspects of the research programme.

2. **Methods**

The study set out to answer the research questions by reviewing existing archaeological records of sweet chestnut finds in Britain, up to the medieval period; and by investigating key sites identified from literature review for potential for new pollen, wood or charcoal studies. The initial studies resulted in the research programme being directed into a broader and deeper multi-proxy study, focusing on England and Wales, but covering Britain and Ireland for additional information. Table 1 outlines the overall approach.

Four key themes were pursued in the multi-proxy framework:

- examination of archaeological records;
- DNA analysis of living and dead sweet chestnut specimens;
- dendrochronological analysis of living and dead sweet chestnut wood;
- historical ecological analysis of ancient woodlands with sweet chestnut trees and stools, and landscapes with ancient sweet chestnut trees.

Details of the methods used for each of the four thematic studies are provided in the respective paper(s) (Appendices A–G). The general methods used are outlined *infra*.

Table 1. Research programme

Research Question	**Selected Methods**	**Rationale**
When is the earliest verified date for sweet chestnut growing in Britain?	Archaeological and palaeoenvironmental evidence; radio-carbon dating of specimens; dendrochronology of archaeological and ancient tree wood specimens; DNA testing of living trees; historical records and onomastic analyses.	Pollen can indicate local historical presence of sweet chestnut, and it can be dated (directly and from its context). Charcoal and wood sections can be identified as sweet chestnut and can be directly dated (radiocarbon dating; and dendrochronologically, when >50 growth rings are measurable). Genetic live testing can confirm that neighbouring stems are from the same parent root/stool and so indicate size/antiquity of individual plants (clones). Historical records of specific trees and places can be

		directly dated, subject to credibility test; place name derivations can be interpreted and dated using onomastics.
Whence do the longest-established British sweet chestnut trees derive?	Genetic analysis of sweet chestnut leaf/bud samples using selected microsatellite markers; aDNA testing of dead plant remains; dendroprovenancing; historical records.	Genetic analysis can determine genotypic similarities within and between populations, revealing relatedness and provenance. The leaf/bud contains the original parent DNA unchanged (subject to somatic minor mutation) throughout the whole of the plant's life; aDNA analysis of archaeological plant remains can determine their source. Dendroprovenancing can indicate source regions for wood samples. Historical records can describe sources of plant material.
Does new evidence for antiquity and origins alter the ecological and cultural significance of sweet chestnut in Britain?	Historical ecology analytical framework. Indigenous or non-indigenous; archaeophyte or neophyte; invasive problem or benign asset.	Synergy and compatibility with 'native' woodland types. Contribution to historic landscapes, their *genius loci*. Crucial host for specific plant or animal communities or species. Invasive or non-invasive.

In order to provide definitive identifications and dates, the research programme was designed to develop new and improved methods for differentiating sweet chestnut wood/charcoal from oak, especially in small samples of roundwood; and for dating and provenancing sweet chestnut wood, using dendrochronological and dendroprovenancing techniques. To complement these techniques genetics analysis was introduced, to provide a method for provenancing specimens from living trees and also from dead plant remains; and to develop methods for clonal identification, so that individual 'plants' of sweet chestnut trees and coppice stools could be delimited, and their antiquity determined. Ancient DNA (aDNA) analysis was attempted, to provenance some of the archaeological specimens.

2.1 Archaeological archives

The objective of the archaeological archive review was to find and re-examine all published and noted records for purported sweet chestnut specimens recovered from archaeological and palaeoenvironmental excavations in Britain, for all periods up to and including the medieval. Literature search and peer review listed all records for sweet chestnut wood, charcoal, nuts and pollen found in Britain, selected for contexts dated pre-AD 1350. The lists of reported finds were presented to various conferences, internet forums and key workers, generating additional reports and feedback. Collaboration with Historic England (HE) staff was established to review all the reported finds and to locate archived specimens in museums and private archives/stores for re-examination (this complemented a research programme within HE to review the role and curation of archives). All published and reported finds were tracked back to museum locations and to their original authors, recorders, identifiers and archivists, who were contacted and interviewed wherever possible.

Where archived specimens were located by the searches, negotiations were necessary to obtain consents from individuals or institutions to access, examine, measure, photograph, and take extracts for specialist examination (aDNA, radiocarbon dating, wood anatomy) by established laboratories and experts. Co-operation with HE experts in the re-assessment of specimens was invaluable.

2.2 Historical archives

Searches were made in a wide range of depositories, using ‘sweet chestnut’ keywords in a variety of languages, looking for the earliest knowledge of sweet chestnut in a British context. Sources included academic journals, Public Records, medieval ecclesiastical and monastic charters, Herbals and Floras, gardening and forestry treatises, books and pamphlets.

The information provided insights into historical familiarity with sweet chestnut and its various uses; and sometimes indicated specific locations for ‘remarkable’ sweet chestnut woods and trees, producing a list of previously noted sites, for visiting and re-assessment. Some records provided dated drawings, paintings and maps for particular trees.

2.3 Selection of sites for fieldwork

A list of sites for field survey was drawn up from the historical records and from contemporary sources: the Ancient Tree Inventory (ATI), National Trust (NT), Woodland Trust (WT), Forestry Commission (FC), Inventory of ancient semi-natural woodlands (ASNW), Register of Historic Parks and Gardens, Future Trees Trust (FTT) Sweet Chestnut Working Group; and from peer review (including recommendations from George Peterken, Oliver Rackham and other workers in tree and woodland conservation). The overall list was refined into a working list for field visits, selected to be representative of geographical distribution, site types and tree antiquities, across England and Wales. Sites in Scotland and Ireland were covered by sampling previously carried out for the FTT Sweet Chestnut collection. A GIS database was established to contain and manage all site-related information. Field survey followed a standard checklist of key parameters, *infra*.

2.4 Site visits

Site visits were undertaken through 2013–2018, principally in summer (May to September inclusive), to collect leaf material from selected trees and coppice stools for genetic analysis. In every case, landowners (where they could be identified) were asked for consent for access and for sampling. Some sites merited several visits over several years for various aspects of survey (genetics, dendrochronology, tree and site recording).

Selected sweet chestnut sites were visited and initially assessed according to the following categories: mature high forest, new plantation, modern coppice, ancient coppice, designed landscape planting, individual or small group ancient trees or pollards, hedgerow or bank stool/layer. Representative trees from each of these sites were selected for detailed survey. Wherever possible, more than one tree was sampled within a site, selected to represent that site's specific characteristics: within an ancient woodland coppice, several stools were sampled from different parts of the wood; within an historic parkland, several veteran trees were sampled from specific features such as an avenue or a grove and some individual trees were multi-sampled. For some historic parkland/garden sites, only a single ancient sweet chestnut tree existed, so this was sampled from several discrete parts of the tree to test its genetic integrity.

Each selected tree or stool was recorded systematically in the field for the following parameters: GPS location (Garmin eTrex Vista HCx) WGS84 Latitude/Longitude; British or Irish Grid Reference; site altitude; site slope; geology and soil; stem girth (dominant stem of multi-stemmed plants) measured at 1.3 m –1.5 m above the root collar (minimising stem irregularities); basal girth (measured at the root collar) of veteran standard and pollarded trees and of discrete coppice stools; associated plant communities; site historical/archaeological features; tree form and evident management history; supported by anecdotal information from owner or contacts re nut quality, present or previous management, site history. Each tree/stool was photographed systematically from North, West, South and East compass points to record location and specific features, with site context and tree structures.

Site visits for detailed fieldwork were only made in England and Wales, owing to resource constraints. Some sites with ancient sweet chestnut trees and coppice woodland were visited for comparative purposes in E Scotland, N Ireland and Eire; and in N Portugal, NW Spain (Galicia; Asturias), France (Puy de Dome; Ardeche), S Switzerland (Ticino) and N Italy (Tuscany – Garfagnana and Amiata), to understand continental European 'chestnut civilisations', including orchard cultivation, in most cases in company with expert researchers.

2.5 DNA analysis

Details of methods used in the genetics analysis are presented in Appendix F.
Plant material was collected in the form of leaves, freshly-picked from the tree and immediately preserved on site in sealed 10mm diameter Eppendorf tubes in a coolbox; and then kept deep frozen (-18°C) until accessed in the laboratory for DNA extraction. In the field, leaves were selected for sampling that were clean, vigorous, exposed to full light, dry and free of rust/mildew/insect damage/bird excreta. Each collected leaf was folded twice to make four lamina layers and then clipped by closure of the lid of the Eppendorf tube over the folded leaf, so as to cut four 9mm diameter discs from each leaf directly into the tube without handling. A replicate sample was clipped from the same leaf in the same manner, as a spare for subsequent analysis. Primary tubes were numbered '001' *et seq*. and replicate tubes were numbered '001R' *et seq*.

Leaves were collected from parts of the tree that were evidently the main growth of the plant – so avoiding subsidiary shoots, or basal grown shoots that might be from separate seed regeneration or, in the case of grafted trees, avoiding repeat sampling of rootstock growth. Canopy leaves were collected wherever possible, by tree climbing or by pulling down low-hanging branches, or by using a catapult to knock down upper canopy twigs and leaves. In most situations, apart from dense coppice and high forest, sweet chestnut trees and coppice had low-hanging boughs that could be readily accessed. Some veteran trees, and coppice stools in ancient woodlands, were deliberately selected for clonal assessment, to test the geospatial characteristics of single plants. For these samples, leaves were selected from discrete parts of a tree or stool or root plate or adjacent stems, to test whether they might derive from separate genetic origins. These sampling locations included: boughs growing at a clear intervention in the tree trunk (as from a pollard crown or ring of branches at a common height) that might indicate a graft; collapsed boughs that had layered away from the 'parent' tree and grown into a separate tree; and stems growing up from large-girthed, circular, hollowed-out stumps, or from linear root systems on ancient banks. In coppice woods, leaves were sampled from several stems growing from large-girthed or broad diameter stools, to test whether the stool was a single plant or several individual plants. Groups of contiguous stools that appeared to be clonal (physically connected, or demonstrating synchronous leaf flushing in May/June or leaf senescence in September/October) were sampled likewise for clonal characteristics.

Nuts, flowers or other plant material were not used for the overall DNA study; neither were attempts made to undertake morphometric analysis of leaves, flowers or nuts to determine type varieties of sweet chestnut. Several samples that needed to be cross-checked for the clonal assessments were re-collected in March 2018, necessitating bud sampling, from the same tree components that had been leaf sampled in 2016.

RJ collected all the plant material for DNA analysis and dispatched it (together with the FTT samples) to IRET laboratory in Porano (Italy) for genotyping; and undertook statistical analyses of the consequent allelic data and their reporting.

2.6 Dendrochronological analysis

Site visits identified candidate trees from which sawn sections or cores might be recovered from fallen deadwood or standing or fallen living wood. Consents for tree work were obtained from owners, and specialist chainsaw operators were contracted to work on the largest tree sections (those requiring a four feet long chainsaw bar): RJ cut the smaller sections and prepared all the sections for micro-analysis by Dr Andy Moir. RJ undertook the statistical analyses of the growth ring measurements and compiled the reports.

2.7 Author Contribution

Throughout the research study, RJ led and co-ordinated all the key aspects across the four themes of the multi-proxy research programme. This necessitated project management skills, and technical expertise and experience to undertake sampling, identification, laboratory analyses and statistical tests. The study required working *inter alia* as a field botanist, historical ecologist, archaeologist, anthracologist, palynologist, geneticist, dendrochronologist and medieval documents examiner. Some of these technical skills (underlined, *supra*) were developed *de novo* during the research programme.

For each published paper, the lead author (indicated by the symbol *) and co-author contributions are described according to the 'CRediT Taxonomy' (CRTT) protocol, as follows:

Contributor Role	**Role Definition**
Conceptualization	Ideas; formulation or evolution of research goals and aims.
Data Curation	Management activities for data collection and storage for initial use and later reuse.
Formal Analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data.
Funding Acquisition	Acquisition of the financial support for the project.
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection.

Contributor Role	Role Definition
Methodology	Development or design of methodology; creation of models
Project Administration	Management and coordination responsibility for the research activity planning and execution.
Resources	Provision of study materials, reagents, laboratory samples, instrumentation, computing or other analytical tools.
Supervision	Oversight and leadership responsibility for the research activity planning and execution.
Validation	Verification of the overall replication/reproducibility of results/experiments and other research outputs.
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/data presentation.
Writing – Original Draft Preparation	Creation and/or presentation of the published work, specifically writing the initial draft.
Writing – Review & Editing	Preparation, creation and/or presentation of the published work – including pre- or post-publication stages.

3. Results

3.1 The research outputs

The data and analyses are organized according to the four main themes of the research programme: archaeological records; dendrochronology; genetics; and historical ecology. Each theme has been presented and peer-reviewed in one or more published/accepted/submitted papers/reports per theme: refer to the original papers for the detailed results and analyses (Appendices A–G).

A brief overview is provided for each theme, followed by additional material supporting that theme's research, presented in the main text and also in Appendices H–O.

3.2 Archaeological records

Forty-nine British records of sweet chestnut specimens were found for the period up to AD 1350. It was decided to draw a cut-off point of AD 650 and to analyse in depth only records pre-dating this, considering them as having the greatest potential to represent sweet chestnut grown in Britain before, during or immediately after the Roman period. Thirty-four records from pre-AD 650 were examined in detail and some specimens were recovered from archives for evaluation: the published results are presented in Appendix A.

There were no verified records of sweet chestnut pollen in Britain since the LGM for any period pre-AD 650: a single grain contextually dated to AD 650 was found at Uckington, Glos. (Pearson et al., 2015); and a reported find at Pins Knoll, Dorset (Sidaway, 1964) could not be dated, as explained in Appendix A. A potential source of pollen information for the Roman period covering SE Wales – the 'Manifestations of Empire Project, Palaeoenvironmental Analysis and the End of Roman Britain' – did not report before the end of the present research study, which is unfortunate, as the study area covered the Catsash-Langstone written record site *infra* and lies within the hinterland of Forest of Dean sites: any data for *Castanea sativa* pollen will be shared (Andy Seaman, 2019, personal communication).

Sweet chestnut wood and charcoal identification were found to be problematic: participation in a wood anatomy training workshop taught by Fritz Schweingruber revealed that distinguishing sweet chestnut from oak, especially in small samples and in branchwood sections, was often impossible, as oak *Q. robur/Q. petraea* can display the same uniseriate medullary rays as the typical 'diagnostic' (Schweingruber, 1990; Hather, 2000) uniseriate rays of sweet chestnut *C. sativa*. This problem was already reported for some of the charcoal and wood finds extracted by this research, such as for Chesters Villa (Figueiral, 1992) and Silchester (Straker, 2000), where the original recorders were unable to make a definitive differentiation between oak and sweet chestnut. It was hoped that re-examination of those specimens might enable a more-definitive diagnosis, but they could not be found in the nominated archives.

Two records of sweet chestnut nuts were found, and their archived specimens were located and recovered for assessment and radiocarbon dating (HE funded the radiocarbon analyses, and the respective museum authorities permitted the partial destruction of two specimens). The published results are presented in Appendix B.

3.2.1. Published results (Appendices A and B)

Appendix A: *Britannia* (2019), 50, pp.49-74	
Contributor Role	**Contributors: RJ*, ZH, GC, FMC, JW**
Conceptualization	RJ
Data Curation	RJ, ZH
Formal Analysis	RJ, ZH, GC
Funding Acquisition	RJ, ZH
Investigation	RJ, ZH
Methodology	RJ, ZH
Project Administration	RJ
Resources	RJ, ZH
Supervision	RJ, ZH, GC, FMC, JW
Validation	ZH, GC, FMC
Visualization	RJ, ZH
Writing – Original Draft Preparation	RJ, ZH

Appendix A: *Britannia* (2019), 50, pp.49-74	
Contributor Role	**Contributors: RJ*, ZH, GC, FMC, JW**
Writing – Review & Editing	RJ, ZH, GMC, FMC

Appendix B: *Historic England Research Report* Series 78-2017	
Contributor Role	**Contributors: RJ*, PM, RA, JD, CBR, ED, PR, FMC**
Conceptualization	RJ, PM
Data Curation	RJ, PM, JD
Formal Analysis	PM, RA, JD, CBR, ED, PR
Funding Acquisition	RJ, PM
Investigation	RJ
Methodology	RJ, PM
Project Administration	RJ, PM
Resources	RJ, PM
Supervision	PM, RA, FMC
Validation	PM, RA, CBR, ED, PR
Visualization	RJ, JD
Writing – Original Draft Preparation	RJ
Writing – Review & Editing	RJ, PM, FMC

3.2.2. Unpublished results

The archival records for sweet chestnut included fifteen that dated from AD 650 to AD 1350: these were not used for the *Britannia* paper (which adopted a cut-off date of AD 650), but they are presented here (Appendix O) as they describe the location and chronology for early medieval sites for sweet chestnut, which may be of interest in determining post-Roman introductions. These sites are all located in S & E England (Norfolk, E & W Sussex, Surrey, Middlesex, Hertfordshire, Isle of Wight). The original reports have all been scrutinised, but none of the reported specimens (except Alverstone, IoW) has been checked or verified in this study.

One particular aspect of the results from the archaeological archives review that was not published relates to evidence for sweet chestnut found in shipwreck excavations. It was

surprising that there were no reports of sweet chestnut remains (such as nuts or timbers) from any Mediterranean or Atlantic shipwreck excavations until the medieval period and thereafter: it was anticipated that if sweet chestnut nuts were transported as widely as purported, then shipwrecks would reveal some evidence, even from the various Roman wrecks excavated in the Mediterranean. However, there is no evidence from any archaeological reports for the European region for whether, and if so how, sweet chestnut nuts were transported, such as loose, or in sacks or containers such as amphora, fresh, preserved (smoked) or prepared (peeled). Reported finds from three European and two central American shipwrecks, dating from the 15th. –17th. centuries AD, revealed that sweet chestnut was transported as nuts (for food, apparently for the crew; and as cargo), and as twigs (possibly for packaging other cargo); it also constituted a very minor component of shipbuilding timbers. These reports are presented in Appendix N.

3.3. **Dendrochronology**

The early site visits revealed in some historic sites a significant resource of large-dimension deadwood from ancient trees, which could serve two crucial research purposes: first, to establish a database of dendrochronologically referenced sweet chestnut growth-ring series, to enable accurate dating of sweet chestnut wood specimens found in archaeological excavations and historic buildings; second, to date specific ancient sweet chestnut trees and thereby their historic settings. An initial trial (reported in Appendix C) of coring several living trees and sawing sections from a long-dead ancient tree was successful, in that it revealed that even a dead sweet chestnut trunk lying on the ground for thirty-five years could yield unrotted sections suitable for dendrochronological analysis, including sapwood and pith wood. A highly significant discovery was that comparison of the extracted sweet chestnut growth-ring series with reference dendrochronologies for oak series (*Quercus robur* and *Q. petraea*) from England and N France yielded a perfect match. This result meant that standard oak growth-ring reference chronologies could be used to date sweet chestnut sections, even if they were incomplete series without pith or sapwood, as typically found in archaeological contexts. Sampling to recover sawn sections for dendrochronological analysis was extended to sweet chestnut sites across southern England and Wales: the results are presented in Appendix D.

3.3.1. Published results (Appendices C and D)

Appendix C: *Arboricultural Journal* (2017), 39(2), pp.100-124	
Contributor Role	**Contributors: RJ*, AKM, JW, FMC**
Conceptualization	RJ
Data Curation	RJ, AKM
Formal Analysis	RJ, AKM
Funding Acquisition	RJ, FMC
Investigation	RJ, AKM
Methodology	RJ, AKM
Project Administration	RJ
Resources	RJ, AKM
Supervision	AKM, FMC, JW
Validation	AKM
Visualization	RJ
Writing – Original Draft Preparation	RJ
Writing – Review & Editing	RJ, AKM, FMC

Appendix D: *Dendrochronologia* (2018), 51, pp.10-21	
Contributor Role	**Contributors: RJ*, AKM, JW, FMC, KR**
Conceptualization	RJ
Data Curation	RJ, AKM
Formal Analysis	RJ, AKM
Funding Acquisition	RJ
Investigation	RJ, AKM
Methodology	RJ, AKM
Project Administration	RJ
Resources	RJ, AKM
Supervision	AKM, FMC, JW
Validation	AKM
Visualization	RJ
Writing – Original Draft Preparation	RJ
Writing – Review & Editing	RJ, AKM, FMC, KR

3.4. **Genetics**

The collection of samples for DNA analysis in Britain commenced in 2013/14, from sites in Gloucestershire and Herefordshire. These samples were analysed by Claudia Mattioni at IRET in 2015/16 and were published in a paper presenting an assessment of the landscape genetics of sweet chestnut across western Eurasia (Appendix E). RJ and FMC were co-authors for this paper and, additional to the provision of 'UK' samples, RJ contributed additional aspects and references to the paper, comparing sweet chestnut with the post-LGM spread of indigenous tree and shrub species across western Europe into Britain and Ireland. It was instructive to have a preliminary evaluation of English sweet chestnut material in this European project, justifying further extensive sampling and analysis of historic trees and ancient woodlands was progressed, leading to the results presented in the *PLoS One* paper (Appendix F). The study area for the present research into sweet chestnut genetics was expanded to cover some sites in Scotland and Ireland, through collaboration with the FTT and inclusion of their British and Irish sweet chestnut collection for comparative DNA analysis. There were insufficient time and resources for RJ to systematically survey ancient and historic trees and coppices in Scotland, N Ireland and Eire, although enquiries and literature searches revealed many such sites in those countries, so the 'historic trees survey' was ultimately restricted to England and Wales. The FTT sweet chestnut collection included material from mature high forest trees and mature coppice, so older generations of sweet chestnut sites from Scotland and Ireland are partially represented. The geographical expansion of the genetics study area provided the opportunity to test for movement of sweet chestnut material across Britain and Ireland, such as from early to late establishment sites, or between related estates and owners. The expanded collection of British and Irish samples also provided a more representative dataset, enabling a deeper comparison with the range of continental European genotypes, which had been included in the Appendix E paper.

3.4.1. Published results (Appendices E and F)

Appendix E: *Tree Genetics & Genomes* (2017), 13(39), pp.1-14	
Contributor Role	**Contributors: CM*, AM, FC, MC, MG, PP, IV, RJ, FMC, LP, VD, GC, FV**
Conceptualization	CM
Data Curation	CM, AM, MC, RJ, IV, LP VD, GC
Formal Analysis	CM, AM, MC, PP
Funding Acquisition	CM
Investigation	all
Methodology	CM, AM, FV
Project Administration	CM
Resources	all
Supervision	CM, FV
Validation	CM, FV
Visualization	CM, MC
Writing – Original Draft Preparation	CM
Writing – Review & Editing	all

Appendix F: *PLoS One* (2019), 14(9): e0222936	
Contributor Role	**Contributors: RJ*, CM, KR, FMC, DB, AM, MC, FV, JW**
Conceptualization	RJ
Data Curation	RJ, CM, KR, AM
Formal Analysis	RJ, CM, KR, MC
Funding Acquisition	RJ, KR, DB
Investigation	RJ, CM, KR, AM
Methodology	RJ, CM, KR, FV
Project Administration	RJ
Resources	RJ, KR, CM
Supervision	CM, KR, FMC, FV, JW
Validation	CM, KR, FV
Visualization	RJ, CM
Writing – Original Draft Preparation	RJ
Writing – Review & Editing	RJ, CM, KR, FMC, DB, AM, FV

3.4.2. Unpublished results

The clonal analyses and results from the relatedness studies for all the British and Irish sites could not be fully presented in the published papers, owing to limitations of space. There is scope for additional work to develop the information for publication, but it is considered that it would not answer the primary research questions posed in this doctoral study. The information would certainly contribute to understanding the life-histories of specific historic trees and coppice stools and the antiquity of their locations.

3.5. **Historical ecology**

This aspect of the research study was developed to be a summation of the information from the three themes of archaeological archives, dendrochronology and genetics, together with results from the site-based assessments and cultural sources, to provide the multi-proxy analysis to answer the research questions.

The historical ecology results fit into several discrete groups: onomastic, literature and art, site history and ecology, and period-specific cultural references; and are supported by case study examples of integrated analyses. The published paper (Appendix G) presents the broad outcomes of the research study, but some of the detailed period and site related information could not be included and is referred to in more detail *infra.*

3.5.1. Published results (Appendix G)

Appendix G: *Landscape History* (2019), 40(2), pp.5-40	
Contributor Role	**Contributors: RJ*, FMC, JW**
Conceptualization	RJ
Data Curation	RJ
Formal Analysis	RJ
Funding Acquisition	RJ
Investigation	RJ
Methodology	RJ
Project Administration	RJ
Resources	RJ
Supervision	FMC, JW
Validation	RJ
Visualization	RJ
Writing – Original Draft Preparation	RJ

Appendix G: *Landscape History* (2019), 40(2), pp.5-40	
Contributor Role	**Contributors: RJ*, FMC, JW**
Writing – Review & Editing	RJ, FMC

3.5.2. Unpublished results

The main aspect of historical evidence that was not fully published relates to place names. The research provided useful insights into how various permutations of '*castanea*' used in names and place names might indicate a chronology to map the development of knowledge of, or familiarity with, sweet chestnut growing in Britain, from the Roman period onwards. The following explanation from Marged Haycock (Welsh language expert) provides an example: this was given in response to a request for interpretation of the 'Castiard' and *castein-iarth* names, as given by Smith (1964) in *Place names of Gloucestershire*:

> Welsh *castan(wydd)* is a learned borrowing from Latin, i.e. not likely to have been borrowed as a live lexical item in the Roman period itself. The other form, *castein*, is from Middle English or French. The species [sweet chestnut] is already mentioned in the famous medieval Tree-list poem called 'Cad Goddau' in the Book of Taliesin (*castan* is the form used there) – although that poem is probably no earlier than 11th –12th century (people have thought it earlier, but I think not since it uses *siryan* 'cherry' borrowed from Anglo-Saxon). Elsewhere it [sweet chestnut] is not really mentioned much. Castiard, if like Penyard (also in that area [W Glos/Herefs]), might have its second element in Welsh *ardd* 'height', rather than, with Smith, *garth* (which becomes *iarth* when mutated in compounds etc.). Both might then be influenced by AS *geard*. (Marged Haycock, 2015, personal communication).

A similar request for interpretation was sent to Richard Coates, Peter Schrijver and Peder Gammeltoft (place names experts) and produced a parallel response (see Appendices I, J and K), but with important nuances, which are explained in discussion *infra*. The main outcome is to identify *castan* forms in names and place names and to separate early 'castan' from later 'cisten' or 'chesten' forms: this allows a differentiation between the Brythonic influence and the Anglo-Saxon and then French influence, whether pre- or post-Roman: this might then be used to indicate an early or a later occurrence of sweet chestnut at the place in question.

Searches for historical literature and art references to sweet chestnut in Britain produced a wide range of evidence, from 16th. century Herbals to 18th. and 19th. century forestry and gardening treatises. More use might be made of this information than could be published in the Appendix G paper, but it has not been pursued here as it was mostly of late-medieval and post-medieval relevance. There were some interesting findings from searches into monastic and ecclesiastical references to sweet chestnut, in a European context especially, but again these have not been pursued here, as they did not help to identify pre-medieval records or evidence of sweet chestnut growing in Britain.

3.6 **Summary of results**

The earliest records evincing sweet chestnut's occurrence in Britain as a growing tree are presented as a timeline - Figure 1. The earliest date boxes shown in italics represent tentative (unverified) evidence.

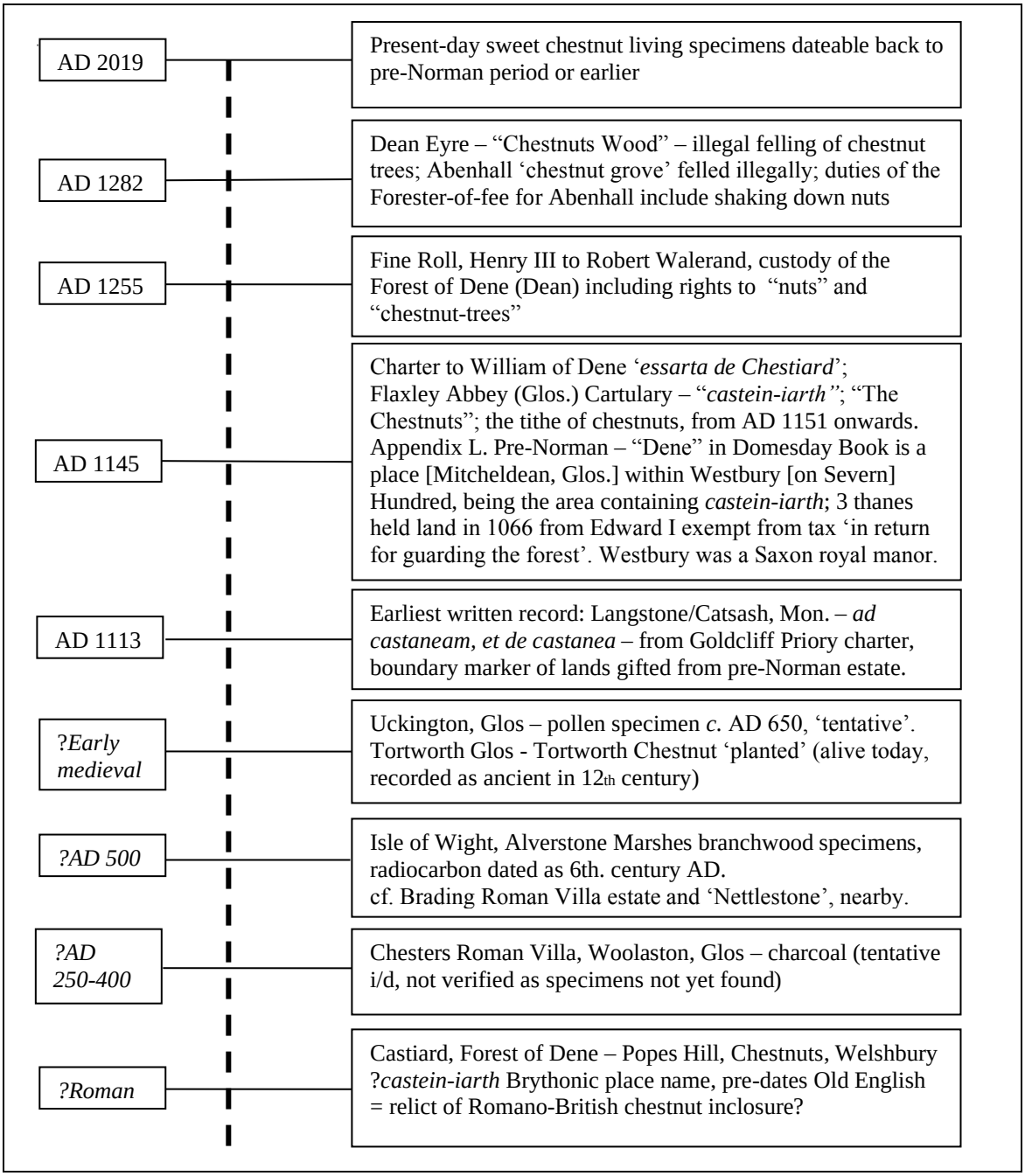

Figure 1. Timeline for evidence of sweet chestnut growing in Britain, using selected examples discovered by this study.

4. Discussion

The multi-proxy approach has realised a wide range of evidence to elucidate the history of sweet chestnut in Britain (and to a lesser degree in Ireland) within a continental European context.

4.1. Archaeological evidence

The examination of all published records for sweet chestnut in archaeological reports for all periods up to AD 650 found none that could be conclusively determined as grown in Britain. The *Britannia* paper (Appendix A) focused on re-examining Godwin's work (Godwin, 1956 and 1975), as most workers since Godwin published have used his findings to state 'as fact' that sweet chestnut was introduced to Britain by the Romans (and grown for nuts and stakes). This 'fact' is now clearly unsubstantiatable, as the present research has dismissed all Godwin's cited examples: either as incorrect identifications of sweet chestnut by the original recorders (determined by re-examining the original archived wood and charcoal specimens); or as not verifiable in date or species (determined by re-examining original reports and excavation notes) – as presented in Appendix A. This is a significant result, with some iconic examples now dismissed. The findings are important for future workers, because the work of analysing the purported sweet chestnut wood and charcoal specimens has clarified the problem of wood anatomy unable to differentiate between sweet chestnut cf. oak, especially in small roundwood and poorly preserved sections. This knowledge should mitigate against future 'false' identifications as 'sweet chestnut', instead using the caveats 'cf. *Castanea*' or *Quercus*/*Castanea*. The *Britannia* paper (Appendix A) makes these points in detail.

The discovery of archived sweet chestnut nut remains from two excavations (Van der Veen, 1983; Murphy et al., 2000) enabled an experiment to attempt to date and also to provenance the nuts, as described in the HE Research Report (Appendix B). Samples from both sets of nuts were submitted for aDNA analysis by the University of Warwick (Robin Allaby): these analyses failed to recover any meaningful DNA, but the process was instructive for future work on aDNA. Samples were also submitted for radiocarbon

dating, which revealed that one collection of nut remains (Murphy's, from Great Holts Farm, Boreham, Essex) was definitely of 3rd.–4th. century AD, as had been estimated in the original excavation report using pottery and oak wood dendrochronology for contextual dating. The other specimen (Van der Veen's, from Castle Street, Carlisle) was found to be of modern origin: it had been introduced somehow into the biological assemblage as 'excavated' and submitted for analysis. These results were an invaluable demonstration of the value of archiving specimens, and of the durability of correctly curated specimens (Murphy's, at Norwich Castle Museum).

Most importantly, this work confirmed that, in the entire British record, there is only this single find (at Great Holts Farm) of sweet chestnut nut remains from before the 13th. century AD. The context of this find indicated a strong probability that the nuts were imported with other exotic food types and used in a single feast occasion (Germany, 2003). All the various references to nuts being grown in Britain to feed the Roman legions and to caches of nuts found at Roman forts (Howkins, 2003; Stace and Crawley, 2015) are evidently unsubstantiated – 'factoids', as Rackham expressed them, *infra*.

The successful use of these archived nut specimens contrasted with the failure to recover specimens which had been reported as archived, but which could not be found (notably the Chesters charcoal specimens in the Reading University Archaeology Dept. store, but also at five other museums): this seemed to indicate an institutional problem with the curation of archives. In addition, it was found that invaluable specimens of unworked waterlogged wood, which had been described as sweet chestnut in excavation reports and were important to re-examine and to verify using new dating techniques, had been systematically discarded as too difficult or expensive to store – notably the London Wall LOW88 sweet chestnut timber (Nayling, 1991), and the Clifton Quarry specimens (Mann and Jackson, 2018). This failure bears comparison with the Alverstone Marshes waterlogged wood specimens (Wroe-Brown et al., 2011), which were stored in the Isle of Wight Archaeology and Historic Environment Service store (Rebecca Loader, 2016, personal communication) and were easily recovered and re-examined. These issues with archiving were presented in the *Britannia* paper and form

an important contribution to Historic England's campaign to promote archiving and good practice for curation (Appendix A).

The Alverstone Marshes wood specimens *supra* provide an enigmatic result. They are the only sweet chestnut specimens of branchwood that were dated (using direct radiocarbon dates – see Appendix A for details) close enough to the end of the Roman period that they might conceivably have derived from sweet chestnut trees/coppice growing in England (potentially near the find site, near Brading Roman villa on the Isle of Wight) during the Roman period. The excavation report awaits completion (Wroe-Brown et al., 2011), but the possibility that these verified sweet chestnut stakes were grown in an English site extant during the Roman period makes them very significant in the British archaeological record.

The archaeological results presented in the *Britannia* paper were terminated at AD 650: fifteen records were found dating between AD 650–1350 that indicated presence or use of sweet chestnut wood in the early medieval period in England. None was checked or verified, but some are from presumed trustworthy recent identifications (such as those by Peter Murphy) and can be thought of as probable definite records (Appendix O); some pre-date the monastic period, which is important as there is a view that sweet chestnut was first introduced to Britain by the monasteries (Brian Huntley, 2015, personal communication).

4.2. DNA analysis - sources of British and Irish sweet chestnut germplasm

The research used DNA analysis to determine relatedness between sweet chestnut trees within and between sites, in order to trace the sources of the oldest British sweet chestnut trees and stools, within Britain and Ireland and across continental Europe. It was hoped thereby to gain insight into sweet chestnut's arrival into Britain. This was only possible because preliminary work to identify sweet chestnut genotypes and to map genepools across continental Europe had recently been completed (Martin et al., 2010; Mattioni et al., 2013): British and Irish samples could be collected and analysed in precisely the same way and then be integrated into the European dataset for comparison and evaluation. Parallel work on identifying refugia for sweet chestnut

during the LGM in continental Europe using palaeoenvironmental and archaeological evidence (Roces-Díaz et al., 2018; Krebs et al., 2019), enabled a combined evaluation of British and Irish sources by relating the genepool and genotype analyses to potential LGM refugia zones. The *Tree Genetics and Genomes* paper (Appendix E) and *PLoSOne* paper (Appendix F) provide full descriptions and analyses of the genetics work.

The genetics analysis was successful in describing the composition of the British and Irish sweet chestnut population, revealing a single overall genepool with high admixture of genotypes. This identified that sweet chestnut populations in Britain and Ireland have higher genetic diversity than any of the European populations, indicating they have multiple origins in continental Europe. This admixture could arise from a single phase of sweet chestnut arrival into Britain and Ireland, but derived from a combination of several continental European sources; or it could arise from several phases of arrival, each from a different source. The extent of genetic diversity imported would also depend on whether the introduced material for propagation was of nuts (already containing an admixture of parentage), or of vegetative material (such as green sticks or rooted layers) from a common parent. In either case, the long-distance transport of viable material for propagation in Britain would be problematic. It is not possible with the genetic information derived from this study to determine a chronology for sweet chestnut's arrival in Britain: this will require complementary archaeological or palaeoenvironmental evidence of sweet chestnut definitively growing in Britain in a dated context, not presently available. The significance of the genetics analysis undertaken in this study is that it indicates specific source zones for British and Irish genotypes within continental Europe; and enables their comparison with other tree and shrub species, which have been examined recently for their migration from continental European LGM refugia to Britain and Ireland (see Appendix F). The main component lacking for the genetics analyses was sufficient number and spatial distribution of comparative sites in France, so that 'stepping stones' for genotype migration and/or translocation from Iberia or Italy might be recognised.

Genetic studies of sweet chestnut across Europe have revealed a complex pattern of indigenous populations that survived the LGM in various refugia zones and then spread

naturally following climatic amelioration, overlain by anthropogenic translocation of selected sweet chestnut genotypes, perhaps occurring even before the Classical Greek and Roman periods (Conedera et al., 2004; Roces-Díaz et al., 2018; Krebs et al., 2019). This pattern appears similar to that found for other European trees, such as ash *Fraxinus excelsior* (Hueurtz et al., 2004; Sutherland et al., 2010); oak *Q. robur/Q. petraea* (Petit et al., 2002; Lowe et al., 2005; Kremer, 2015); small leaved lime *Tilia cordata* (Fineschi et al., 2003; Pigott 2012); hazel *Corylus avellana* (Boccacci and Botta, 2009; Brown et al., 2016); and beech *Fagus sylvatica* (Magri et al., 2006; Sjolund et al., 2017). The evidence for oak, beech and hazel distribution is particularly relevant to the sweet chestnut analysis, as these trees were highly valued for their nuts for human food and for livestock farming, as was sweet chestnut (Conedera, 2004). Genetic analyses of oak, beech and hazel have revealed natural spread (from LGM refugia in northern Iberia, the Pyrenean foothills and northern Italy) interacting with human translocation of selected genotypes, so that two streams of colonisation can be detected. The notion that oak, beech and hazel are purely 'native' species is perhaps thereby compromised, as there have been phases of anthropogenic introductions that have influenced the 'natural' genepool composition. On the basis of pollen analysis (*inter alia* Godwin 1975; Huntley and Birks, 1983; Birks, 1989) oak, beech and hazel have conventionally been deemed indigenous, whereas sweet chestnut has been deemed introduced, in Britain. This study found no verifiable evidence for sweet chestnut growing in Britain until the early medieval period: however, given the problems with sweet chestnut pollen and wood identification (the 'silent/quiet taxon issue') as discussed in Appendix A, the absence of sweet chestnut pollen may be no more significant than the presence of oak or hazel pollen in determining which species might be indigenous or introduced. The net effect of the recent genetic findings for these tree species is to blur the distinction between 'native' and 'introduced', as theoretically described in Preston et al. (2004).

4.3. Dating trees and stools and their sites

Conventional dating methods in archaeology and the historic environment include radiocarbon, dendrochronology and contextual dating from artefacts (such as pottery, metalwork) (Greene and Moore, 2010). In this study, radiocarbon dating was used to successfully confirm as 'Roman' the sweet chestnut nut remains from Great Holts Farm

supra; and had been previously used to date as '6th. century AD' the Alverstone Marshes wood specimens *supra*. Two significant and innovative outcomes from the present study provide an extension of dendrochronological dating to sweet chestnut wood sections (Appendices C and D); and development of genetics analysis to provide clonal information to determine extent, structure and antiquity of individual trees and coppice stools (presented in Appendix F).

The dendrochronological analyses of sawn sections from ancient sweet chestnut trees across southern England and Wales discovered that sweet chestnut growth-ring series match oak growth-ring series, at a regional scale (covering England and northern France). Reference chronologies for oak *Q. robur* and *Q. petraea* in Europe, which span from present back to 8480 BC (Haneca et al., 2008; Andy Moir, 2019, personal communication), can now be used to match and date sweet chestnut wood sections recovered from archaeological contexts or historic structures, which may lack sapwood and/or pith elements, provided they bear >50 growth rings. This technique has been used for sweet chestnut in two examples in continental European studies (Domínguez-Delmás et al., 2013; Čufar et al., 2014), as explained in Appendix D.

Furthermore, the dendrochronological ages assigned to trees with measured girths indicated that there was no relationship between age and girth, such that girth cannot be used as a proxy to describe tree age (Appendix D).

The DNA analyses for clonal groups of sweet chestnut were undertaken using data derived from the multiple sampling of apparent (visually) 'individual' trees and coppice stools. Ancient and iconic trees were selected for DNA sampling, to determine whether they were grown from a single plant or from several plants (termed 'bundle planting'); and to determine whether there were any grafted components, as was typical continental European practice for varietal selection for eating nuts (Pereira-Lorenzo et al., 2019). As a result, several ancient sweet chestnut trees that had been described as 'bundle' plantings, owing to their fluted and separated-stem structure (such as the ancient tree at Silwood, Berkshire) or growth of close-spaced trunks in a ring form (such as the ancient tree at Luton Hoo, Bedfordshire), were found to be genetically identical in all their main

stems. Were they ‘bundle’ plantings, then each separate plant in the bundle would have to be a vegetatively propagated cutting/rooted layer from a common parent tree. This would not be impossible, as the practice of propagating rooted layers for planting out was traditional even until modern times (Evelyn, 1664; Roy Keeler, 2016, personal communication). The Luton Hoo tree can now be considered to be a ring planting with a hollow interior space, so not established from stump regrowth but from separate plants that had been propagated vegetatively from a common parent. For comparison, another ring-form tree, the ancient ‘Seven Sisters’ tree near Penshurst in Kent, was found to be genetically identical in six out of seven of the main trunks arising from a single base: here, the root plate is evidently formed from a single stump, so the six identical stems are stump regrowth. Intriguingly, one of the seven trunks is a different genotype of sweet chestnut, so perhaps an original inclusion of a sapling from a different parent, or a naturally regenerated nut incorporated into the circle.

Large coppice stools were also selected for the clonal analyses, and were tested to check whether every stem arising from what appeared visually and structurally to be a single stool was in fact genetically part of that stool, or was a separate genetic individual. Some of these stools had been described by workers such as Rackham as ‘massive’ or ‘enormous’: in some cases they were vindicated, where the stool was shown to be a single genotype; in others proved wrong, where an ‘individual’ stool was shown to be a composite of several separate genotypes. The time scale for the single-genotype ‘massive’ stool to form, compared with that of a group of several smaller stools to form, is probably hundreds of years different, based on observations in the fieldwork.

These are significant findings, as researchers and practitioners in ancient trees and woodlands are beginning to realise the inaccuracy of many previous ‘guesstimates’ of tree age from girth measurements and of coppice stool antiquity: genetic analysis can identify clones and reveal the size and physical structure of discrete plants, and evince management history and longevity.

The present research with sweet chestnut has developed innovative methods and actual data for dendrochronological evidence of exact tree age; and also innovated the use of

genetic evidence to determine exact tree and stool size and composition, using clonal analysis. Combined, the dendrochronological and genetics analyses can now provide precise indication of tree or stool antiquity, avoiding the inaccuracy of girth-related or visually estimated ages.

4.4. Naturalised sites

In the preliminary research phase and the search for potential sites to survey, George Peterken (GFP) and Oliver Rackham (OR) proposed some woodland sites that they had previously visited where they had noted sweet chestnut appearing naturalised and behaving 'like a native'; viz. not evidently planted, clustered or forming an even-aged stand, but appearing to integrate with the semi-natural woodland environs. GFP suggested Bedford Purlieus, Edlington Wood, Dock Copse and Kilnwood Copse, and OR suggested Holbrook Park, Chalkney Wood and Norsey Wood. These sites were surveyed and OR's sites were found to be of large stool-grown trees, some with collapsed and layered stems, evidently centuries old, interspersed with equally large stools of field maple, ash and hazel; whereas GFP's sites were of minor coppice forms or standard trees, with no evidence of planting so presumably self-regenerated, across a relatively short time scale, but of the same age and stand structure as the surrounding semi-natural woodland. Genetic analyses did not reveal any specific differentiation between these sites and other sampled sites.

In general terms, an interesting pattern was revealed by the DNA analyses: woodland sites with full-sibling and half-sibling stools and trees indicated the natural regeneration of these plants from on-site sources, rather than from planting of nursery or propagated stock from elsewhere, which would probably not show any relatedness with the site genotypes. Whereas woodland sites with clonal stools indicated two possible causes: where the stools were of ring form, with clonal stems forming a ring around a hollow interior, then these stools were most probably the product of long-term outgrowth from an original cut stem, which produces new shoots on the periphery of the stem each time it is coppiced and eventually creates a root system without a centre (Harmer, 1995; Jarman and Kofman, 2017 – Appendix H). Large stools of this form can be many hundreds of years old and would qualify for 'naturalised' status as defined by Preston et

al. (2004). Stools with clonal components may also be uni-directional, forming linear (not ring) stools: these are probably managed artefacts, where a stem has been deliberately laid down into a gap to establish a new stool in the coppice, but may also be created from a blown down stem or stool that had naturally regrown by sprouting along the stem(s), forming a line of clonal stems (as recorded on three sites in this study). These stool features can be used to indicate sweet chestnut's duration on a woodland site and the antiquity of specific stools. In non-wooded settings, ancient trees were recorded as clonal where components had been formed by layering, such as bough collapse and regrowth, indicating natural collapse and regrowth phases over hundreds of years. Such ancient trees, developing over centuries a natural form of collapse and regrowth, might also be described as 'naturalised', as at Tortworth, Kateshill and Wymondley.

Stace and Crawley described sweet chestnut as 'naturalised' only in southern England, as 'the British climate is marginal for the ripening of its nuts, which occurs regularly only in the south of England north to parts of East Anglia and the south Midlands' (2015, p.36). This is evidently not correct, as sweet chestnut was found naturally regenerating from seed at Sutor in Cromarty, NE Scotland. They describe sweet chestnut coppice in southern England as 'a valuable habitat that has become greatly reduced and much flora and fauna lost' (2015, p.37), apparently recognising the ecological and conservation values of the naturalised sweet chestnut woods there.

4.5. Place names (Onomastics)

This study has used place names to provide supplementary evidence for the antiquity of a location for sweet chestnut. The *Landscape History* paper (Appendix G) explored various instances where a name including '*castan*' or its derivatives provided a clue to the origins and antiquity of sweet chestnut. Onomastics is a complex discipline and the assistance of expert researchers was needed for these assessments (as evinced in Appendices I, J and K). There is considerable scope to develop this aspect of the study, principally to try to determine the cultural significance of sweet chestnut in specific locations, using the evolution of language to provide a chronology for the development of knowledge of sweet chestnut in human society. One example that arose in this study

was provided by Jessica Treacher, a PhD student with the Institute for Name-Studies at the University of Nottingham who is studying tree names in place name elements: Jessica pointed out the place 'Nettlestone' in the east of the Isle of Wight. In discussion (see Appendix M) it became evident that 'Nettlestone' (referenced in Domesday Book as 'Hotelestone') derives from AS *hnutu+leas+tun*, meaning approximately 'the farmstead/settlement at the nut-growing place'. This interpretation is based on recent analysis of the meaning of *lēah* as both 'wood' and 'clearing', which concluded that *lēah* names should be defined as 'light areas' that are surrounded by woodland: 'a *lēah* might have been used for pasture, but 'wood pasture' is not a satisfactory translation of *lēah*, because in some cases the *lēah* was cultivated, rather than grazed or browsed, at the time it was named.' (Wager 2017, 5–16). This description of a 'nut leah' matches closely the management of a typical continental European sweet chestnut orchard, where arable intercropping, pig grazing and pasture were integrated and rotated with the orchard nut tree management, over many centuries (Watkins, 2004). The 'nut' in 'Nettlestone' could be several species (hazel, oak, beech) or sweet chestnut: the context of the Alverstone Marshes sweet chestnut wood specimens *supra* (located *c.* 6 kms distant), and the Brading Roman villa estate that covered both sites, might be significant.

4.6. Ecological significance

The *Landscape History* paper (Appendix G) set out the general consensus on the ecological importance of sweet chestnut in Britain. It can be concluded that, irrespective of whether it is 'native' or 'alien', the species performs an important ecological function in specific types of ancient semi-natural woodlands, notably in southern Britain where it does behave like the 'honorary native' that Rackham (1980), and indeed the earlier ponderers (Evelyn, 1664; Ducarel, 1771; Thorpe, 1771; Hasted, 1771 and 1798), had observed it to be.

Outside of woodland habitats, sweet chestnut performs a different ecological role, as in wood pastures and historic parklands, where stands of single or groups of ancient trees, stubs and stools support many veteran tree features (Lonsdale, 2013). Such trees sustain a wide diversity of scarce and sometimes endangered invertebrate and other animal species; and host a specialised flora, notably lichens, bryophytes and fungi. These trees and their associated communities are typically many centuries old and provide sites of

high ‘ecological continuity’ (Rose, 1974 and 1976) in landscapes where these are rare. The concepts of ‘ancientness’ and ‘continuity’ should not be used simplistically (Watkins and Kirby, 1998; Norden and Appelqvist, 2001): veteran sweet chestnut trees, stubs and stools can appear much older (or younger) than they actually are, but when surveyed for their associated flora and fauna they can prove remarkably special.

4.7. Cultural significance

In that context of ecological continuity and antiquity, cultural significance is not a separate concept – humans can be considered as part of nature, and the ‘sweet chestnut-scapes’ that were discovered and surveyed during this research reflect that: ancient inclosures, ancient coppice woods, historic boundaries, historic gardens, historic deer parks and designed parklands, historic formal avenues, and high forest and production coppice are all artefacts of management. These ‘landscapes of sweet chestnut’ in Britain are socio-economic constructs, which have diverted nature to provide for divers human needs in different periods from past to present. They may be endowed with ancient trees, stubs and coppice stools of great significance for ecological interests, but they still perform essential functions for people and their lives, as discussed in the *Landscape History* paper.

Two cultural aspects that were highlighted during the research merit discussion: first, an evident symbolic respect, even spiritual affection, for the sweet chestnut tree, which has endured over centuries and is demonstrated in totemic plantings of individual trees and groups of trees in highly significant cultural spaces (gardens, house entrances, landscape prominences) – and the retention of these trees as ancient and decrepit ‘characters’ long past their prime, even in settings of high formal and aesthetic status (as at Tortworth, Kateshill or Canford, for example). Second, an utilitarian valuation of the tree as a resource for food and fibre: nut production for people and for animals, and wood production for stakes and pales, were important resources. Investment of craft and labour over perhaps two millenia has created a legacy of types, forms and settings of sweet chestnut that can appear ‘natural’ but is highly manipulated, even genetically. Some minor evidence was found in the present study for grafting and for varietal selection for nut production in orchard settings, with a few examples of vestigial terrace

cultivation (Appendix G), but as nothing compared with the sweet chestnut landscapes of continental Europe (Grove and Rackham, 2003). The classic infrastructure associated with sweet chestnut cultivation there is either well-hidden or absent in Britain.
The use of sweet chestnut timber (as separate from poles or stakes) is similar: in continental Europe there has been much use made of it in building construction, as roundwood and sawn beams; but in Britain, despite many assertions, there is not a single verified record of sweet chestnut timber in building. A potential study in England of historic building timbers of sweet chestnut might be conducted at Penshurst Place in Kent, where the roof of the Baron's Hall, known to have been constructed in ~AD 1341, is purported to contain the original roof timbers including sweet chestnut (Kent County Council, 2018). There is no record of any specific timber assessment for this building: the present study has confirmed that sweet chestnut trees were growing in Penshurst Place park in AD 1650; and other historical records evince sweet chestnut's presence even before that, suggesting that an assessment of the roof timbers in the Hall could be rewarding.

4.8. Factoids

Oliver Rackham decried factoids – 'an item of unreliable information that is reported and repeated so often that it becomes accepted as fact'. This study has exposed some interesting statements about sweet chestnut in Britain that fit this description. Most accounts of sweet chestnut inevitably begin with the 'fact' of its Roman introduction– whether as sign boards next to ancient trees on National Trust sites (such as at Felbrigg, Norfolk), or in visitor guides (such as NT Croft Castle), or in publications by the Forestry Commission and Woodland Trust. These comments are hardly surprising, when authoritative writers such as Rackham have made definitive statements such as 'archaeologists have identified its [sweet chestnut's] wood or charcoal at many [sic] Roman sites from Essex to Dorset ' (2006, p.370), even though he qualified this with 'it is thus an archaeophyte, introduced probably by the Romans, which has persisted and has become a component of native vegetation' (2006, p.371). Ironically, some archaeological reports have used the 'fact' that sweet chestnut is not indigenous and was introduced by the Romans as a basis for contextual dating, citing Godwin or Rackham as the source, such as Sidaway (1964), Clapham (1988) and Challinor (2003).

Stace and Crawley stated as fact ‘walnut and sweet chestnut were introduced by the Romans’; and also ‘sweet chestnut probably reached Britain with the Romans, who used the nuts to feed their army’ (2015, pp. 24–5, 35–7). There is no known evidence for these assertions, and none is referenced by Howkins (Stace and Crawley’s cited source for the history of sweet chestnut in Britain). Howkins cited ‘caches of chestnuts found by archaeologists at Roman sites…e.g. Caerwent’ (2003, p.60), but as shown by the present study, there is no evidence of any sort for caches of sweet chestnut nuts from any period, certainly none for Caerwent in particular, and certainly no evidence for Roman armies feeding on chestnuts, nor for its growth in Roman Britain. Indeed, it is difficult to understand Stace and Crawley’s position on sweet chestnut, especially in the context of a preceding paper co-authored by Crawley (Lim et al. 2014). There, citing Stace and Crawley (2015), table S1 describes sweet chestnut as an archaeophyte with ‘high invasive impact’, in the same category as *inter alia* ground elder (*Aegopodium podagraria*), Turkey oak (*Quercus cerris)* and *Rhododendron ponticum.* Sweet chestnut does not behave like those species - it does not spread profusely by seeding and smother semi-natural vegetation: it does spread by seed, but in a rather selective manner, in synergy with the host community, hence Rackham and Peterken’s description of it as an ‘honorary native’. Stace and Crawley (2015) had not described sweet chestnut as an invasive species; rather they prevaricated as to whether it is even a Roman archaeophyte, first saying (p.24) that the Romans introduced it to Britain, then saying (p.25) there is no evidence for it growing in Britain during the Roman period, in which case it would not be an archaeophyte. Field surveys of divers sweet chestnut woods in England and Wales have shown that, where single-species dominance of sweet chestnut exists in high forest or coppice stands, they were planted to that effect: they are not the product of invasion. Some woods with scattered sweet chestnut trees and stools appear to be self-regenerated and of mixed age classes, but here, sweet chestnut grows in mixtures typically with small-leaved lime, oak, ash and hazel on a narrow range of soil types, even as very ancient stools such as in Welshbury (Glos.): from the present research, sweet chestnut could not be considered a highly invasive species having ‘high invasive impact’ (Lim et al., 2014).

It was evident from the field surveys that the non-woodland locations for sweet chestnut in Britain were almost exclusively planted. Where several sweet chestnut trees of different ages grew proximate to each other, as at Tortworth, their genetics showed they were parent-offspring related, so possibly self-sown but more likely, in these designed garden and parkland settings, grown from a planted nut from the parent tree.

Another aspect, similar to that of the Roman introduction, surrounds the planting of sweet chestnut following the Spanish Armada attempted invasion of Britain in AD 1588. There are several sites where individual sweet chestnut trees or avenues of trees are claimed to be grown from nuts found in the pockets of shipwrecked Spanish sailors from the Armada – most notably at Croft Castle, Herefordshire, where the layout of sweet chestnut avenues across the parkland is claimed to represent the battle formation of the Armada and to derive from Spanish sailors' nuts. In N Antrim, Ireland, a sweet chestnut tree in the graveyard of St. Patrick's church, Carncastle, is claimed to have grown from a nut in the pocket of a buried Spanish sailor from the Armada.

Legends linking sweet chestnut nuts with sailors may have some factual basis – the excavation of the '*Aber Wrac'h 1*' shipwreck (Appendix N) found sweet chestnut nuts in the crews' food remains. In Shakespeare's Macbeth (1606) the First Witch says 'a sailor's wife had chestnuts in her lap and munch'd and munch'd and munch'd…': Shakespeare knew that the contemporary audience would be familiar with eating chestnuts, and would also appreciate the irony of a sailor's wife (in particular) eating the chestnuts that her sailor husband would have better profited from… The dietary value of sweet chestnut nuts is significant: they are the only nuts to contain vitamin C (*c.* 43mg per 100g, eaten raw) and so were an important antidote to scurvy.

A particularly worrying 'factoid' concerns the estimation of tree ages from their girths. This study is the first to gain precise ages for specific sweet chestnut trees from dendrochronological analysis: Appendix D presents a graph of measured tree girths against measured tree age and there is a very low level of correlation between the two measures, especially after the age of *c.*150 years. Most trees with 'guesstimated' ages are probably over-estimates, although this study showed some surprisingly small-

girthed trees to be of equal age to large-girthed trees, so under-estimates of age also occur: it is these that would be of particular concern for ancient tree conservation, where size indicates status…

5. Conclusions

The conclusions are presented in the form of responses to the original research questions – when, whence (and perhaps why) sweet chestnut first came to Britain; and whether its cultural and conservation significance might be altered by the research outcomes.

5.1. When

Overall, no evidence was found to justify the conventional 'Roman introduction' thesis, in terms of sweet chestnut first growing in Britain in the Roman period. Indeed, there was no incontrovertible evidence of it growing in Britain before the 12th. century AD, when localized written records first vouch for its existence, cultivation and harvesting (indicating establishment, at the latest, by the 11th. century AD). Re-examination of archaeological specimens using modern techniques concluded that previously purported 'Roman' finds of 'sweet chestnut' are inadmissible: there are no pre-AD 650 sweet chestnut finds verified as grown in Britain.

The earliest locatable record of sweet chestnut growing in Britain is the written account of the Goldcliff priory charter from AD 1113, which cites *ad castaneam, et de castanea* as a boundary marker, in the vicinity of Catsash and Langstone in Monmouthshire. The next oldest reference is from AD 1145–51, for the place name *Castiard* in the Forest of Dene, Gloucestershire, with an associated tithe of chestnut nuts given to Flaxley Abbey, Glos. Further 12th –13th. century AD records for sweet chestnut trees and woods were found in Gloucestershire, Kent and Essex. These early records evinced nut growing, coppicing and historic boundary markers: the sites must pre-date their first written record, possibly by several centuries, providing a certain pre-Norman earliest date.

The oldest extant living sweet chestnut trees definitively dated by this research were from AD 1640. Several iconic ancient trees were dated accurately for the first time, using the innovation developed in this research study of comparing oak *Quercus* growth-ring reference chronologies with sweet chestnut wood sections. Significantly,

the dendrochronological research discovered that sweet chestnut growth-ring series mirror oak reference chronologies, opening the potential for sweet chestnut wood samples from archaeological or historical contexts to be accurately dated and dendroprovenanced, for the first time. This technique successfully sampled sawn sections from long-dead ancient trees, evincing the invaluable resource for dendrochronological studies residing in ‘deadwood graveyards’ in many historic parks and gardens.

The genetics research produced innovative clonal analyses that verified individual tree and coppice stool antiquity for the first time. Purported ‘very large and therefore ancient’ trees and stools were shown to have been either correctly described, as a single genetic plant, or incorrectly described, as a composite of several genetic plants. Life histories of some iconic trees and stools were revealed by the evident clonal structures of trunks and root systems.

It is conceivable that early finds of sweet chestnut do exist in the archaeological and palaeoenvironmental records but have been overlooked. Sweet chestnut was shown to be an elusive species, in pollen records and in wood and charcoal specimens as typically found in archaeological deposits. It can be mistaken for other species, or not be conclusively identifiable, as its key features are insufficiently distinctive. Several iconic records of sweet chestnut wood and charcoal were found to have been incorrectly identified by their original, widely acknowledged expert recorders.

Some invaluable archaeological finds of sweet chestnut wood in the Isle of Wight (the Alverstone Marshes specimens), which were radiocarbon dated as grown in the 6th.–7th. century AD, might be describable as ‘English-grown’ when the final excavation report is published. Place name evidence and genetics analysis indicated a potential early presence of sweet chestnut in this eastern part of the Isle of Wight.

5.2. Whence

The genetic studies found that sweet chestnut trees and woods across Britain and Ireland formed a single overall genepool, but that Welsh sites differentiated from Irish and

English sites. Genetic analysis determined the sources of the oldest British sweet chestnut trees/stools in parts of southern France, Spain, N Portugal and central Italy, which have been identified as refugia during the Last Glacial Maximum, and in Romania and Slovakia. Clonal analysis verified individual tree and stool antiquity, enabling the finding that modern (post-AD 1800) trees and coppice in Britain were genetically differentiated from ancient trees and coppice, indicating alternative origins; of especial interest was the discovery of a particular association between ancient (typically dating from the 12th–14th. centuries AD) garden sweet chestnut trees in Britain and sites in N Portugal, possibly a relic of early (medieval) selection of sweet chestnut nut varieties from N Portugal. The predominant linkages of British and Irish sites with continental European sweet chestnut sites were with N Portugal, NW and NE Spain, S and SW France, central Italy, and two sites in Romania and Slovakia.

5.3. Why

The genetics evidence identified sweet chestnut spreading to and through Britain from the same continental European LGM refugia as other nut-bearing tree and shrub species (oak, hazel and beech). The genepool distribution of sweet chestnut in Britain and continental Europe shows a similar pattern to that of oak, beech, ash and hazel genepools: these species have been considered native in Britain, derived through colonization from refugia in N Iberia and S France along the Atlantic fringe. Genetic studies are now revealing the post-LGM spread of these species to have been through a combination of natural and anthropogenic vectors. This had already been shown to be the pattern for sweet chestnut in continental Europe and from the present research it appears also to be the case for sweet chestnut in Britain. Nuts (for human and livestock consumption), and durable wood for stakes and for use in watery contexts, were the predominant reasons for growing sweet chestnut and for taking it to places where it did not already grow (or in the case of nuts, to improve the quality of indigenous nut varieties especially for eating).

5.4. Cultural and conservation significance of the research

Seven types of British ‘sweet chestnut landscape’ were revealed: ancient inclosures; ancient coppice woods; historic boundaries; historic gardens; historic deer parks and

designed parklands; historic formal avenues; and more recent high forest and production coppice. Present ‘landscapes of sweet chestnut’ in Britain are endowed with ancient trees, stubs and coppice stools of great significance for cultural and ecological interests, and merit protection in the face of biohazards and environmental change.

The status of sweet chestnut in Britain as ‘non-indigenous’ or ‘indigenous’ has not been conclusively re-defined by this research, but its importance as an ecological and cultural asset in specific types of semi-natural and designed landscapes has been demonstrated. Its original designation as an ‘honorary native’ by Oliver Rackham is endorsed.

Further research should focus on finding sweet chestnut pollen in dateable contexts, and sweet chestnut wood specimens for dendrochronological analysis, to determine its earliest growth in Britain. This requires improved/new techniques for identification of wood, for pollen and for dating.

6. Future perspectives

This study has indicated where future research might be directed to achieve specific objectives.

6.1. Genetics

Further DNA analysis of sweet chestnut could focus on extending the scope of the clonal studies, to try to find more evidence for grafted trees and to determine the antiquity of ancient trees and coppice stools. Extension of the survey's geographical coverage to Scotland and Ireland to include their ancient and historic trees would be highly informative. Addition of haplotype studies of sweet chestnut across Europe would improve the tree ancestral analysis; and inclusion of orchard populations in continental Europe to compare with British and Irish sites might indicate additional links specifically resulting from introduction of genotypes for their eating nut qualities.

6.2. Pollen

The 'silent/quiet taxon' issue relating to sweet chestnut pollen in the British record requires examination, initially with a search of old records for possible misidentifications of sweet chestnut pollen. This could be followed by a search for potential new sites for pollen analysis within likely historical sweet chestnut catchments. A good example is the 'Manifestations of Empire Project', developing accurate and dated pollen records for SE Wales sites, especially relevant to the present research outcomes identifying Langstone-Catsash area of SE Wales as the first written record for sweet chestnut in Britain.

6.3. Dendrochronology

The many 'deadwood graveyards' of ancient trees lying in historic parks and gardens are an invaluable resource that merits urgent survey before wood degradation proceeds too far. This can yield vital information on individual tree histories as well as their landscape settings; it also provides a wider representative sample of ancient sweet chestnut growth ring sections, to form reference chronologies of sweet chestnut for

dendrochronological studies. There needs to be an attempt to dendroprovenance sweet chestnut from British samples on a regional basis.

6.4. Archives

One of the disappointments of the present study was the failure to find important reported archived specimens (such as the Chesters charcoal specimens identified by Figueiral), as reported in the *Britannia* paper (Appendix A). Searches for archived specimens of sweet chestnut should be continued. The Alverstone Marshes finds of waterlogged wood are exceptionally important in this respect, yet the final report of their analysis and context is long overdue.

7. **References**

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8. **Appendices**

Appendix A

Britannia paper

Appendix B

Historic England Research Report

Appendix C

Arboricultural Journal paper

Appendix D

Dendrochronologia paper

Appendix E

Tree Genetics & Genomes paper

Appendix F

PLoS ONE paper

Appendix G

Landscape History paper

Appendix H

Jarman, R. and Kofman, P.D. (2017). *Coppice in Brief*. COST Action FP1301 Reports. Freiburg, Germany: Albert Ludwig University of Freiburg.

Appendix H: *Coppice in brief.* Eurocoppice project, COST Action FP1301.	
Contributor Role	**Contributors: RJ*, PK**
Conceptualization	RJ, PK
Data Curation	n/a
Formal Analysis	RJ, PK
Funding Acquisition	Eurocoppice management committee
Investigation	RJ
Methodology	RJ, PK
Project Administration	Eurocoppice management committee
Resources	Eurocoppice management committee
Supervision	Eurocoppice management committee
Validation	PK
Visualization	RJ, PK
Writing – Original Draft Preparation	RJ
Writing – Review & Editing	RJ, PK

Appendix I

Richard Coates (2015, personal communication)

RJ - I have come across another reference to this place named Castiard - and in this source it is written "Chestiard"... the source is a charter given by Roger Earl of Hereford to William of Dene - I think the charter must date from between 1144 (when Roger adopted the title Earl of Hereford from his father Miles on his death and with it the authority over the Forest of Dene and Manor of Dene which Matilda had given to Miles) and 1155 when Roger died. I would put the charter to the time pre-1153, when the gifts of land in and around Castiard to Flaxley Abbey from Roger were confirmed by Prince Henry (later Henry II). It would seem to slightly pre-date the references in the Flaxley Abbey Cartulary to 'Castiard', Casteyerd, Casthard.

RC - Let me muse a bit on the name-form, in case I wasn't really clear yesterday. The only problem with this [Chestiard] is the <e>, not the <ch>. Once you have the <e>, then the <ch> is a typical Anglo-Norman spelling for the sound /k/. Why the <e>, though, I can't be sure, though it's not implausible as a spelling for an English /a/-sound. Adsett is Eddeseta in 1220, Chaxhill is Chekeshull' in 1220, and Flaxley of course often appears as Flexeley and the like. So altogether not too much of a problem.

1. Castan-iarth vs castein-iarth, two hypothetical possible sources of the Gloucs name
The former form, if it can be taken at face value, indicates a borrowing before the change of the vowel to <ei> in anticipation of the "y"-sound in the final syllable (represented by the <e> in Latin) AND therefore before the loss of that final syllable: i.e. before the late 5th century (on Jackson's dating). That would almost certainly mean that castan was borrowed into the local English, and that the second element is therefore Middle English yerd 'yard'. But how did it get into English here before 500???
The latter form is compatible with Middle Welsh castein, and also with any relatively late borrowing into Late British/Brittonic/Old Welsh of Latin castanea, in which the final syllable has affected the second vowel before the final syllable disappeared: i.e. any time after about 500. PROBABLY THE RIGHT SOLUTION!
The latter form is also compatible with borrowing from French casteine, i.e. a Norman form of the French word descended from Latin castanea. Happily for you, there is no evidence for this word-form in Anglo-Norman, though the Anglo-Norman form of the word for the tree is found, written castenere. The

existence of casteine remains a theoretical possibility.

2. Getting to ‘Castiard’
The big problem is getting rid of the syllable with <n> in the name. I don't know of any process in Brittonic/Welsh which would remove it. Its disappearance must therefore be an English phenomenon, which Jackson glosses over.
English medial <n> most often disappears if the syllable it was in was an inflection. That doesn't apply here. But it happened so often in the medial syllable of three-syllable place-names (e.g. *niwan tun > Newton) that you could appeal to analogy here. Other Marches place-name analogies might include Wigstanes tun > Wistaston (Cheshire), Wisteston (Herefs), Alhmundes tun > Alcaston (Shrops), Wulfrune tun > Wollerton (Shrops), though they could just be evidence of the massive reduction of a 4-syllable name and/or dissimilative loss of <n> before another <n>. This remains a tricky point that will need arguing carefully. There are plenty of examples of the loss or reduction of <-ing>, and also examples of its hypercorrect introduction (e.g. Merrington (Shrops)).

(In this mailer, unfortunately, I've had to omit all diacritics.)
Richard

Appendix J

Peter Schrijver (2015, personal communication)

PS - It may well be that Jackson [in Smith, Place names of Gloucestershire] is correct in tracing the name Castiard to something like British Celtic *kastan-gard 'chestnut enclosure'. Unfortunately, I am not aware of other place-names on English soil that contain a Celtic (or Latin, hence Roman-period) reference to chestnut. What may be of help, however, is the following consideration.
The Welsh word for 'chestnut' is castan. It has a cognate in the closely related Breton *kistin* 'chestnut(s)'. The vowel difference reflects an old difference between singular (Welsh) and plural (Breton). Both are obvious borrowings from Latin castanea. The question is: can we find out when the Latin word was borrowed into Welsh and Breton? The answer: yes, up to a point. In order to turn Latin *castanea* into Welsh *castan*, it is crucial that Latin -ea is lost early enough for the -e- to no longer be capable of change the vowels of the preceding syllables. That early loss of -ea only happens to EARLY Latin loans into Welsh and Breton, that is to say, to loans that were adopted during the period of Roman rule over Britain.
So, based on our knowledge of regular sound changes in British Celtic, I would think that the Latin word for 'chestnut' was already borrowed in Roman-age Britain. Whether this means that chestnut was known only as imported fruit and wood at the time, or chestnut trees were already planted in Britain, I cannot say, however.

Appendix K

Peder Gammeltoft (2015, personal communication)

PG - It is indeed intriguing that Castiard is specifically mentioned in relation to chestnuts. That is significant, I would say. What you have to ascertain is that Castiard cannot be a loan from Norman French, then you have your evidence for an early introduction of chestnuts to the British Isles and most probably also evidence of a continued use and importance of the site as a chestnut-producing site.
Castiard's survival is significant in itself. That means that the place was important enough for its name to be transferred into Old English. What the significance was, however, is difficult to say. What do the charters mention Castiard for? I think it would go a bit far to stipulate the survival of a British culture and customary life from the survival of the name alone (including certain payments associated with the place).
But what you can say from the name, is, if the interpretation that it is a name of Brythonic origin of the presence of a chestnut enclosure when this language was still spoken - so that is up until the 5th century or so, right? If the word and the concept did not exist in Brythonic, then you'd never have a name like this. So, yes, your name seems to be evidence of an early introduction into the British Isles.
…the word (and the species sweet chestnut) was known on the continent prior to the Germanic invasions - but it does show that the word itself must stem from contact with Latin.
…the Old English form for Chest(nut) is Cisten-, and it has already then undergone i-mutation and palatalization owing to the new front vowel created because of the i-mutation. I-mutations are usually thought to be prior to the Germanic conquest of England.

Appendix L

Oliver Rackham 2014 - opinion on chestnut tithes in Dene

RJ - I have been trying to pin down the chestnut story in Flaxley - what is this 'tithe of chestnut' in the original grant from Earl Roger/Henry II in 1153 - and am receiving some help from Della Hooke and some of her friends with the translation and interpretation of the original Latin i.e. et singulis annis totam decimam castanearum de Dena" – does "castanearum" mean chestnuts nuts - and does "decimam" mean tithe...given the status of the Royal Forest there would presumably not have been a pre-existing ecclesiastical tithe?

OR - I don't think there is any difficulty here. The decima would normally be an ecclesiastical tithe of chestnuts, as of other short-term products of the soil, like barley and lambs and wood (but not timber). Although Dean is one of the Domesday Book Forests, the tithe record dates from within a century of the founding of the Forest, and probably relates to a pre-Forest custom which was left undisturbed when the Forest was established.

[NB “Dene” in Domesday Book is a place [viz. Mitcheldean, Glos.] within Westbury [on Severn] Hundred: 3 thanes held land in 1066 from Edward I exempt from tax ‘in return for guarding the forest’. Westbury was a Saxon royal manor.
So the Forest existed already in the pre-Norman period and the tithe may well have an older origin].

Appendix M

Correspondence with Jessica Treacher, Institute for Name-Studies, University of Nottingham. March 2019.

JT - My research examines place-names that contain tree species and I am attempting to understand what these linguistic artefacts can tell us about the use of trees as resources in Anglo-Saxon (and Scandinavian) England. I am currently working on a case-study that concerns OE *hnutu* 'nut' place-names and trying to determine which species might be represented in these names, or whether the reference is to more than one nut-bearing tree. Usually this name has been glossed simply as nut, but hazel has also been suggested. Hazel place-names are common in their own right and so the use of *hnutu* instead seems significant. The distribution of *hnutu* names favours the southeast, which prompts the question of whether this is a regionally distinct linguistic choice, or whether perhaps there is something of ecological interest going on. These *hnutu* sites often seem to have more in common with oak settlements than with hazel, which has led me to consider sweet chestnut as a possible alternative, or perhaps mixed oak-chestnut woodland.

I've found that oak, beech and hazel names are present in the regions where *hnutu* names appear most frequently, which is what initially got me seeking a potential alternative in sweet chestnut, although that seemed like too simple a suggestion even before I came across your research. I'm currently more inclined to think *hnutu* may have indicated an area of mixed nut woodland or wood pasture, but this is only a tentative theory. It's all still a bit of a conundrum.
I've enclosed a preliminary map of the distribution of oak, beech, hazel and *hnutu* names that are first attested by the end of the 12th century (a cut-off point that aims to avoid later medieval linguistic influence).

RJ - I am v interested in IoW as it is presently the earliest verified site for sweet chestnut wood (branchwood, radiocarbon dated to 7th century AD) potentially grown nr where it was found. This was in Alverstone Marshes next to Brading Roman villa and near the ancient woods of Borthwood Copse which have big sweet chestnut coppice stools...and an early medieval history...

it would be nice to try to tease out any different meaning from the 'nutty' place names between woods valued and harvested for nuts i.e. orchards or groves; and woods bearing nuts probably valued for mast for swine and also sheep and cattle...see in my papers the ref to Lambarde re Kent. Domesday says a lot about swine...

there's also a potential link between honey and nuts, as sweet chestnut is renowned in continental Europe as a honey tree and of course this goes v well with nut growing...

Domesday has some useful info on honey as a payment - which interestingly some archaeologists and onomasts think indicates survival of British people within the Anglo-Saxon settlement...

and near here in Newport Monmouthshire there is a wood called Coldra, which apparently originates from old French 'coudraie' meaning coppice especially hazel for nuts - I was intrigued when I first found this in Eton College Records, as I always thought of hazel coppice as an abundant woodland type especially by the 12thC so how could you name a wood as 'the hazel coppice' and distinguish it from all the others - so I wondered whether this was a distinction for a hazel wood managed for nuts, as opposed to just coppice - which might indicate some deliberate selection for nut-bearing varieties...I am interested in this area as it is where the first written record for sweet chestnut was found (the Goldcliff Priory charters) and nut production would probably have been the objective for sweet chestnut here also (perhaps the Roman estate at Langstone, between Caerleon and Caerwent), so maybe we have hazel and sweet chestnut nut groves as an estate land use...

my question is - is there a name difference between nut groves/orchards for people and nut woods for animals...

JT - The IoW name is Nettlestone, which seems to mean 'Farm at or called Nuteles', which is itself an older place-name meaning either 'nut pasture' or 'nut clearing' (Watts 2004, 432). The first attestation is in DB, but the Nuteles part could be and probably is a lot older. It's rather exciting how early the radiocarbon date for sweet chestnut is there.

RJ - looking at BHO, gives this: *NETTLESTONE* (Hotelestone, xi cent.; Hutleston, Nutteleston, Notteleston, xiii cent.) so is this 'Hotelestone' (if an accurate citation) a *hnutu* form?
the location here relative to Brading does give a potential link with sweet chestnut as the 'nut', rather than immediately assuming it's hazel (or oak).

I did not point it out before, but the genetic studies for oak/beech/hazel and sweet chestnut all point to deliberate selection for good nut varieties and their translocation across the landscape, overlying the natural spread of those species post LGM, so we should expect to see 'ordinary' nut woods which have a general mixture of genotypes, and 'special' nut groves which have selected varieties (taste, low tannin, ease of peeling, good flour making, size, annual regularity, etc). e.g. the gross difference we can now see between hazel nuts and filberts; or ordinary woodland chestnuts (French *chataigne)* and special orchard chestnuts 'marrons'. ..maybe this is what the early place name variants might be reflecting...

JT - It's really interesting that genetics supports the idea of deliberate selection and I certainly think this could be reflected in place-names. There may be parallels here with place-names that denote fruit production, which could be interesting.

The earliest forms of Nettlecomb in both Somerset and Dorset appear to be OE *netel* 'nettle', there are no attestations that I can see which might suggest *hnutu* or *hnot* and an early sound change from u/o to e would be unlikely. What about them makes you think nut would make more sense in this context?

I've had a very quick glance through the *netel* corpus to see if there are any parallels in early spellings and I can't see any medieval Nettleton names with an -s-, or any that begin with H, like the earliest attestations of Nettlestone (IoW). There does seem to be something different going on with this name.
To expand a bit on Watt's gloss: P.n. *Nuteles: *hnutu+laes* 'pasture/meadow with the nut-tree(s)' or *hnutu+leas* (gen. sg. of *leah*) 'clearing/open space of the nut-tree(s)'. Use of 'pasture' perhaps suggesting wood-pasture for livestock, although I'm not aware of any direct link between *laes* and woodland and I can't think of any other tree species I've seen it compounded with. I'll have to have a think on that.

RJ - well, traditional continental practice with nut growing was for intercropping, so an orchard type structure for the nut trees with grazing or even arable underneath/between - this enabled the ground to be kept clean = easier for collecting nuts when shaken down (as was typical) and gave better growing conditions for nuts to ripen etc, also gave ground for pigs/sheep/cows to clean off after harvest

I am pretty sure we should think of nut groves as 'orchards' - so *hnutu+laes* makes sense to me!

it's interesting that there are so few mentions of nuts as tithes or payments, none in DB that I can find??

also interesting that there's an association in DB with land valued for swine and payments of sesters of honey

and remember that royal, noble and especially monastic/ecclesiastical estates had a huge need for wax (candlewax) and they favoured clean burning beeswax cf tallow because the soot from tallow ruined their decorations and MS and vestments etc - wax from small-leaved lime and from sweet chestnut was favoured due to clean and sweet burn...(so I've been told from current preferences, I don't know whether there is any evidence in archives for such judgments)

wax honey nuts swine = wood pasture & orchards…

JT - There's an excellent new journal article that has just been released in JEPNS (2017) by Sarah Wager. She re-analyses the duality of *lēah,* as meaning both 'wood' and 'clearing', and comes to the conclusion that *lēah* names should be defined as 'light areas' that are surrounded by woodland. She says that:
'a *lēah* might have been used for pasture, but 'wood pasture' is not a satisfactory translation of *lēah*, because in some cases the *lēah* was cultivated, rather than grazed or browsed, at the time it was named.' JEPNS, 49: 5–16.

This sounds rather like the open orchard cultivation of chestnuts that you mentioned.

The addition of *tūn* 'farmstead' to the pre-existing *Nuteles* place-name could be quite significant. This is the only 'nut' major or minor medieval name with *tūn* that I have discovered. When combined with a fruit (apple, pear, plum), *tūn* seems to imply an orchard, possibly for surplus production. There are lots of other nut-*lēah* names (I have collected seven others), and *lēah* is a topographical element, which means it didn't necessarily indicate a settlement initially. *Tūn*, on the other hand, is habitative and in this context perhaps implies the establishment of a farmstead at *Nuteles*, possibly for, or as the result of, a more focused cultivation of nuts on a pre-existing 'nutty' site.

Appendix N

Shipwrecks

The earliest record found was from the '*Aber Wrac'h 1*' wreck in Brittany (NW France): the ship was dated to the 15th century AD (L'Hour and Veyrat 1989). In the hull was a mixture of plant remains interpreted as food for the ship's crew:

The carpological analysis of the 'Aber Wrac'h I' wreck essentially relates to the feeding of the ship's company. Thirteen different macro-fossil plants were identified; seven are cultivated species or considered as such. The others belong to the wild flora. Specimens of fruit present were walnuts, hazelnuts, chestnuts, grape pips, a few plum stones and apple pips. Many rye seeds were identified, and the three wild flora identified are typical of cornfields. Common to all the alimentary species identified in the wreck is the ability of their fruits to survive storage for a long time. In addition, these fruits concentrate very nutritious substances (chiefly carbohydrates and lipids) in a small bulk.

The next earliest record was for the '*Arade 1*' shipwreck in Portugal (Domínguez-Delmás *et al*. 2013): this wreck was dendrochronologically dated to have been constructed using oak and sweet chestnut timbers felled *c.* AD 1580; the sweet chestnut was dendroprovenanced to have grown in the Pays de la Loire region of France.

The first shipwreck record from the British Isles was found in the 'Calendar of State Papers relating to Ireland' from the time of Charles 1 (AD 1628): it appears to indicate that chestnuts were being transported with a cargo of wine, although it is unclear whether the chestnuts were loose or bagged (sacked):

Feb. 4. Dublin (?).

916. Sir Edward Bagshawe to Secretary Nicholas.

Eight days ago there arrived at the Skerries, twelve miles from this town, a ship of 80 tons (Commander Roger Deane), with two prizes of French wines. Deane petitioned the Deputy to be allowed to unload and sell one here, saying she was too leaky to go to England. The Commissioners appointed to examine the matter (including Sir Beverley Newcomen and myself) found this to be the case with one. The other was a good Flemish ship, with French wine, but the four feet of chestnuts which covered the wine will make it sour, colourless, and unsaleable in a short time. The Lord Deputy gave leave to sell the ships, but I fear they will not be good prize unless they can be proved to be derelict, which there is some ground to expect. You shall hear what goes on in the matter. Kindly let me know how his Grace would have me proceed. *P.* 1. *Endd.* (*Hol.*)

March 8 1628 Skerries? 953. SIR EDWARD BAGSHAWE TO SECRETARY NICHOLAS.
The two Dutch ships which were brought into Skerries were not sold there owing to the orders of the Deputy, but were taken to Strangford, and there the goods and ships were sold to one Valentine Payne, His Majesty's customer. He gave them 5001. and provisions, and said they should have more, and a fair share, of the purchase money. The wine was sent up by sea to Dublin to be sold, and passed by here [Skerries]. As it paid no tonnage I seized what came here, and sent down an officer to do the same at Strangford. I am the only officer who does things of this kind, though I have no authority. The Vice-Admiral (the Lord Chancellor) is forbidden by the Lord Admiral from taking any part in such matters, and everybody does just what seems good in his own eyes. Send me instructions.

Some shipwreck reports from the central Americas from the 16th and 17th centuries AD relate to Spanish shipping and trading. The Western Ledge reef shipwreck (Watts 1993) was recorded as: *Pumpkin stem (Cucurbita pepo) of a variety that was grown in the pre-Columbian New World was also recovered from the Western Ledge Reef wreck site, similar to a possible pumpkin seed (cf. Cucurbita sp.) recovered from Emanuel Point II. Chestnut twigs (Castanea dentata) are also reported among the remains. Also, two rather unique items, a legume seed pod (Cassia fistula) originating from southeast Asia and often used in traditional medicines, and samples of what are rhizomes or tubers, likely Jerusalem artichoke (Helianthus tuberosus), which is native to North America and was cultivated by Native Americans, were recovered. Similar to Emanuel Point I, pieces of hemp cordage (Cannabis sativa) were preserved. This data, along with other parts of the material culture assemblage, were used to help elucidate the voyage of this vessel, suggesting that it was perhaps navigating in North American waters and trading with Native Americans in the late sixteenth century.*

A later record of the shipwreck of the Spanish fleet off Tortugas (Florida) in AD 1622 reported finds relating to the ship the '*Buen Jesus*': *Juan de Cespedes loaded packaged food, quince meat, hats, fabrics, raisins, hazelnuts, almonds and chestnuts bound for the city of Nueva Cordoba. The merchandise was consigned to Luis de Lemos, and in his absence to Diego Lopez Aries, and in the absence of both to Gaspar Fernandez Rebelo, all citizens of Cartagena*. (Kingsley 2013).

Appendix O.

The archival records of purported sweet chestnut *Castanea sativa* wood/charcoal/nuts/pollen in Britain, dated from AD 650 to AD 1350.

HE = Historic England; ABCD = Archaeobotanical Database (Tomlinson and Hall, 1996)

Period	Type of find	Site	Original reporter and citation	Brief description
AD 400-1350	Pollen	Pins Knoll, Litton Cheney, Dorset	Sidaway (1964), cited in Waton (1983)	Primary source checked: no dateable context was described for the pollen, so this record cannot be verified for any period.
	Charcoal	Ben Bridge, Chew, Somerset	Metcalfe & Levy (1977), cited in Smith (2002)	Primary source checked, but no information to verify the find was found. Gill Campbell (HE) advised that searching for archived specimens would not be productive.
	Charcoal	Testers, West Sussex	Cartwright (1988), cited in Smith (2002)	Primary source checked: Cartwright recorded *Castanea* charcoal (2.5 g) found in "Context 152 medieval pit fill". Not verified.
	Charcoal	Langhale, Norfolk	Jones (1976), cited in Groves et al. (2001)	Primary source checked: 77 g of "Castanea sp. (Sweet Chestnut)" charcoal was recovered from the west end of an 11th century pottery kiln (Jones 1976, 127). Murphy and Macphail (1985, 61-62) discuss this site: "Its [sweet chestnut] use for such a humble purpose serves to confirm that the tree was naturalized in Norfolk by this date and there is thus no need to suggest importation of timber for use in the church". Not verified.
	Charcoal	Norwich Castle, Norfolk	Murphy and Macphail (1985), cited in Groves et al. (2001)	Primary source checked: charcoal from posthole fills of buildings B and C (late Saxon) was identified as "*Castanea* sp. (chestnut, mature wood) (Murphy and Macphail, 1985, 61). Not verified.
	Charcoal	North Street, Lewes, East Sussex	Cartwright (1976), cited in ABCD as Site 1467.	Primary source checked: Cartwright found *Castanea* charcoal in Pit 33 (Trench B) of Norman context, possibly up to early 14th century AD (the number and characteristics of charcoal specimens were unreported). Not verified.
	Charcoal	Lewes Friary, Lewes, East Sussex	Dobinson (1996), cited in Smith (2002)	Dobinson (1996, page 115) summarises the charcoal results, including: "The friars… were chiefly concerned with the provision of fruit and timber… Pomoideae and *Castanea* being orchard trees and *Populus/Salix* as hedges… and *Betula* used

				for timber": these assertions were unreferenced. Not verified.
	Charcoal	Northolt Manor, Middlesex	Levy (1961), cited in ABCD as Site 1748	Primary source checked: 1 piece of *Castanea* charcoal from a twig, with *Fagus* (beech) and *Pyrus* (pear) twigs, in a tiled cooking hearth of AD 1300–1350. Not verified.
	Charcoal	Barnett's Mead, East Sussex,	Cartwright (1981), cited in Smith (2002)	Primary source (Cartwright in Hadfield, 1981) checked: a total of 11 g of "*Castanea sativa*" charcoal was recorded in total, from context 16 which "lies directly beneath plough soil" and context 42 – a "post-kiln layer" (page 92) (see charcoal results in table 3, page 105). "The other trees represented in small quantities – the sweet chestnut (*Castanea sativa*), and birch (*Betula* sp.) probably occur as fuel from gathering of any locally available timber." (page 104). Not verified.
	Charcoal	Brooman's Lane, Lewes, East Sussex	Cartwright (1983), cited in Smith (2002)	Primary source (Cartwright in Rudling, 1983) checked: "Castenea [*sic*] sativa" was recorded from medieval contexts but Cartwright does raise issues about urban deposits and context disturbance (page 62). She also states that "a number of the trees represented i.e. sweet chestnut, pear/apple, yew, would have been growing in the back gardens of medieval tenements in this area (or possibly in local churchyards": these assertions were not referenced. Not verified.
	Charcoal	Church Street, Seaford, East Sussex	Cartwright (1978), cited in Smith (2002)	Primary source (Cartwright in Freke, 1978) checked: "Castanea *sativa* (Sweet chestnut)" charcoal was recovered from cess pit and well features (page 222). Not verified.
	Charcoal	Alsted, Surrey	Western (1976), cited in Smith (2002)	Primary source checked: Western in Ketteringham, (1976) reported "*Casternea* [*sic*] *Sativa* [*sic*] sweet chestnut" listed amongst other charcoals (including oak) recovered from a Period 3 (c. AD 1395–1405) industrial site (Site 3). Not verified.
	Charcoal	Nuthampstead (The Warren, Scales Park) Hertfordshire TL 4200 3426	Williams (1946), cited in Godwin (1975)	The charcoal assemblage from a hearth within a Medieval moated site consisted of 11 fragments, of which two pieces were identified as *Castanea* by Hyde (1946, 144) – "out of 11 small fragments of charcoal all but three were identified as follows: Ash 3 pieces; Oak 3 pieces all very slow grown, the rings too close and indistinct to be counted; Sweet Chestnut 2 pieces (a) part of a small branch with the base of a branchlet 0.6x0.8x2.0 cm; (b) more mature wood 0.8x1.0x2.1 cm" – dated to AD 13th century. The charcoal

				specimens were not searched for, so not verified.
	Wood	St Martin-at-Palace Plain, Norwich, Norfolk	Hillam (1991); cited in Groves et al. (2001)	Primary source checked: post-medieval (late 16th century) barrel well (feature 1079) boards were identified as "sweet chestnut (*Castanea sativa*)" (pages 127, 128 and microfiche Table 30). Not verified.
	Nut	Watermark Place, London	Fowler & Mackinder (2014)	Primary source checked: Davis in Fowler and Mackinder (2014, 92) reported a "complete fruit of sweet chestnut (*Castanea sativa*)"; from Sample 6, Context 410, Open Area 1 (a jetty inlet). Anne Davis (MOLA) reported (2015, personal communication) that the chestnut nut came from a late 13th century waterfront dump and was most likely to have been spilled during unloading of a cargo, so not evidence for chestnuts being grown locally. A Corporation of London Records Office reference from the late 1260s (transcribed by Riley, 1859) details the 'scavage' [import/export duty] of sixpence for a cargo [4 cwt] that included figs, raisins and chestnuts. Anne Davis (2015, personal communication) suggested that the chestnut fragment could be in the MOLAS Archives store. Not verified.

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9. Supporting material

9.1 Conference posters (pdfs available on request)

- QRA Conference, London
- EAA Conference, Glasgow
- AEA Conference, Nottingham
- SNSBI Conference, Norwich
- Tortworth exhibition, Tortworth Court
- Woods of Essex (Oliver Rackham memorial Conference), Gilwell Park

9.2 Conference presentations (powerpoints available on request)

- AEA, York
- Tree archaeology, Sheffield
- Ancient Tree Forum Conference, Hereford
- NT Conservation Conference, Ireland
- Coppice forests in Europe Conference, Antwerp
- Eurocoppice Conference, Chatham