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Archaeological Palaeoenvironmental Archives: Challenges and Potential

PhD

School of Geography, Archaeology and Environmental Science

Paul Flintoft

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Archaeological Palaeoenvironmental Archives: Challenges and Potential

Abstract

This Arts and Humanities Research Council (AHRC) sponsored collaborative doctoral project represents one of the most significant efforts to collate quantitative and qualitative data that can elucidate practices related to archaeological palaeoenvironmental archiving in England. The research has revealed that archived palaeoenvironmental remains are valuable resources for archaeological research and can clarify subjects that include the adoption and importation of exotic species, plant and insect invasion, human health and diet, and plant and animal husbandry practices. In addition to scientific research, archived palaeoenvironmental remains can provide evidence-based narratives of human resilience and climate change and offer evidence of the scientific process, making them ideal resources for public science engagement. These areas of potential have been realised at an imperative time; given that waterlogged palaeoenvironmental remains at significant sites such as Star Carr, Must Farm, and Flag Fen, archaeological deposits in towns and cities are at risk of decay due to climate change-related factors, and unsustainable agricultural practices. Innovative approaches to collecting and archiving palaeoenvironmental remains and maintaining existing archives will permit the creation of an accessible and thorough national resource that can service archaeologists and researchers in the related fields of biology and natural history. Furthermore, a concerted effort to recognise absences in archaeological archives, matched by an effort to supply these deficiencies, can produce a resource that can contribute to an enduring geographical and temporal record of England's biodiversity, which can be used in perpetuity in the face of diminishing archaeological and contemporary natural resources.

To realise these opportunities, particular challenges must be overcome. The most prominent of these include inconsistent collection policies resulting from pressures associated with shortages in storage capacity and declining specialist knowledge in museums and repositories combined with variable curation practices. Many of these challenges can be resolved by developing a dedicated storage facility that can focus on the ongoing conservation and curation of palaeoenvironmental remains. Combined with an OASIS + module designed to handle and disseminate data pertaining to palaeoenvironmental archives, remains would be findable, accessible, and interoperable with biological archives and collections worldwide. Providing a national centre for curating palaeoenvironmental remains and a dedicated digital repository will require significant funding. Funding sources could be identified through collaboration with other disciplines. If sufficient funding cannot be identified, options that would require less financial investment, such as high-level archive audits and the production of guidance documents, will be able to assist all stakeholders with the improved curation, management, and promotion of the archived resource.

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‘Declaration: I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.’

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Chapter One - Introduction

Archaeological Archives

The rationales that support archaeological archiving have their roots in the epistemological enquiries and achievements of Aristotle in the third century BCE (Barnes 1982; Pearce 1999; Harrison *et al*. 2016). These can be characterised by a drive to create collections of the natural world, such as plant and animal specimens, to make empirical observations and develop hypotheses regarding the natural world (Doer and Iorizzo 2008). The formalised notion of collecting for empirical observation has accompanied the development of the sciences throughout Europe and have become mandatory apparatus, providing empirical frameworks for the classical naturalists and early scientists, and continuing to play a vital role in contemporary scientific enquiries (Findlen 1994; MacGregor 2000).

Archaeological archives sit within this European tradition of maintaining evidential materials from scientific investigations and retaining them for future scientific use (Lucas 2012). Within the domain of archaeology, the most conducted form of data collection and experimentation is the excavation (Evis 2016). The archaeological archive is the legacy of excavation and interventions and can be used perpetually to test and re-test theories and allow the data to be repeatedly reinterpreted and synthesised (Oniszczuk *et al.* 2021). Therefore, a selection of materials recovered from archaeological excavations is retained in a museum or repository for use and reuse in future research and public science outreach (Perrin *et al*. 2014). The selected materials comprise the final archaeological archive and can include photographs, drawings, paper records, digital data, artefacts, ecofacts and samples collected from archaeological investigations (Brown 2011).

Despite the benefits for enduring research that archaeological archives can offer the research community and public science communicators alike, the topic of archiving has too often been an afterthought and has not received the intellectual or financial consideration the subject deserves (Oniszczuk *et al.* 2021). This is highlighted in the opinions of collection and archive-based researchers, heritage analysts, and museum professionals, who have argued that in the minds of many archaeologists, 'doing archaeology' means 'doing fieldwork' (Frieman and Janz 2018). Field-centric thinking has consequently perpetuated a disregard for the rich body of archaeological remains diligently excavated and archived in museums and repositories for reuse and re-analysis (Huster 2013). We are, therefore, swiftly led to an unwelcome realisation – if no one uses the archived archaeological resource, why collect it? (Bauer-Clapp and Kirakosian 2017; Swain 2003).

The apparent reluctance to use archaeological archives with greater frequency is unfortunate. This fact is especially pertinent for palaeoenvironmental science, which has burgeoned over the last couple of decades with developments in DNA applications (Gómez-Zeledón, *et al*. 2017; Schlumbaum *et al.* 2008; Fernández *et al.* 2013; Green *et al*. 2017), stable isotope analyses (Bogaard *et al.* 2016; Macko *et al.* 1999; Stroud *et al.* 2021) and advances in morphometrics (Portillo *et al.* 2020; Jesus *et al.* 2021). Furthermore, remains stored for decades or centuries can be reused to learn new things about previously unexplorable topics.

Globally, archaeological archiving is experiencing many challenges and tensions (Kersel 2015 and Flexner 2016). In England, the 'curation crisis' has developed and multiplied over the last 30 years since contract-led archaeology has been conducting field investigations at a rate that has outpaced Collecting Institutions' capacities (Willis 2018). The challenges include declining space and limited investment to develop the capacity to store archives and provide in-house expertise, coupled with staff shortages due to budget cuts and loss of revenue streams (Boyle *et al.* 2016). Historic England commissioned a series of research projects to understand better these challenges as part of the Future for Archaeological Archives programme, which responded to Mendoza's independent review of museums in England (Mendoza 2017). The research projects include: i) reviews of archive rationalisation (Baxter *et al.* 2018), ii) standardisation of fees for charging for transfer (Vincent 2019), iii) alternatives for storage capacity (Tsang 2017), and iv) improving selection, facilitated by the Selection Toolkit for Archaeological Archives developed by Historic England and the Chartered Institute for Archaeologists (CIfA 2019). This thesis accompanies these recent research projects by contributing best practices and identifying solutions to the curation crisis.

Archiving Archaeological Palaeoenvironmental Remains

Archaeological palaeoenvironmental research is a sub-division of environmental archaeology - namely, the study of animals (zooarchaeology), plants (archaeobotany), geology (geoarchaeology) and ecology and (palaeoecology) (Howard 2019; Wilkinson and Stevens 2003; O'Connor 1998). Palaeoenvironmental research involves the reconstruction of past environments using proxies preserved in archaeological contexts, which requires "*knowledge of species' ecological tolerances, geographic ranges, habitats, environments, and niches"* (Lyman 2017 pp 315). The palaeoenvironmental materials in archaeological archives typically include charred and waterlogged seeds and chaff, phytoliths, wood and charcoal, insect remains, pollen and diatoms, snail shells, bi-valve shell, eggshells, preserved hair and fur, and microfauna such as ostracoda, diatoms and foraminifera. These remains could be preserved in various contexts such as waterlogging, charring and mineralisation (Green 1979; Campbell *et al*. 2011). Large mammal remains have specifically been excluded following advice from the Historic England. Large mammal remains have a defined history within archiving and have received more significant consideration than non-faunal palaeoenvironmental remains (see LeFebvre 2019; Rainsford 2014). Therefore, large mammals are regarded as a separate challenge that falls outside the remit of this project.

Consulting literature regarding archaeological archiving and the role that ecological specimens have for long-term use and reuse, three fundamental contemporary opportunities emerge: i) research value, ii) public science communication currency, iii) their role as enduring evidence in the face of diminishing natural resources i.e. biodiversity (McGhie, H.A. 2019; Oniszczuk 2021; Swain 2012; Brown 2011). The first of these themes, research value, has been increasingly realised in recent years, as evidenced by the following quote from Zoë Hazell, Historic England Senior Palaeoecologist.

> *"the research value of archaeobotanical and other environmental materials stored within archaeological archives, some of which have been kept since the 1880s. As such, it is exciting to think about the untapped potential that currently sits within archives, and also how samples we recover now may be used in the future"* (Hazell in Krakowka 2019).

This comment, in relation to Jarman *et al.* (2019) research into the introduction of (*Castanea sativa*) sweet chestnut to England, highlights the potential for research that archived remains can contribute towards. In recent years, the research potential of archived remains has been realised by researchers as part of projects including Feeding Anglo-Saxon England, which has sourced archived faunal, and botanical remains from across England to elucidate Anglo-Saxon agricultural practices (Hamerow *et al*. 2019). Although there is clear research potential, it is unclear how frequently the palaeoenvironmental components of archaeological archives are accessed by researchers, especially if the comments of Swain (2003), Frieman and Janz (2018), Bauer-Clapp and Kirakosian (2017), regarding the limited use of archived resources, are correct. This study, therefore, sets out to determine the perception and use of archived remains in the face of the seemingly low frequency of use.

The use of palaeoenvironmental remains in public science engagement is an area with promise, especially in view of the climate change-related themes that make up headlines almost daily (Monbiot 2022; Olteanu *et al.* 2015). Palaeoenvironmental remains can be used in evidence-based education opportunities to articulate human-environment relations and human resilience in museum-based learning environments (CIfA[1] 2019; St Amand 2020; Pearson 2019). The role of museums in education has received a great deal of published literature (Hawkey 2004; Mujtaba *et al.* 2018; Bourdieu 1979; Bennett 1995), as has the teaching of climate-related topics (Rockman and Hritz 2020; Monroe *et al.* 2019; Cameron *et al*. 2013). Absent from the literature is how palaeoenvironmental remains can be used in display and participatory led communication. This project uses this opportunity to examine how archived remains can be utilised for this purpose.

A clear and significant opportunity for archiving remains, is revealed through climate change-related pressures, including the drying of wetlands, bogs, and moors which is causing significant threats to environmental archaeological resources, potentially reducing occasions for future fieldwork such as the Somerset Levels, Must Farm, and Star Carr (Knight *et al.* 2019; Brunning 2013; Pearson *et al.* 1997; Van de Noort 2013; Burke *et al.* 2021). Having curated and accessible archived palaeoenvironmental remains representative of England's human-ecology relationships and biodiversity can protect archaeology from a depletion of material remains. As non-renewable archaeological resources deteriorate, the research currency of palaeoenvironmental remains will surely increase due to their rarity.

Another opportunity for England's palaeoenvironmental archives is to contribute substantially to England's record of biodiversity. Biodiversity is a topic of renewed scientific in the context if increasing habitat losses. Creating a record of biodiversity has traditionally been the role of natural history, a discipline that discovers, classifies, and taxonomically organises extant and extinct biodiversity (Cotterill and Foissner 2010; Greene 1994). Natural history museums aim to be comprehensive in their collections, with material ranging from palaeoenvironmental samples and specimens that are palaeontological and archaeological in nature, to specimens that have lived over the last few years (Johnson 2007; Strasser 2012; Jardine *et al.* 1996; Minteer et al. 2014; Cucchi *et al.* 2017; Mol *et al.* 2006; Peeters and Amkreutz 2020). The remit of archaeological practice has not included the collection of remains with the intention of contributing to a national or global record of biodiversity.

Footnote 1 – The Chartered Institute for Archaeologists (CIfA) is an organisation that promotes ethics and standards and archaeology both overseas and the UK (https://www.archaeologists.net/about).

However, with declining opportunities to return to sites that have been so productive in the past (see Star Carr - Catling 2013; High and Penkman 2017; Milner et al. 2011 and Flag Fen - Powell 2001; Taylor 1992 as examples) to collect additional material, coupled with declining global biodiversity (Lanz *et al.* 2018; Mora and Sale 2011; McKee 2003), perhaps archaeological practice could contribute towards the development of a geographic and temporally comprehensive record of life on earth. Currently, mechanisms such as the archaeological archive selection process do not include any recourse to consider how certain remains can contribute to England's record of biodiversity.

Amongst the potential opportunities that archived palaeoenvironmental remains can realise, there are many challenges that need to be overcome. For example, in addition to being exposed to the wider 'curation crisis' (see Chapter Two), it is recognised that some museums do not accept environmental samples and collecting institutions do not accept waterlogged remains (SMA 2020). The reluctance to accept environmental remains and waterlogged items may be creating biases in archival representation. Comprehensive representation can allow for multi-proxy palaeoenvironmental research to be conducted, and the absence of a comprehensive range of remains may prove detrimental to the success of archive-led palaeoenvironmental research (O'Brien *et al.* 2005; Gearey *et al.* 2017). In the interest of providing a wide array of remains for research, appropriate collection policies and selection strategies that allow for the collection of palaeoenvironmental materials must be achieved. Identifying the extent to which failures to collect remains and recognising the methods by which all palaeoenvironmental remains can be archived for future research and revaluation by subsequent generations is a priority of this project.

How current researchers and subsequent generations can find and access archived palaeoenvironmental remains also requires consideration. There are digital tools for storing and disseminating digital data relating to excavated palaeoenvironmental remains, but it is unclear how these incorporate and prioritise archived remains (Jarman *et al.* 2019; P Buckland 2022 personal communication 13 March). Additionally, developments in digital data dissemination, such as the FAIR (Findable, Accessible, Interoperable and Reusable) principles, are introducing new standards and techniques for handling digital data (Wilkinson *et al.* 2016). Institutions and organisations outside archaeology have quickly embraced FAIR principles and harnessed their potential. Functional ecologists, natural history practitioners and biodiversity scientists have successfully disseminated natural history collections to users globally. Concepts such as 'the global museum' (Bakker *et al.* 2020) and practical advances through initiatives such as the Extended Specimen Network have used web-based tools to provide open access to biological museum collections. These developments may yield positive results for the accessibility and sharing of archived palaeoenvironmental remains and, as a topic, require further elucidation.

An additional clear challenge is the ongoing conservation and curation of palaeoenvironmental remains. Archaeological palaeoenvironmental archives are distinct from their non-organic counterparts as they demonstrate a fragility and propensity to decay, which does not readily threaten materials such as ceramics and lithics (Coles and Coles 1986; Dincauze 2000; Purdy and Clark 1987; Royce *et al.* 2021). Consequently, they require curatorial methods that are equally distinct and promote long-term conservation. The curation of palaeoenvironmental archives is a topic that has received little consideration from the archaeological community and requires an evaluation of best practices gleaned from archaeology and adjacent practices such as natural history. To date, there have been numerous guides that have outlined broad recommendations (see SMA 2020; Brown 2011 for example) of how-to curate palaeoenvironmental archives. These documents are broad and no not have a wide-ranging appeal and do have not have the remit to identify best practice of archaeological palaeoenvironmental archiving. This dearth of prescriptive and detailed advice has led curators and keepers of archaeology to feel that they require further advice that relates explicitly to palaeoenvironmental archiving, as highlighted by the comments below.

> *"As the curator of a collection that holds a large number of environmental archives, I would appreciate more assistance and improved signposting to help me find out about best practice."* A Khreisheh (Curator of Archaeology at South West Heritage Trust) 2018 personal communication 19 December.

> *"I am very open to learning about new approaches and ways of doing things, but it is hard to find out about new developments. It would be useful to have information that uses real-world science projects that examine the chemical and biological sciences relevant to the archiving of environmental remains."* S Wilson (Archaeology Development Manager and Team Leader at Vivacity Peterborough Culture and Leisure) 2019 personal communication 8 February.

> *"Yes, I would appreciate guidance on the subject (of palaeoenvironmental archiving). It would be useful to know more about how to store such items and also how to make these archives available to researchers*." M Jasko-Lawrence (Curator of Archaeology, Museums Sheffield) 2018 personal communication 23 August.

To resolve the challenges relating to promotion and use, curation practices and archive creation methods, this thesis examines what challenges and potential opportunities exist within these themes and identifies areas of best practice.

Project Aims and Objectives

The original project aims and research questions outlined in the January 2017 Collaborative Doctoral Agreement (CDA) and the March 2017 CDA proposal are outlined below. The aims are supplemented with updated aims and objectives designed to add structure and direction to the thesis. Furthermore, the aims and objectives evolved in line with the background and interests of the author.

Original CDA Aim:

-Maximise the potential of palaeoenvironmental remains for academic research and public science engagement.

Original CDA Project Questions:

- What are the threats and opportunities for environmental archaeological archives?
- Which aspects of these archives are especially important to users?
- How can these archives be improved?
- How can theoretical and practice-based developments in public archaeology and science engagement enhance archive potential?

Updated Research Aims

Five updated priority aims have been designed to interrogate the original project questions. Each of the five aims has dedicated objectives that are included to assist in achieving the aims.

Aim one

The first aim of the thesis is to identify and characterise threats confronting the survival of archived archaeological remains whilst simultaneously recognising remedial solutions and controlled environments that can ensure the survival of this archived resource and reduce bias caused by differential decay. Aim one will be accomplished by examining current practices, standards and views of authors and museum curators across museological, archaeological and natural history domains. The following objectives focus on this aim.

Objective 1.1 – Determine where accessioned and undeposited palaeoenvironmental components of archaeological archives are located to glean a comprehensive understanding of where threats to long-term preservation exist.

Objectives 1.2 – Investigate published standards and guidance that promote the conservation of archaeological archives and biological collections, determine areas of best practice and gaps in knowledge, and identify measures to remedy decaying items and improve long-term preservation. Additionally, examine what facilities and standards exist in England's museums and repositories and demonstrate if they can sustain palaeoenvironmental materials.

Objective 1.3 – Examine the efficacy of recognised approaches in conservation by establishing if they are appropriate in a real-world example through an examination of remains in a historic undeposited archive.

Aim two

The second aim of the thesis is to consider how findable and interoperable archived archaeological palaeoenvironmental remains are. Developments in approaches to data sharing have demonstrated theory-practice-based methods that can unify the efforts of data producers and provide measurable principles that determine availability to use and reuse and may expose strengths and weaknesses in the accessibility and findability (Wilkinson *et al.* 2016) of archived palaeoenvironmental remains. Furthermore, identifying weaknesses in the findability of archived remains will facilitate implementation of technological advancement that can increase the frequency of access to and improve resource interoperability.

Objective 2.1 – Examine the platforms, tools, approaches, working cultures and published materials to glean how the dissemination of digital data associated with archived palaeoenvironmental materials is achieved.

Objective 2.2 – Identify emerging concepts in data sharing and discover what approaches to information dissemination are utilised and encouraged across broader domains that engage in ecological inquiry.

Objectives 2.3 – Determine the optimal platform or combination of platforms that can effectively share and promote the data specific to the archived palaeoenvironmental resource.

Aim three

The third aim is to investigate how excavated palaeoenvironmental materials are selected for long-term storage. Cognitive approaches to selection that reflect the project's aims recognise the intrinsic significance and contribute to England's biodiversity record need to be considered to create efficient, manageable archives. Archaeological palaeoenvironmental remains have distinct requirements that will inform the selection process and need to be understood to ensure aspects are not overlooked, resulting in inefficient archives that prevent multi-proxy investigations involving multiple sources of palaeoenvironmental evidence from being performed in the future. The objectives within aim three are:

Objective 3.1 – Identify the stakeholders involved in the selection process and establish their role and understanding of the selection process.

Objective 3.2 – Explore what resources are available to guide stakeholders in their decision-making and determine the efficacy of these resources.

Aim four

The fourth aim of the thesis is to consider how proposed forms of archaeological archive storage, such as the development of regional archaeological archive hubs, can suit the specific needs of archaeological palaeoenvironmental remains. This will be achieved by examining the history of the discourse surrounding the development of additional storage capacity in England and comparing proposed embryonic plans with developments on mainland Europe. Aim four contains two objectives with which to focus the aim.

Objective 4.1 – Determine the frequency with which the archived palaeoenvironmental resource in England is accessed to recommend ways in which access can be increased.

Objective 4.2 – Identify examples of venues that could support repositories and recognise which options would best support, promote and advocate palaeoenvironmental remains and archaeological archiving.

Objective 4.3 – Examine the outcomes of a government-sponsored national approach to developing regional archaeological archive depots and determine the suitability for storing and promoting archived palaeoenvironmental materials.

Aim five

Aim five is to examine how museum professionals and science communicators can renegotiate archived archaeological palaeoenvironmental remains through various physical and digital modes to communicate millennia of human-environment relationships (Harrison *et al.* 2020; Shanks and Tilley 1987; Trow 2018; St Amand *et al.* 2020). This will be accomplished by examining the experiences and approaches of archaeologists, science communicators and natural history museums in their handling of materials similar to those focused on as part of this doctoral research. The following objectives focus on aim five.

Objective 5.1 – Identify the tools and techniques prevalent in science communication and museological practice and determine which are suitable for communicating archived palaeoenvironmental remains.

Objective 5.2 – Examine examples that have successfully articulated palaeoenvironmental remains and ecological specimens to identify appropriate techniques and approaches in science communication.

Structure, Themes and Chapters

Chapter two provides a literary review to offer context to the thesis and highlight the perennial 'big questions' pervading the archaeological archiving discourse, such as accessibility, storage space, frequency of use and the potential for developing new archive storage facilities. A methodology is also provided.

Chapter three establishes areas of best curatorial practice. This is developed using guidance from institutes including the University of Reading Herbarium, the Natural History Museum, Oxford, and organisations such as the Natural Science Collections Association. To achieve this, a range of dry and wet archives will be considered using recent advances in conservation science, and controlled environment management for each class of palaeoenvironmental material will be determined. Using the established best practice, examples from museums and repositories are examined to identify how practices compare to real-world examples. These comparisons highlight areas that require priority consideration to ensure the long-term conservation of the archived palaeoenvironmental resource.

Chapter four uses results from chapter three to examine how recommended forms of curation and conservation can be utilised to stabilise materials that has not been accessioned. The chapter uses the Wilsford Shaft as a case study to demonstrate how a decades-old materials can be reassessed. The chapter also identifies what resources can be introduced to ensure the archive meets contemporary standards and recognise the research questions to which it can contribute to.

Chapter five considers the practicalities of improving individual museum practices to ensure they can provide the facilities necessary to curate palaeoenvironmental archives and additionally examines the potential for developing a single specialist archive facility. A review of potential solutions is examined to determine which options would best suit the needs of archaeological palaeoenvironmental archives through an examination of themes including accessibility, public benefit, cost-effectiveness and the desires of stakeholders (Mendoza 2017). Finally, short case studies from Flag Fen, Cambridgeshire, Fort Cumberland, Hampshire, and a consideration of the Netherlands model of regional archaeological repositories are examined.

In addition to examining new forms of storage for palaeoenvironmental archives, a methodology for audits of museum stores is also proposed. Museum audits can provide enhanced data regarding palaeoenvironmental archives' contents, condition, and potential. This section of Chapter five is achieved through a case study example conducted at the Somerset Heritage Centre, Somerset. The Somerset Heritage Centre was selected for the case study as they hold many archived palaeoenvironmental remains.

Chapter six examines challenges in accessing archive data (Jarman *et al.* 2019; Lodwick 2016). The challenges can be summarised as incorrect or missing metadata and data and sub-optimal promotion and dissemination practices. Improved dissemination methods could allow for increased use of the archived palaeoenvironmental resource and lead to more occurrences of reuse. This chapter examines how the digital data that locates and links palaeoenvironmental archives can be better mobilised and identifies if new techniques and methods are required.

Chapter seven investigates how the selection of palaeoenvironmental remains can ensure that sufficient remains enter the final archive. The drive for consistent archiving selection has been championed by the Association of Local Government Archaeological Officers (ALGAO), Chartered Institute for Archaeology (CIfA), Federation of Archaeological Managers and Employers (FAME), Archaeological Archive Forum (AAF) and the Society for Museum Archaeology (SMA).

Chapter eight considers the low levels of attention palaeoenvironmental archives have received in the exhibition ecosystem and on the public science stage. The reasons for this are unclear but likely lie in a general unfamiliarity with environmental remains, perhaps due to a perception that they are more akin to natural history and do not possess a straightforward human story. Regardless of the reasons, the subject would benefit from examining the current methods employed to communicate palaeoenvironmental remains and concepts to identify areas for improvement and best practices. To appreciate the current landscape, an examination that extends beyond a collection-centred approach and considers multimedia technology and engagement events is included (Styliaras and Koukopoulos 2012, Barker 2010). This chapter will examine the currently used methods and explore how stored items can be communicated, the less aesthetically pleasing items can be displayed, and palaeoenvironmental remains can be incorporated into storytelling.

Chapter nine will discuss the results from chapters two through eight and provide recommendations for future work and conclusions.

Chapter Two – Critical Literature Review and Survey and Methodology

Introduction

The context and methodology chapter begins with a review of the historical context of collecting and retaining palaeoenvironmental remains in England. This section progresses through the last 150 years, highlighting significant events and publications pertaining to the aims of the thesis. An emphasis on contemporary attitudes, guidance and publications is provided on page 19. Finally, the methodology provides details regarding the methods used to conduct the Research and outlines the selected case studies.

Part 1 - Critical Literature Review

Archiving palaeoenvironmental remains in England – A Historical Context

Early examples of the collection and retention of palaeoenvironmental remains

England's 150-year-old relationship between the recovery of archaeological palaeoenvironmental remains and their retention for future study has been complex. An examination of early forays in archaeological excavation reveals that the retention of excavated palaeoenvironmental remains for future research was rare, with General Pitt-Rivers and J. R Mortimer emerging as pioneering practitioners who recovered, interpreted, and crucially retained palaeoenvironmental remains (Pitt Rivers 1898; Mortimer 1905). Deconstructing the motivations that supported Pitt-Rivers and Mortimer's decision to retain palaeoenvironmental remains reveals judgments based on personal interest rather than predetermined methodological principles dictating archaeological archiving procedures. This is evidenced by the activities of Pitt-Rivers, the celebrated 19th-century collector of archaeology and ethnography, who employed the meticulous attitude of a collector, and retained charcoal from Romano-British deposits at Rotherley, Wiltshire and Woodcutts Common, Dorset, Cranbourne Chase (Larson 2008; Petch 2006; Petch 1999; Pitt Rivers 1898). The Cranbourne Chase charcoal has been subjected to re-analysis, which has revealed historic misidentification and to determine the assemblage's potential to contribute to our understanding of the introduction of sweet chestnut (*Castanea sativa* Mill.) in Britain (Hazell and Campbell 2018; Jarman *et al.* 2019). The re-analysis demonstrates how these early examples of palaeoenvironmental archiving can have an enduring use and purpose.

J. R Mortimer, a part-time antiquarian and seed salesman, had his interest piqued when, in 1865, he identified carbonised wheat seeds whilst excavating deposits at Hanging Grimston barrow, East Yorkshire (Harrison 2009; Mortimer 1882). The professional interest in cereals presumably culminated in their retention. The seeds are currently curated in the Hull and East Riding Museum (Hull Museum Accession number - KINCM:2017.182.1). The examples provided by Pitt-Rivers and Mortimer are conspicuous in their decision to retain palaeoenvironmental remains in addition to the non-biological cultural items, an attitude that, as evidenced by contemporary archaeological archives, differed from their peers. These behaviours hint at a widely held conceptual separation between cultural items and non-cultural biological remains. Rather, biological remains were viewed within the purview of natural history collecting and research (Strasser 2012; Cornish and Driver 2020).

19-century efforts in natural sciences were advancing the methods and practices of collecting and conserving biological items. Influenced by pioneers such as Alfred Russell-Wallace, Charles Darwin, Ernst Haeckel, Wilhelm Roux, and Hans Driesch, the natural history practitioners that were collecting materials included palaeontological samples and 'exotic' specimens and began to focus on describing the idiosyncrasies of species and global biodiversity to detail the phylogenetic 'tree of life' (Bakker *et al.* 2020; Clements 1983; Endersby 2007; Cicuzza 2014; Berry 2013; Smith and Beccaloni 2010; Wieczorek 2012; Levit 2022; Driesch 1908). The effect of these prominent researchers' work was two-fold; i) the development of phylogenetic histories and ii) establishing inductive methodologies for creating a phylogenetic record (Glick & Kohn 1996). These methodological developments in natural history and burgeoning evolutionary science were accompanied by significant technical developments in the conservation of biological specimens, which ensured that specimens would not decay whilst being stored for enduring research opportunities (Duckworth *et al.* 1993; Marte *et al.* 2003). The use of spirits and controlled environments to conserve recently killed specimens (Fagan 2007; https://www.nhm.ac.uk/discover/14-must-see-spirit-collection.html) and palaeontological samples (Brown 2012) became widespread and still influences practices in natural history collecting today (Carter and Walker 1999). Compared to natural history collections, biological remains recovered from archaeological contexts throughout much of the 19th Century did not receive the same technical attention as comparable materials in natural history collecting.

The conceptual separation between the domains of natural history and archaeology began to dissolve at the close of the 19th Century, primarily due to the conformity of aspects of scientific developments such as evolutionary science and ecology (Schiffer 1988; Dunnell 1980; Jones 2005).

One of the most significant examples was the emergence of modern ecology in 1893 and the publications of key texts in the field, such as Warming's 1895 *Plantesamfund* and Drude's plant geography in 1896 (Warming 1895). These publications respectively demonstrated how floristic communities could change depending on factors such as topography and climate and the nuanced floristic mapping and the influence of geography on floristic elements (Bowler 1992; McIntosh 1986; McLaughlin 1994). Influenced by the work of Drude, Arthur Tansley and William Smith established the Survey and Study of British Vegetation committee in 1904, which in 1913 became the British Ecological Society, the world's first society dedicated to ecology (Bowler 1992; Tansley 1947). Ecology as a subject was quickly combined with palaeontology and botany, which developed into the recognised disciplines of palaeoecology, the study of ancient ecosystems (Clements 1916; Clements 1918). In the late 19th and early 20th Centuries, examples of the blending between ecology, palaeoecology, and archaeology emerge.

A prominent example is the work of palaeobotanist Clement Reid and antiquarian Arthur Lyell, who conducted Britain's first large-scale archaeobotanical survey at Silchester Roman Town. Perhaps influenced by Clement Reid, the material was retained for future scientific analysis and currently resides at Reading Museum (Lodwick 2017). The palaeoenvironmental archive from Silchester has recently been re-examined by Dr Lisa Lodwick, who revealed taxonomic misidentifications, demonstrating the enduring value of archaeological archives from the late 19th and early 20th Century (Derrida 1996; Lodwick 2017). It is regrettable then that so few palaeoenvironmental archives from the 19th and early 20th Centuries seemingly exist, and archival practices regarding palaeoenvironmental remains were only sporadically considered.

Critical Approaches to Archiving

As Reid and Lyell were concluding their excavations at Silchester, the subject of archaeological archiving began to receive critical attention. Flinders Petrie observed that museums were collecting archaeological remains and needed to be mindful of the potential challenges on the horizon, as demonstrated in the following statement from the 1904 publication, *Methods and Aims in Archaeology*.

> *"If a site is certain to be destroyed by natural causes, or the cupidity of man, then an imperfect examination and a defective record of it is better than none. But to ensure the fullest knowledge, and the most complete preservation of things, in the long run, should be*

the real aim. To raid the whole of past ages, and put all that we think effective into museums, is only to ensure that such things will perish in course of time. A museum is only a temporary place. There is not one storehouse in the world that has lasted a couple of thousand years. Only two or three bronze statues have come down to us from classical times preserved by each generation. A few pieces of gold work have been treasured for a little over a thousand years, but only in North Italy". (Petrie 1904 pp 180)

As Petrie highlights, a significant aim within the archaeological practice is to ensure that important remains are preserved against their eventual decay, a topic that for palaeoenvironmental remains bears particular relevance. He astutely observes that practices extend beyond simply depositing material in a museum or repository to preserve archaeological remains appropriately. As Petrie indicates, in addition to identifying practical solutions and facilities that can house items, pragmatism should be complemented by well-understood motivations that can support rationales for retaining materials. If appropriately conceived, an enduring impetus for retaining materials that outlast the ephemerality of museum structures can be expected.

Environmental Archaeology Comes of Age

The strategies for collection and retention became more formalised in the mid-20th Century, largely due to significant advancements by the likes of Graham Clark, who broadened the remit of environmental archaeology to consider preservation factors and the improved methods of the excavation of waterlogged deposits (Clark 1939). The excavation conducted by Clark and botanist, Sir Harry Godwin at Star Carr in the 1940s emerged as a significant event in British environmental archaeology and produced an equally significant archive of palaeoenvironmental remains (Saul and Milner 2013). The archaeological palaeoenvironmental archive from Star Carr continues to be researched today, demonstrating how prescient the decisions to archive the remains were (Lodwick 2017; Saul and Milner 2013). Both Star Carr and Silchester share mutual involvement of botanists, which arguably helped to emphasise the significance of the biological remains and may have influenced the various actors involved in depositing the archives in a museum.

In the late 1950s and early 1960s, the collection and analysis of palaeoenvironmental and palaeoecological material became more routinely undertaken within archaeological practice (Gifford 1981; Terry 2009). This is evidenced by the changes in language and nomenclature, which up to the 1960s included terms such as 'vegetation histories,' 'Quaternary research,' ‘Pleistocene research,’ but shifted towards the adoption of terms from the geosciences (Hafsten 1960; Szabó 2015; Zeuner 1959). Titles such as *Petrogenesis and Palaeoenvironment of Devonian Algal Limestones of New South Wales* (Wolf 1965), which use palaeoenvironmental approaches, began to permeate the archaeological literature and authors such as Dimbleby encouraged a focus on soils and sediment for aechaeolgical research (Dimbleby 1962). The adoption of geosciences and geoscience nomenclature demonstrates a move towards a focus on ancient geology and environments and using a range of proxies to elucidate palaeoenvironments. In addition to the change in terminology, there was also a shift towards a more critical use of palaeoenvironmental remains (Revelles 2021). Sites excavated in the 1960s benefited from developments in methodological and theoretical approaches to interpreting palaeoenvironmental materials. Excavations such as the Wilsford Shaft, a 30m Neolithic shaft excavated through the Wilshire chalklands that demonstrated an exceptionally high degree of preservation, produced a wide array of palaeoenvironmental remains (Ashbee *et al*. 1989). Materials including pollen, seeds, plant fibres, cordage, buds, wood, charcoal, mosses, insects, land snails, small vertebrates, animal skin and hairs and parasites were recovered from the shaft. This wide array of remains was used to clarify land use and divisions between pasture and arable land (Ashbee *et al*. 1989). Some of the remains were archived techniques including freeze-drying, whilst others were suspended in fluids and not accessioned, but rather stored in various universities (Ashbee *et al*. 1989). Given the diverse array of materials collected from the shaft and the assiduous approach to archiving, it potentially presents opportunities to re-analyse the excavation using modern methods and techniques. The remains are currently held at the University of Reading and is not managed according to recognised curatorial guidelines. This case study is examined further in chapter four.

Excavations at Silchester, the Wilsford Shaft and Star Carr set the stage for the second half of the 20th Century, and the large-scale research excavations that produced palaeoenvironmental remains propelled the sub-discipline of environmental archaeology. In the 1970s and 1980s, sites including the Bronze Age timber structure at Flag Fen, Peterborough (Pryor *et al*. 1986), the Somerset Levels (Coles 1976), London Waterfront sites (Schofield 1987) and Coppergate, York (Tomlinson 1985; McCobb 2001; Walton 1989) were instrumental testbeds for the formalised discipline of environmental archaeology (O'Connor 1998). However, the absence of guidance or advice regarding archiving palaeoenvironmental remains led to an approach that can be considered variable. For example, museums within Somerset (A Khreisheh 2018 - Curator of Archaeology at South West Heritage Trust - 2018 personal communication 19 December) and London (A Corsini 2019 - Museum of London Archaeology Collections Manager - personal communication 29 January) did not accept waterlogged materials for archive, whereas the York Archaeological Trust were routinely preserving insects from Coppergate in ethanol (Christine McDonnell 2018 – Head of Collections and Archive at the York Archaeological Trust – personal communication 22 August).

The Global Curation Crisis

Excavations conducted in the 1970s and 1980s produced unprecedented large quantities of archaeological materials (Brown 2015). Organisations, including the Council for British Archaeology (CBA) and RESCUE (The British Archaeological Rescue Trust) commented that with the increase in archaeological materials intended for archive, funding for storage capacity needed to be increased if archaeological archives are to be appropriately curated in perpetuity (RESCUE 2005; CBA 1996). Quantities of materials were intensified by the introduction of the Planning Policy Guidance notes (PPG) 15 and 16 in 1990, formally introducing archaeology into the planning system (Wills 2018). In the 1990s, contract-led archaeology began producing material for storage at a rate that has outpaced museums and repositories' capacity to collect archaeological archives (Wills 2018). Merriman and Swain (1999) perceived many of the challenges on the horizon for the 21st Century in their article '*Archaeological Archives: Serving the Public Interest?*' referring to the commenters who have made observations regarding the failings of archaeological practices and archiving. In this publication, the authors highlight that, despite decades of warning regarding diminishing storage capacity and resources, insufficient investment was being provided to resolve the sizable developing issues.

The challenge of storage capacity has been reviewed, with solutions such as the procurement of new facilities and on-site storage containers (Christine McDonnell 2022 – Head of Collections and Archive at the York Archaeological Trust – personal communication 21 October; D Fox 2018 City Art Gallery and Museum personal communication 24 September), archive rationalisation (Baxter *et al.* 2018) and off-site storage such as the DeepStore salt mine in Cheshire (Tsang 2017). Archive rationalisation can reduce the quantity of materials in the store, but as a long-term solution, the method has been found to have limited results for what can require large investment of time. In a case study conducted by the Museum of London, found that reviewing space in boxes and repackaging to exploit spaces in boxes could save between 5% and 10% and de-accessioning marine shell and unprocessed soil samples could create a further 5% of space (http://socmusarch.org.uk/socmusarch/gailmark/wordpress/wp-content/uploads/2018/10/AARP_final-consolidated-report_final-002.pdf). The off-site storage facility DeepStore has been used as a method of storage for Cambridgeshire County Council (Q Carroll 2018 – Historic Environment Team Manager – personal communication 29 August;

https://www.deepstore.com/resources/case-studies/cambridgeshire-county-council/). The DeepStore storage facility is not accessible for the public, but samples can be recalled from the facility in 24 hours and delivered to researchers. Neither off-site stores, or rationalisation have been identified as solutions to the challenges of storage capacity.

Existing challenges facing archaeological archives in the early 21st Century were further compounded by the 'Great Recession' of 2008, which resulted in drastic cuts in government spending on the arts (Science and Technology Committee 2009). Government figures indicate that museum funding in England for 2016 was 31% lower than in 2010. The reduction in funding resulted in closures, reduced opening hours and a reduction in skilled staff (Museums Association Review 2016). As a result, museums have been forced to seek funding away from the government. Private giving, the National Lottery Heritage Fund (formerly the Heritage Lottery Fund, (HLF), and commercial project partnerships are regularly used to acquire additional funds to remain open to the public (Ray *et al.* 2013). This group of challenges is occurring globally and is commonly referred to as the 'curation crisis' (Kersel 2015; Flexner 2016).

A response to the curation crisis

In the early 1990s, the museum services and special interest groups published multiple standards and guidelines. A notable example is the Standards in the Museum Care of Archaeological Collections which was published in 1992 as a response to an increased quantity of materials collected from archaeological investigations (Museum and Galleries Commission, 1992). This document drew together advice available across the sector into a single document which signposted organisations and sources that could provide further assistance. This document was complimented by the SMA, who is 1993 and 1995 published documents such as Towards an Accessible Archaeological Archive (Owen 1995) and Selection, Retention and Dispersal of Archaeological Collections 1993 (SMA 1993). Selection – whereby items that reflect the aims and objectives of an archaeological scheme of work are selected for the final archive – is a necessary step in creating efficient, manageable archives free of material of extrinsic value and which invite greater use by being relevant (SMA 1993; Brown and Bibby 2017). To achieve informed selection, a strategy that collaborates with stakeholders such as managers, conservators, local authority archaeologists, specialists, and collections curators who can devise a project-specific strategy that, throughout the life of a project, need to be designed (Brown 2011; CIfA 2019). The selection process develops

Petrie's observation and provides protocols which ensure that a cogent meaningful archive is created.

In the early 2000s, challenges within the sector were becoming evident. Some more prominent published responses include Brown and Perrin's (2000) '*A Model for the Description of Archaeological Archives'* and Perrin's '*Archaeological Archives: Documentation, Access, and Deposition*', both of which were published by English Heritage. The former document was the report lead to the foundation of the Archaeological Archives Forum (AAF), a group founded in 2002, and took a much-needed overview of archiving practices in England. In 2007 the Archaeological Archives Forum published Archaeological Archives: A guide to best practice in creation, compilation, transfer, and curation (Brown 2011). Importantly, this document was supported by multiple heritage and archaeology organisations based in England, Scotland and Northern Ireland. In 2014 the Europae Archaeologiae Consilium (EAC) produced A Standard and Guide to the Best Practice for Archaeological Archiving in Europe Guidelines as part of the Archaeological Resources in Cultural Heritage: a European Standard programme (Perrnin *et al.* 2011). This document keenly acknowledges the value archived archaeological material possesses beyond that which pertains purely to the archaeologist.

In 2010 Planning Policy Statement 5 (PPS5) was introduced, replacing Planning Policy Guidance note (PPG) 16. This was one of the first pieces of heritage legislation to change policies in a post-recession world. In the same year, the Conservative Party's Open-Source Planning Green paper (Open source planning 2010) was published, which, along with the Localism Act (Department for Communities and Local Government, 2011) published the following year, heralded deregulation and the shrinkage of government-run organisations and museums (Buser 2013; Raco 2013). In response to the changing nature of legislation and the outlook of government regarding the funding and management of cultural heritage, the Southport Group, a cross-operational group of archaeologists and stakeholders, used the opportunity of the adoption of PPS5 to review archaeology in the planning process and the sector (Southport 2011). Through a series of workshops, consultations and an economic study, the group published a report in 2011 that detailed the challenges and opportunities that archaeological practice following PPS5 would reveal. Regarding archaeological archiving, the group identified 16 key points (Southport 2011 pp. 17-18). They are detailed below.

1) The promotion of archaeological archives as valuable resources that can provide data for academic, research and planning-led projects, information for museum visitors and the wider communities.

2) Bring archaeological archiving into the same level of importance as the rest of the archaeological process.
3) Bring parity to standards of archiving across all repositories
4) Many repositories are unable to achieve acceptable standards of curation for digital material.
5) Archaeology stores are full to capacity, to the extent that more and more museums/repositories cannot control the rate of collection of archaeological archives.
6) Selection of the material to be curated in perpetuity should be informed by the aims of the project, and the potential for that material to inform future research. This means considering the value of each aspect of the archive rather than classes of artefact or ecofact in general.
7) The planning process does not successfully monitor archive delivery. Archive transfer may be completed long after the planning process has any purchase.
8) There are problems with the transfer of title to physical archives, which is a cumbersome and time-consuming process which contractors and developers find difficult.
9) For projects in many areas there is no repository for the archive generated.
10) There may be little synchronisation between museums/repositories and other research resources such as HERs, (Historic Environment Record) record offices and universities. Many museums/repositories are also finding it difficult to provide the levels of expertise required properly to facilitate access to collections.
11) Archaeologists and museum workers should consider new techniques for new vehicles and media for dissemination.
12) There are many options for the dissemination of information to different audiences, including oral presentation, exhibitions, displays, interaction, participation digital media and a variety of print formats. The best choices are not always made for a wide range of potential audiences, which might include clients, planners, technical experts, the community, schools and researchers.
13) Individual projects often do not lend themselves to detailed publication: syntheses and themed delivery may be better.
14) Communication plans for projects could engage people throughout the life of the project and stimulate the dissemination of results and interpretations in more innovative and far-reaching ways.

15) At the heart of the management of historic environment in the planning process lies the HER, itself a dissemination vehicle of huge but under-used potential that needs to be widely promoted, understood, and used.

The Southport Group's critical evaluation of archaeological practice in England in the early 21st Century, through the lens of recently introduced guidance, offers an extensive critique of archiving practice. The report's remit was to expose key challenges confronting commercial archaeology. Regarding archaeological archives, these challenges can be summarised as improving digital curation, and the promotion of archived materials, enhancements to the methods that support the selection of remains and the creation and compilation of archaeological archives, the improvement and adherence to standards, the storage capacity crisis and the curation of archives and the communication of archived remains to the public. In addition, the Southport Groups (2011) report set the scene for a slew of projects in the 2010s, such as Archaeological Resources in Cultural Heritage: A European Standard (ARCHES) and Historic England/SMA surveys which interrogated the themes acknowledged in the Southport report in greater detail.

The ARCHES project, a collaboration between eight partners from across seven European states (Perrin *et al.* 2014) set out to "promote the sharing of best practices for archaeological archives in the protection, preservation and presentation of archaeological materials and information. In addition, it will facilitate access to our common cultural heritage across Europe (https://archaeologydataservice.ac.uk/arches/Wiki.jsp?page=ARCHES%20Introduction)." The definition of an archaeological archive, as defined by Perrin *et al.* (2014) is used as the definition of an archaeological archive throughout the rest of this thesis.

> *"All records and materials recovered during an Archaeological Project and identified for long-term preservation, including artefacts, ecofacts and other environmental remains, waste products, scientific samples and also written and visual documentation in paper, film and digital form"* (Perrin *et al.* 2014, 20).

Using this definition, further discerning factors emerge. To be considered an archaeological archive, selected records and materials that form the final archive must be transferred to the designated museum or repository (Brown 2004; Perrin *et al.* 2014). This accredited facility will ensure that archives and collections will be cared for following curatorial standards and can guarantee that access to the material will be granted (CIfA 2014). Final archives not deposited in a museum or repository due to collection policies that prevent material from being deposited are considered undeposited materials (Adams 2017; Mendoza 2017). Regarding palaeoenvironmental material, there are additional challenges, given that waterlogged materials are not accepted by many museums and repositories (SMA 2020).

Archaeological archive Surveys

In the 2010s, several surveys facilitated by the Society for Museum Archaeology (SMA), and the Federation of Archaeological Managers and Employers (FAME), with financial assistance from English Heritage, were conducted to understand more about the ability of England's museums to collect archaeological archives and provide sufficiently qualified curatorial staff. For example, the Edwards survey published in 2012 reported the results from 134 museums and revealed that 28% of the respondents do not accept archaeological archives due to capacity, and only 30% of those museums have specialist archaeology curators (Edwards 2012). Due to the limitations caused by the absences of specialist curatorial staff, less than a quarter of the museums reported that they could produce detailed information related to accessioned archives.

The Edwards report was followed by three annual reports produced and executed by the SMA and commissioned by Historic England. The SMA reports were published in 2016, 2017, and 2018 and gathered data on the challenges that museums holding archaeological archives face. Receiving results from 200 museums in England, the three SMA reports Boyle *et al.* 2016, 2017, 2018 examined factors including availability of expertise, staffing, and capacity to collect archaeological archives. The surveys were repeated for three consecutive years to i) gather baseline data regarding collecting practices conducted by museums, ii) collect quantitative and qualitative data that reveals how disruption to staffing levels and funding impact archaeological archiving, and iii) to develop a resource that stakeholders can use to resolve issues relating to the loss of expertise funding and un-deposited archives (Boyle *et al.* 2018). The surveys were successful in gathering data, and the association of the SMA, Historic England and the authors being well networked in the museum community ostensibly inspired high levels of buy-in.

Mendoza and Beyond

In response to the curation crisis in England, organisations, most prominently Historic England, Arts Council England, and the Society for Museum Archaeology, have commissioned enquiries into potential solutions to confront archiving challenges. A prominent example of the response is the

Mendoza review, a 2017 Department for Digital, Culture, Media and Sport (DCMS) sponsored review of museums in England to establish how the government influences and financially resources the museum sector (Mendoza, 2017; Heyworth, 2018). However, within the report, archaeological archives received little specific mention.

> *"Shortage of storage is becoming a particular issue for museums located near significant construction schemes, particularly national infrastructure projects such as transport links (e.g. HS2). Finds from archaeological excavations are deposited in the nearest museum, which often do not receive adequate – or sometimes any – additional resources to manage or store such items."* Mendoza (2017) pp47

The report was criticised for being overly simplistic in identifying funding by suggesting that groups that have not traditionally worked together share resources (Maurice Davies 2018). An additional criticism is that archaeological archiving receives such little attention. Given that the remit of the Mendoza review was to investigate museum practices in the broader sense, it is unsurprising that archaeological archives received such scant reference. Regarding archaeological archiving, the report defers to Historic England to recommend to the Department of Digital, Culture, Media and Sport. The most noticeable of these recommendations is recommendation 27, which states that Historic England should *"Work with key stakeholders to produce recommendations for DCMS early in 2018, which will improve the long-term sustainability of the archaeological archives generated by developer-funded excavations"* (Mendoza 2017 pp16). The responding Historic England recommendations to DCMS include 12 points as part of an action plan that, if better understood and adhered to, will guarantee sustainability for archaeological archives (Trow 2018).

1) Professional Standards and Guidance.
2) Best practice in planning.
3) Advice on the costs of archival deposition, storage and curation.
4) A 'digital first' approach to archaeological archives.
5) Digital archives and museums.
6) Framework for legal ownership.
7) Joint sector best practice guidance.
8) New approaches to selection.
9) Regional Research Frameworks.
10) The ability of museums collecting archives.

11) Understand patterns and frequency of archaeological archive usage.

12) Archive retention reviews

These 12 action points consider a proposed approach to archaeological archiving throughout the entire life of an archaeological project and examine the legacy of archaeological archives and their findability and accessibility. The themes are similar to those observed seven years earlier with the Southport report (Southport 2011). However, the presented solutions are arguably more pragmatic than the Southport report, largely due to proposed collaborations with organisations and strategies that have developed since 2011. The 'digital first approach' recommends integration with the Heritage Information Access Strategy (HIAS) – a response to the 2016 Culture White Paper (Department for Culture, Media and Sport, 2016.) that recommended that digital information relating to the historic environment be made more available. Adjoining strategies can provide additional platforms to improve archaeological archiving, which will likely prove beneficial for the practice.

A further outcome of the Historic England response to the Mendoza report was the suggestion of examining the patterns and frequency of use of archaeological archives, an issue that was not given as much attention in the Southport report (Southport 2011). The frequency of archive usage, along with understanding how archive use is perceived, is worthy of significant consideration. Data about patterns of use could be used to develop business cases that can contribute to building additional storage capacity. The topic has received relatively little focus, with researchers such as Stone (2018) and Childs *et al.* (2006) emerging as rare examples of publications that have commented on the frequency of access to archaeological archives. The occurrence of access to palaeoenvironmental remains has not received any attention, and no published works exist regarding the issue.

Another significant review was being conducted whilst the Mendoza review was being undertaken. The Seeing the Light of Day project was funded by the Arts Council England's Museum Resilience Fund to investigate how pressures associated with the international curation crisis affected archaeological archives in counties in the South-West (Fernie *et al.* 2017). Specifically, Seeing the Light of Day determined how, with insufficient financial intervention, museums and repositories can continue to collect and effectively curate archaeological archives (Fernie *et al.* 2017). The project concluded with eight critical points.

1) The archaeological sector must champion the value of archaeological archives.

2) The storage and access crisis can be solved at a regional and national level.
3) Effectively manage transfer of title and copyright for both orphan and newly created archives.
4) A standard framework on archaeological archives to be required in all briefs and Written Schemes of Investigation.
5) Improve communications by developing Online Access to the Index of the archaeological investigationS (OASIS).
6) Enable preservation of, and access to, digital archaeological archives.
7) Establish Continuing Professional Development training programmes.
8) Ensure that opportunities to engage communities in accessing archives are maximised.

The conclusions from the Seeing the Light of Day report can be summarised as addressing the following themes- 'standards, guidance, training and advice', 'promotion and digital curation', 'selection and archive creation', 'ownership', and 'the storage crisis'. The themes covered are arguably similar to those highlighted in the Historic England response to the Mendoza Review. A critical difference between the outcomes of the two reports, is that Seeing the Light of Day offers more direct options to remedy some of the challenges, such as the use of OASIS as a method to promote digital data and Written Schemes of Investigation being a vehicle for the promotion of standards and suitable source for the promotion of archiving throughout the archaeological project.

In response to reviews such as Mendoza, Seeing the Light of Day and the Society for Museum Archaeology and Historic England surveys, a raft of additional Research was commissioned to identify solutions to the archiving challenges. These enquiries include reviews of the standardisation of fees for charging for transfer (Vincent 2019), archive rationalisation (Baxter *et al.* 2018), storage alternatives (Tsang 2017) and producing a Selection Toolkit for Archaeological Archives (CIfA 2019). The Selection Toolkit develops existing archive selection guidance and provides adaptable resources to guide practitioners throughout an archaeological project. Resources such as the Selection Toolkit and Perrin *et al*. (2014) guide best practices and provide practitioners with the tools to add a cognitive process that considers the multifaceted, long-term applications of the working project archive. How archaeological palaeoenvironmental remains are considered within the selection process, and the implications for specialists and stakeholders working in the field have not been researched.

Archaeological Palaeoenvironmental Archiving in the 21st Century

Resources such as Seeing the Light of Day (McNulty 2017), the HE response to Mendoza (Mendoza 2017) and the Southport Report (Southport Group 2011) highlight common themes and challenges. These can be summarised as variable collection policies, absence of sufficient standards, failure to adequately promote archives, and the storage crisis and selection strategies. There are additional challenges and opportunities specific to palaeoenvironmental archives. An area where archived palaeoenvironmental remains may prove particularly useful in the future, is in the face of diminishing opportunities to collect materials due to a combination of agricultural intensification, peat extraction and climate change-related factors have enhanced the drying and decay of wetland resources (Salimi *et al.* 2021; Zhongming and Wei 2018; Ockenden *et al.* 2014; Davis 2020). For archaeological sites situated in marshes, peat bogs and fenlands which have produced 'classic' waterlogged archaeological sites, this is particularly concerning (Knight *et al*. 2019; Brunning 2013; Pearson *et al.* 1997; Van de Noort 2013; (High *et al.* 2016; Wagstaff 2016; Brunning 2019; Van de Noort *et al.* 2002). In addition to the rural sites, urban centres are also at threat from climate change-related challenges (Kenward and Hall 2000; Van de Noort *et al.* 2002). Sub-surface hydrology in English towns and cities such as Canterbury, Carlisle, London, Nantwich, and York are experiencing wetting and drying because of unpredictable water tables (Van de Noort *et al.* 2002; Heathcote 2012; Holden *et al.* 2006). Wetting and drying can cause the degradation of waterlogged and charred and calcium carbonate-based remains (Kibblewhite *et al.* 2015). Archaeological deposits and the palaeoenvironmental materials suspended within them are non-renewable resources, and their decay will likely lead to a heightening of the significance of the archived palaeoenvironmental resource. In the adjacent practice of natural history collecting, the decline in native species has demonstrated that museum specimens are increasingly important (Nakahama 2021; Meineke *et al.* 2019).

Each of the challenges identified in published resources regarding archaeological archiving in the broader sense, and those specific to palaeoenvironmental remains, such as measures required to curate them adequately, are worthy of further investigation and will be explored in greater detail. The following part of this chapter outlines in greater detail the contemporary challenges confronting the archiving of palaeoenvironmental remains.

Collection policies

Regarding collection policies, many museums state in their collections policy that they do not collect waterlogged materials or unprocessed soil samples due to the necessity of controlled environments required (SMA 2020). For example, the most recent update of the Birmingham Museums Trust collections policy states the following.

> *"Textiles, leather and other finds recovered in a waterlogged condition must be conserved to a dry state (eg by freeze-drying) before deposition; the Museum will not accept finds in a waterlogged state."* (Birmingham Museum Trust 2019 pg 12)

Similarly, in an example provided by Lincolnshire County Council, the collections policy outlines the following.

> *"Wood will not be accepted by the museum if it is still in a waterlogged condition."* (Lincolnshire County Council 2012 pp 19)

Conversely, the collections policy for the Northamptonshire Archaeological Resource Centre, the repository that receives and curates archaeological archives in Northamptonshire, takes an approach that is more open to accepting waterlogged materials and allows for waterlogged materials to be deposited within the repository if sufficient notice is provided.

> *"NARC will only consider accepting waterlogged materials and other remains which require specialist facilities or conditions (such as those items which require refrigeration or suspension in Industrial Methylated Spirits) if an agreement has been made at the project design stage. If encountering waterlogged materials that were not anticipated at the project design stage, then please contact NARC as soon as possible. Archaeological units should be aware that the deposition of waterlogged remains may incur additional costs".* Donnelly-Symes (2020) pp. 32.

It is clear from the examples provided that collections policies that concern palaeoenvironmental remains have shifted over time, but the variability between regions continues. Decades of shifting policies may have resulted in regional variability and a bias in the varieties of materials that have been conserved in England's museums.

Curation of Palaeoenvironmental Remains

The curation of palaeoenvironmental remains has received little published guidance. Guidance such as Historic England's *Environmental Archaeology: A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation (second edition)* alludes to archiving and curation standards, but its focus is much more comprehensive than just archiving (English Heritage 2011). The most comprehensive effort is the Society for Museum Archaeology's Standards and Guidance in the Care of Archaeological Collections (SMA 2020a) and the SMA material fact sheets that provide details on the curation of botanical remains (SMA 2020b) and waterlogged remains (2020c). These much-needed resources offer information on the practical curation of palaeoenvironmental remains, although they lack detail regarding the long-term management of wet collections and genetic material.

An increasingly common use of biological specimens in natural history museums and archaeological remains in museums within collections and archives is genetic research (Burrell *et al.* 2015; Raxworthy and Smith 2021; Bakker *et al.* 2020). Since the late 1980s - when ancient DNA (aDNA) was first sequenced - samples that have been retained for decades or centuries have had aDNA extracted to explore decades-long held theories regarding the migration of people, plants and animals (Orlando *et al.* 2021; Callaway 2017; Sawchuk and Prendergast 2019; Mullis and Faloona 1987). The application of archived remains to reveal new insight into enduring questions has created a gold rush mentality (Austin *et al.* 2019). This has led some specialists, laboratories, and museums to hoard samples to prevent over-exploiting the resource. The requirement for the management of biological archaeological resources has been realised as a significant challenge in Israel, that a national centre has been established to curate and store animal bone as a clearing house for ancient DNA (Callaway 2017). This facility is expected to ensure that protocols and standards for managing the palaeoenvironmental remains are maintained and can adequately serve the researchers' needs.

Selection and Collation of Final Palaeoenvironmental Archives

Although future research potential cannot always be anticipated, where possible, items selected for the final archive should be appropriate to the aims of the project and free of any items that are not relevant (as outlined on pages 20-21). A selection strategy is a process whereby stakeholders – e.g., specialists, collections curators, project managers, contract archaeologists, and academics – that are involved in an archaeological project make judgements that determine relevance and value for future research, display, or public science engagement (Brown 2011). As highlighted by SMA (1993), Brown *et al.* (2011), and Brown (2011), selection is a process that should be engaged with before fieldwork commences and should be considered throughout a project, rather than solely at the end of a project. The Chartered Institute for Archaeologists (CIfA) published the CIfA Selection Strategy Toolkit (CIfA 2019) to guide the selection process. Specific materials are used in the examples provided in the toolkit, but with exceptions such as ceramics groups (Barclay *et al.* 2016), special interest groups have not published details on how materials should be considered for long-term storage.

Findability

Challenges such as sample findability and locating remains in a suitable condition have been experienced by environmental archaeologists, as highlighted by the following comment from Lisa Lodwick, Lecturer in Archaeobotany - Department of Archaeology University of Cambridge, who has used archived palaeoenvironmental remains on multiple research projects:

> *"(The) main challenge is finding information on the archive in the first place (i.e. reading many site reports to track down good quality assemblages), and then figuring out which archive they are in. Some assemblages I have given up on as the archive isn't where it should be. More generally, charred plant remains are often in too bad condition for isotope analysis – given time/expense of accessing archived material, perhaps easier/more efficient to access material still in post-ex as can get more accurate assessment of preservation quality through an in-person specialist".* L Lodwick 2019 - Academic Researcher at the University of Oxford - personal communication 28 January.

Unpacking this statement, Lodwick has identified challenges in locating archaeobotanical remains and further struggles in determining the preservation of these remains. First, Lodwick states that site reports are critical in locating archived remains, but these are not guaranteed to provide enough information to do so successfully. The challenge of locating archived palaeoenvironmental remains is echoed in Jarman *et al.* (2019), which outlines research that set out to locate archived samples of Sweet Chestnut (*Castanea sativa Mill*.) and determines when it was first imported and cultivated in England. That study significantly informed the project design for this scheme of doctoral research and highlighted the key challenges that are confronted by environmental archaeologists who wish to use archived remains, as outlined in the following statement extracted from the conclusion of the article:

> *"The present research was clearly assisted by the invaluable previous inventories of archaeological reports. However, in many instances, recourse had to be made to original authors and taxonomists to recover accurate information. In some instances, this 'umbilical cord' to original workers stretched back over fifty years to the 1960s: this is a risky (albeit very personable) way of accessing crucial information. Sharing full datasets, through publication and/or the use of a common database such as ArboDat (Archaeobotanical Database), will also help ease data access".* Jarman *et al.* (2019 p68)

Like the Lodwick statement, the Jarman *et al*. declaration presents a reliance on inventories in archaeological reports. Contacting original authors and researchers is also dependent on locating relevant information. As is noted by Jarman *et al.* (2019), this method of discovering information about archived remains is 'risky' and requires further consideration to determine more sophisticated and secure methods of providing data links.

The promotion of archaeological palaeoenvironmental archives and digital curation

The archaeological process is destructive, permanently reducing 'the site' into mutually comprehensible data consisting of quantitative and qualitative measurements and observations, and physical remains regarded as having historical or cultural significance (Richards 2002; Richards and Hardman 2017; Aitchison 2010). Artefacts, ecofacts, and samples are ascribed values such as contextual data at the point of discovery, but these are not indelible and there is a perpetual risk that contextual data degrade, becoming lost or separated from each other and/or from the physical artefacts and ecofacts (White and Breen 2012; Binding et al. 2019). The separation of supporting data from physical remains has been observed by archive and collection-led researchers (Stone 2018; Jarman *et al.* 2019). These challenges are manifest across the data ecosystems supported by Historic Environment Records (HERs), Archaeological Data Service (ADS) and OASIS, archaeology databases and museum resources which hold data that are either not sufficient to locate archaeological remains or provide reference to additional relevant associated data (Faniel et al. 2010; King 2016). The most used and trusted form of data storing and sharing within English archaeological practice is the Archaeology Data Service. The Archaeology Data Service (ADS) was established in 1996. The ADS originally intended to catalogue and preserve digital data created through the archaeological process (Richards 1997). Today, the ADS is a Trusted Digital Repository with Core Seal certification. They curate data, which encompasses preservation and the provision of access. The ADS now plays a vital role in British archaeology and is internationally recognised as a leader in digital archaeology's theory, method, and practice (Moore and Richards 2015). Indeed, a review by Beagrie and Houghton (2013) revealed that commercial archaeology organisations rely on the ADS Library of Unpublished Fieldwork Reports to draft desk-based assessments and produce written investigation schemes. The report demonstrated that the utility of the ADS is being realised by the archaeological community and has become a trusted resource used by most members of the community (Evans 2015). As ADS usership has increased, some users have recognised the resource's value and have taken steps beyond minimum compliance to make enhanced levels of data available. Projects such as Star Carr (https://archaeologydataservice.ac.uk/archives/view/postglacial_2013/downloads.cfm) and The Silchester Project (https://archaeologydataservice.ac.uk/archives/view/silchester_ahrc_2007/) have used the ADS to deposit large amounts of data that surpass the minimum basic requirements and enable greater opportunities for data reuse. The resulting data is available via downloadable spreadsheets of specialist and excavation data, videos, photographs, photogrammetric models, specialist reports and publications. In the instances of these projects, the data can be found on pages in the ADS Archives.

In 2004, ADS extended its service with the OASIS (Online AccesS to the Index of *archaeological* investigationS) project (Moody et al. 2021). The OASIS project was designed as a centralised digital repository for unpublished fieldwork reports generated in England, Scotland, Northern Ireland, and Wales (Wright and Richards 2018; Moody *et al*. 2021). Information including archive identifier, archive contents, archive media, archive location, and notes is inputted by the party committed to the investigative work, most likely a commercial archaeology organisation (Richards 2002; https://archaeologydataservice.ac.uk/blog/oasis/?p=383). The uploading of information in the OASIS form is therefore at the mercy of the organisation who conducted the investigation. This relies on a combination of factors, including the organisation's values, the attitude of the project team towards compliance, and the availability of a HER to enforce the completion of the form (Richards 2017). Once a scheme of fieldwork is completed and the documentation has been deposited, access to the material is provided to researchers who can make appointments to visit the physical reports in the HER, or are hosted online via the ADS library (Newman 2010; Illsley 2019; Moore and Richards 2015; https://historicengland.org.uk/advice/technical-advice/information-management/hers/).

Outside archaeology, methods of sharing and interrogating digital datasets are being propelled by initiatives such as the FAIR (Findability, Accessibility, Interoperability and Reusability) principles (Wilkinson *et al.* 2016). However, it is unclear to what extent FAIR principles have been taken into account within archaeological and museological practice in England. Researchers such as Faniel *et al.* (2010) and King (2016) have commented that data linked to items in museums and repositories often falls short of principles such as FAIR, with inadequate data ecosystems resulting in artefacts not being accompanied by contextual description or relevant information associated data (Faniel *et al.* 2010; King 2016). These apparent challenges that face archaeological archiving have received significant attention from researchers in Europe and the United States, but the specific needs of archaeological palaeoenvironmental remains in the archival system as ecological entities have rarely been considered (Henninger 2018; Colten and Worthington 2019). The thesis will need to consider the appropriateness of the available resources through criteria that meet FAIR principles whilst determining the ability to enable the use and reuse and Historic England's Heritage Information Access Strategy (Wilkinson *et al.* 2016; Carlisle and Lee 2016; Huggett 2018). There will also need to be an exploration of how an archive-led data-sharing resource can broaden the users and include researchers and scientists from outside of the domain of archaeology (Amand *et al.* 2020).

Communication

Archaeological archives present opportunities to articulate millennial-scale narratives of human experience and resilience through museums and science communicators (Merriman and Swain 1999, Harrison *et al.* 2020, Shanks and Tilley 1987, Trow 2018, St Amand *et al.* 2020, Baird and McFayden 2014). Over the last 20 years, an increasing host of methods incorporating discursive modes of engagement, Information Communication Technologies (ICTs) and social media posting have supplemented traditional labelled object displays. (UNESCO Institute for Information Technologies in Education 2011, Fedeli 2017, Jagodzinska 2017, McCall and Gray 2014). This chapter examines how palaeoenvironmental archives can complement the growing array of technologies and practices to invoke discussions regarding economically and environmentally related contemporary global challenges within the purview of environmental archaeology. This research topic also contributes to 21st-century challenges in archaeology as identified by CIfA as enhancing the means to promulgate archaeological Research for public benefit (Wills 2018).

To determine how archived palaeoenvironmental remains are used in museum and public science engagement events, a combination of quantitative data, in the form of survey data retrieved from the museum partners, and qualitative methods, in the form of case study data, have been used. Of the three case studies, two examine archaeological archive use in the exhibition ecology, and a third complement archaeological archive use by providing an extra-disciplinary example. When combined, the results reveal that best practice can be achieved by inviting specialist collaboration and applying mixed media alongside authentic evidence.

Part 2 – Survey and Methodology

Survey and Methodology

The study area includes all museums and repositories in England. In order to refine this area and identify museums and repositories that curate palaeoenvironmental remains in a significant quantity that lend themselves to analysis, a series of methods have been employed. In the first instance, a survey questionnaire was sent to 394 museums and archive repositories across England. This first survey was carried out using the Google Forms platform and PDF pro-forma and distributed to 394 museums (appendix I). The option to either use the online form or download, complete and scan the form opened the survey up to potential participants that could not use or view the online version. The museums selected for the survey were drawn from the Museums Association Yearbook and were selected on account of them being used in Historic England/Society for Museum Archaeology (SMA) Museums Collecting Archaeology (England) project (Boyle *et al.* 2016). As part of the surveys, the SMA dispatched surveys to 493 Collecting Institutions to determine which are still actively collecting archaeological archives, identify what obstacles prevent them from collecting archives, what deposition standards and guidance they operate and assess available space to accommodate future archives. Distributed in January and February 2018, the survey was sent to 394 of the 493 museums listed in the SMA survey (Boyle *et al.* 2016; Boyle *et al.* 2017; Boyle *et al.* 2018). This discrepancy in 99 museums is a consequence of a combination of smaller museums not including contact details in the Museums Association yearbook, the museums themselves not promoting contact on their websites, and the SMA inability to pass on the contact details due to data protection.

Of the 394 surveys distributed, representatives from 76 museums responded. The survey questions were as follows

1) Do you have palaeoenvironmental materials in your collection?
2) Are you currently accepting palaeoenvironmental materials with archaeological archives?
3) Are the palaeoenvironmental materials in your collections catalogued sufficiently to provide location details and quantities?

4) Are the organic remains in your custody stored correctly to ensure their long-term preservation?

Developing a long list

Of the 394 facilities, the survey returned 76 respondents, 33 of which agreed to participate with the project and have archaeological palaeoenvironmental materials in their possession. The 33 survey respondents that stated that they held palaeoenvironmental archives and were prepared to engage with the project were selected as a long list of study participants. As a starting basis, the palaeoenvironmental archive survey questionnaire was intentionally brief to encourage greater participation and contained only four questions. Once a selection of participants was established and cross-referenced against the heatmap (explained below), a second, more in-depth survey could be presented to the participants.

Identifying relevance

A geographic search further refined the long list of 33 study participants to identify regions more likely to possess higher quantities of archived palaeoenvironmental remains, providing more informative assemblages. The geographic search was achieved using a keyword search in ADS online search facility (https://archaeologydataservice.ac.uk/archsearch/browser.xhtml). Keyword search terms including 'waterlogged', 'charred', ‘plant’, 'palaeoenvironmental', and 'insect' revealed areas with the highest quantities of recorded interventions produced, according to OASIS ADS palaeoenvironmental remains. A total of 80 counties and unitary authorities were searched in OASIS using keyword terms using the search tool available on the website. The aggregate results of positive keyword search are included in table 1.

Aggregate quantities	**County/unitary authority**
483	Greater London
98	Cumbria
80	Kent
73	Shropshire
68	Lincolnshire
66	North Yorkshire
56	Suffolk
53	Cambridgeshire

53	Somerset
51	Merseyside
50	Northumberland
37	Essex
36	Warwickshire
30	Devon
28	Norfolk
24	Gloucestershire
24	Leicestershire
24	North Lincolnshire
23	Cornwall
22	Staffordshire

Table 1. Quantity of positive keyword terms and corresponding county

These results were then cross-referenced with the 33 respondents of the survey questionnaire. Museums in this these regions should therefore possess elevated quantities of archived materials. The disparate quantities of quantities (with Greater London standing with a much higher quantity of positive search word occurrences) were rationalised using standard deviation to create a heatmap indicating where the highest concentrations of palaeoenvironmental remains in England are most likely to be located. The commonalities between the ADS keyword search results and project participants begin to hint at regional patterns which could be selected for a case study. In addition to the survey results and the heatmap, a mix of different ownership was also regarded as an essential factor in areas for case-study selection. This insight will assist with the identification of differences in approach and management of the archived palaeoenvironmental resource. The ADS keyword search (where/how) and survey respondents were cross-referenced with the survey respondents to reveal museums that correspond with productive areas.

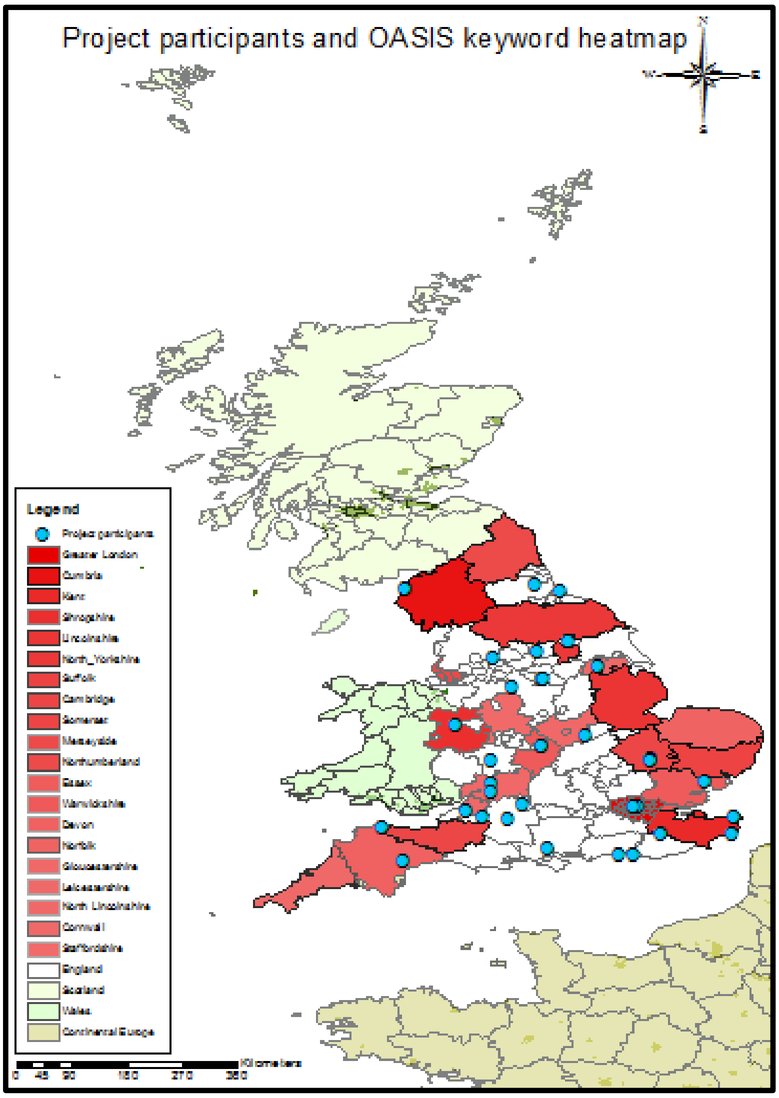


Figure 1. Heat map that demonstrates the higher occurrence of OASIS keyword search in red and the survey participants in blue

Focusing the Study Area

Museums in the most productive regions were selected as short-list project partners (table 2). Where possible, provider-type – i.e., funder – was chosen to reflect the national composition of Collection Institution funding providers (table 3). Museum ownership and management can be divided into four categories, as demonstrated, and quantified by the 2016 SMA survey, which concluded that of the 200 respondents to their survey, museum ownership falls into i) university and academic museums, ii) local authority-funded and managed facilities, iii) independently run organisations and iv) charitable trusts.

Collecting Institution	**Provider**	**Region**
Cambridgeshire HER	Local Authority	East of England
Leicestershire Museums	Local Authority	East Midlands

Peterborough Museum	Local Authority	East of England
Museum of London	Charitable Trust	London
Corbridge Roman Town – Hadrian's Wall	Charitable Trust	North East
South-West Heritage Trust (Taunton)	Charitable Trust	South west
Wiltshire Museum	Independent Charity	South west
Bristol Museum & Art Gallery	Local Authority	South west
Museums Worcestershire	Local Authority	West Midlands
Leeds Museums and Galleries	Local Authority	Yorkshire and the Humber
York Museums Trust	Charitable Trust	Yorkshire and the Humber
Hull & East Riding Museum	Local Authority	Yorkshire and the Humber
Sheffield Galleries & Museums Trust	Charitable Trust	Yorkshire and the Humber
North Lincolnshire Museum	Local Authority	Yorkshire and the Humber

Table 2. Ownership and region of museums selected for an interview and in-depth survey.

These 14 museums offered quantitative and qualitative data that has been instrumental in understanding first-hand experiences and challenges in archaeological archiving across England. Each institution was visited in person, allowing for face-to-face meetings with each of the curators and providing the opportunity to examine a selection of archives and inspect palaeoenvironmental remains. The questions are included in appendix 1. In addition, two of these participants, York Museums Trust and South West Heritage Trust, were selected for in-depth archive audits.

Provider-Type	**The proportion of Provider-Type for Museum Curator Interview (this study)**	**Estimated National Proportion of Provider-Type**
Local authority	53.3%	51%
Charitable trusts	33.3%	38.5%
Independent	6.7%	13%
university and academic museums	6.7%	4%

Table 3. Participation of Provider-Type for this study, in Comparison to Estimated National Proportion

Case studies

The museum surveys are expected to provide baseline data that can inform the survey of attitudes and trends within the museum sector and Historic Environment Records. To provide greater detail and to explore certain poignant themes, 11 case studies have been selected. Case studies have been obtained from excavations that have provided large palaeoenvironmental datasets such as Star Carr, the Wilsford Shaft and Flag Fen. Additional qualitative data has been obtained from practitioners who work within the field of environmental archaeology in England. Case studies derive from excavations in the regions from which museum partners have been selected, as well as international examples and initiatives that transcend a geographic relevance. The case studies are detailed below.

Case Study One – Chapter Four: The Wilsford Shaft, Wiltshire

A large amount of waterlogged, charred and mineral-replaced remains were recovered from the Wilsford Shaft excavations in the 1960s. Upon the completion of the project, the archive could not be deposited as a portion of it is waterlogged, criteria that prevented it from being accepted by Salisbury Museum. The archive is currently stored in the University of Reading and, since the analysis, has not received specialist management as part of its ongoing curation. The Wilsford Shaft presents an opportunity to examine the palaeoenvironmental component of an archaeological archive and determine what measures are required to ensure its continued survival.

Case Study Two – Chapter Five: Regional Archaeological Archive Depots in the Netherlands

The Netherlands has operated a system of regional archaeological archive depots for decades. Using published data and new data provided by curators and managers of the regional archive depots, it is expected that the relative merits and potential weaknesses for storing and promoting palaeoenvironmental remains within a regional framework or repositories will be revealed. Data from this case study will assist with the determination of regional or national suitability for the curation of archived palaeoenvironmental remains.

Case Study Three – Chapter five: National Archive Repository: Flag Fen Archaeology Park, Cambridgeshire

The case study provided by the Netherlands can provide data relating to the operation and suitability of regional archive repositories. Following on from the results of the Netherland's case study, an examination of the Flag Fen Archaeology Park is provided to examine its suitability for a site of a repository for palaeoenvironmental archives.

Case Study Four – Chapter Five: National Archive Repository: Fort Cumberland, Hampshire

Using a similar approach to the Flag Fen example, the Fort Cumberland case study investigates if it is an appropriate repository of palaeoenvironmental archives. Fort Cumberland is managed by Historic

England, houses many team heads and specialists, and may have on-site facilities and skills to manage the resource.

Case Study Five – Chapter Five: Archive Audit: The Southwest Heritage Trust Archive Facility, Taunton, Somerset

The Southwest Heritage Trust Archive Facility, Taunton, Somerset, stores archaeological archives for the county of Somerset (with the exception of the unitary district of North Somerset). Somerset has a rich history of investigating productive sites such as Meare and Glastonbury Lake Villages and the Somerset Levels Project, all of which are stored at the archive facility. An in-depth audit of the palaeoenvironmental components of the archaeological archives will provide an insight into the findability of archived remains, the quality of the packaging used and the identification of challenges that may threaten the long-term security of palaeoenvironmental remains.

Case Study Six – Chapter Seven: Star Carr POSTGLACIAL Project

The POSTGLACIAL project involved multiple seasons of excavation at the internationally significant site of Mesolithic occupation at Star Carr, North Yorkshire. Since its discovery, the recovery of palaeoenvironmental remains has produced results that have been transformative in understanding daily life in Mesolithic Europe (Milner *et al.* 2016). The Project Investigators of the POSTGLACIAL project, undertaken in 2012 to 2017, engaged in archaeological archive selection strategies at the project design stage and throughout until archive deposition. This case study can demonstrate how the selection of archived palaeoenvironmental remains can operate to achieve optimal results.

Case Study Seven – Chapter Seven: Greatham South Flood Alleviation Scheme, Stockton on Tees

The Greatham South Flood Alleviation Scheme, Stockton on Tees, provides an example of a project that has not archived the palaeoenvironmental remains with an approved repository. The case study considers what opportunities may have been missed and how a selection strategy may have improved the outcome for this archive.

Case Study Eight – Chapter Seven: The East Midland Historic Environment Research Framework

The East Midland Historic Environment Research Framework case study examines how research frameworks promote archive-led research and reveal to what extent the sources can assist with the selection process.

Case Study Nine – Chapter Eight: Guerilla Archaeology's 'Footprints in Time.'

Guerilla Archaeology's 'Footprints in Time' has been selected to explore how participatory practice and environmental archaeology can cohesively operate. The Guerilla Archaeology team use a combination of materials from the domain of environmental archaeology in their creative approaches to community engagement and public participation. The case study intends to determine if palaeoenvironmental remains could be used in schemes of public participation.

Case Study Ten – Chapter Eight: Worcester City Art Gallery and Museum: Ice Age

The Worcester City Art Gallery and Museum Ice Age exhibition used a combination of techniques to communicate archived remains from decades of excavations. An examination of the methods used in the exhibition will shed light on what techniques have been productive and those that have been less successful in communicating archived remains in the display environment.

Case Study Eleven – Chapter Eight: The Horniman Museum: Nature Base

The Horniman Museum 'Nature Base' exhibition does not use archived remains but does display a selection of materials that are analogous to items identified in palaeoenvironmental archives. The Nature Base exhibition uses multiple techniques to communicate ecological materials and promote themes relating to declining species and threats to biodiversity. This study hopes to reveal techniques to communicate themes surrounding palaeoecology and palaeoenvironments.

Chapter Three – Archaeology Palaeoenvironmental Remains in Perpetuity: The Curation and Conservation of Archaeological Palaeoenvironmental Archives in England's Museums and Repositories

Introduction

As highlighted in chapter two, archaeology in the 21st century will likely face fewer opportunities to retrieve data from well-preserved sites due to climate change related pressures (High *et al.* 2016; Wagstaff 2016; Brunning 2019; High and Penkman 2017; Milner *et al.* 2011; Van de Noort *et al.* 2002). Declining opportunities to revisit and recover palaeoenvironmental materials from sites of significance and sites yet to be revealed is a troubling prospect and will, over time, limit the prospects of the sub-domain of environmental archaeology. This phenomenon is currently being experienced in the adjacent domain of natural history collecting, where diminishing opportunities to collect specimens of living species and greater emphasis on the ethics of collective endangered species that are becoming rarer are enhancing the research currency of biological materials in museum collections (Winker 2005; Meineke *et al.* 2019; Shultz *et al.* 2021; Suarez & Tsutsui 2004). Parallels can be drawn between the increasing rarity of living species and diminishing prospects to excavate and collect ancient remains within the soil archive. It is therefore not unreasonable to expect that existing palaeoenvironmental archives that reside in England's museums and repositories and universities, archaeological contractors' stores and independent specialists may increase their perceived value as research materials. In the face of the prospect of a growing interest in archived remains, curatorial and conservation practices are examined to determine if they can adequately ensure that archived remains are secured for future generations. A combination of techniques and practices from archaeology and natural history conservation are examined to identify best practices and gaps in conservation or curatorial knowledge that may require further research. This chapter sets out to achieve the following.

1) Recognise the threats to the long-term conservation of the archived archaeological palaeoenvironmental resource.

2) Define what conservation standards exist across broader disciplines and examine the efficacy of those techniques when applied to archaeological practice. This chapter sets out to identify gaps in research regarding the conservation of palaeoenvironmental remains.

3) Determine if archived palaeoenvironmental remains are at threat in their current setting and seek to identify potential remedies.

When considering the long-term conservation of palaeoenvironmental remains, an appreciation of where items are located, and their subsequent accessioned status will have a bearing on how they are being curated. If archives are undeposited and not receiving active curation, they may be at risk. Chapter two outlines an estimated quantity of undeposited archives in England. The results an archive audit conducted at the Somerset Heritage Centre (detailed further in pages 140-141), revealed that respectively *c.*11% and *c.*33% of archaeological archives contain a palaeoenvironmental component. If these figures are applied to the 9,000 undeposited project archives, hundreds or thousands of undeposited site archives will likely contain palaeoenvironmental remains (Smith and Tindall 2012). This estimate is likely conservative, given that the quantities provided by the Somerset and York examples derive from museum accessions accrued over centuries and include archives that predate the formal adoption of environmental archaeology as a sub-discipline.

In addition to the quantities of palaeoenvironmental materials contained within undeposited and accessioned archives, there are also, as demonstrated in the Wilsford Shaft chapter and the Somerset Heritage Centre archive audit (chapters four and five respectively), a selection of the palaeoenvironmental remains have been retained by specialists for research or reference purposes (Historic England 2011). The Somerset Heritage Centre case study (page 140-141) revealed that a specialist had partially or entirely retained archives listed on museum collections management databases as containing a palaeoenvironmental component. Principally, it is uncertain to what extent specialists have retained palaeoenvironmental remains but given numerous reports from other museums and repositories describing the same practices; it suggests that this is not an isolated event (H Huisman 2020 personal communication 18 September).

Based on factors relating to selection and collecting practices, it is hypothesized that archaeological archives are biased in archive representation. Biases in representation within the archaeological record occur pre-during and post-depositionally (Peacock 2000; McClatchie et al. 2014; Jones 1987). Pre-depositional preservation factors can be influenced by non-anthropogenic process such as the movement of water and frost, as well as through human agency (Schiffer 1972). The pre-depositional biographies of palaeoenvironmental remains are often complex due to the varied ways in which they may have been buried (Historic England 2016; Jones 1987). Depositional factors could include items being broken through the process of deposition, perhaps, for example, the dumping of shell in a pit that leads to mechanical breakage (Peacock 2000). Post depositional factors can be characterised as the circumstance leading to decay within the buried environment, such as alternations to geochemistry (Kibblewhite *et al.* 2015). Pre and post-depositional factors are well researched, whilst the potential biasing factors such as collection policies and selection strategies are less understood. For example, samples that have not been deposited are not being curated and may therefore be at risk from decay. Additionally, items could be retained by specialists and not deposited with the rest of the archive and may be at risk of decay (Callaway 2017).

In addition to selection and collection strategies, palaeoenvironmental items deposited in a museum or repository may become biased in their representation if not correctly curated due to decay (Meineke and Daru 2021). As evidenced by SMA 2020 and Museum and Galleries Commission 1992, palaeoenvironmental materials that are archived may be at risk from factors including incorrect storage, insufficient packaging, and the absence of controlled environments, which could lead to the decay of remains. The factors that can result in bias are highlighted in diagram 2, which shows the hypothesised flow of bias, from the collection in the field to curation in the museum/repository.

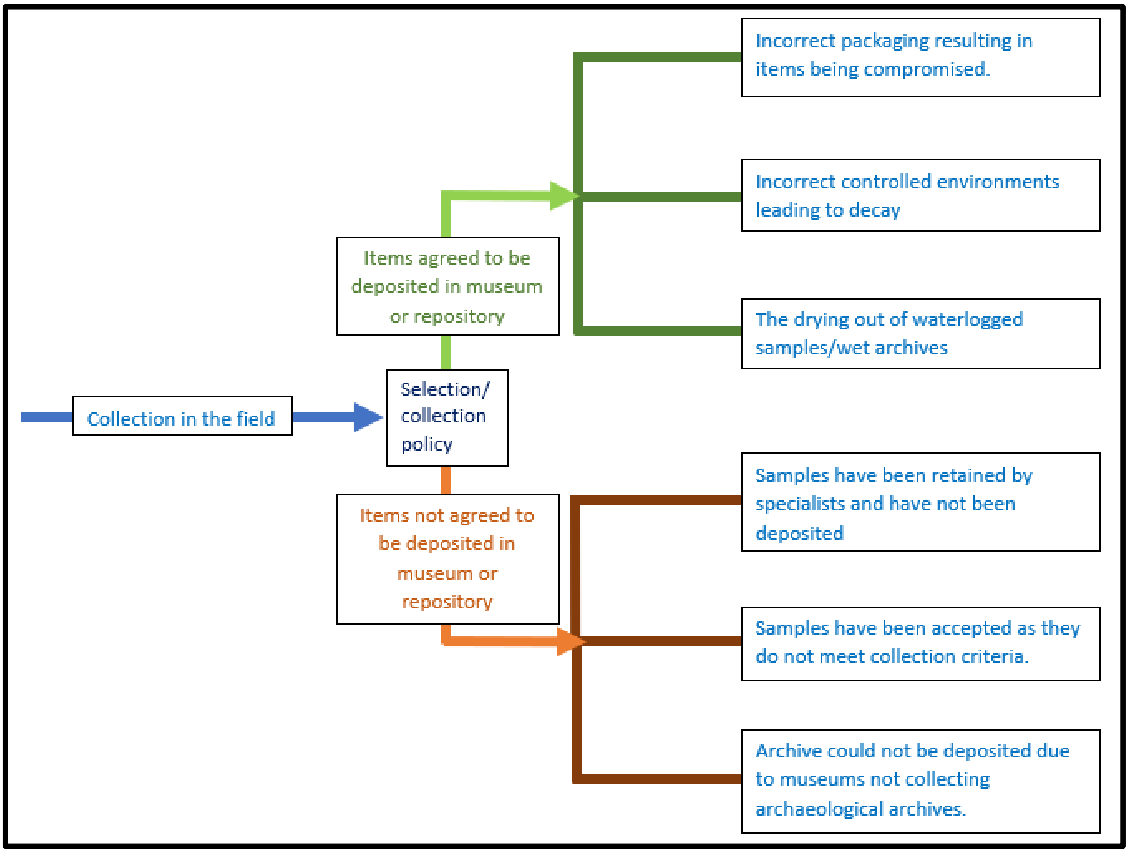


Figure 2. This flowchart demonstrates the factors that can result in archival bias

To examine the extent to which decay is challenging and potentially leads to a bias in the archive record, this chapter examines the prominent issues in conservation. This chapter draws on advice and standards from the following organisations: The Natural Science Collections Agency, the Natural History Museum, Oxford, Historic England, York Archaeological Trust, Society for Museum Archaeology, and the University of Reading Herbarium. Using a combination of published material and direct advice from associated specialists has allowed for the formulation of best practices for the conservation and design of optimal environments in which to store dry and wet archaeological palaeoenvironmental archives. Dry palaeoenvironmental archives can be characterised as materials which are either robust due to their composition, such as mollusc shell, or have been transformed through charring either via anthropogenic agency or by non-anthropogenic factors, including mineral replacement (Miksicek 1987). Wet archives include organic remains that have been retrieved from waterlogged contexts and need to be treated using drying techniques or maintained in a waterlogged state using a combination of spirits.

The best practice is then compared to real-world examples from museum facilities and repositories in England. These comparisons are assessed to determine the efficacy of current curation practices to establish their suitability for storing archaeological palaeoenvironmental archives. This examination is later used to make recommendations that can improve legacy archives and ensure better quality and usable archives for the future. To better understand how modifications to practices could be implemented to improve the health of legacy archives, a case study using the Wilsford Shaft, Wiltshire, is included in the following chapter. The Wilsford Shaft case study provides an example of a palaeoenvironmental remains that have yet to be deposited and archived and demonstrates the effects of not having received full-time curation of an archive that contains dry and wet materials. The case study also examines how historic archives can be reused to shed light on newly developed research questions. The results of Chapters Three and Four could be used to contribute toward consistent and thorough standalone standards for archiving palaeoenvironmental materials. The drive for consistent archiving protocols has been championed by the Association of Local Government Archaeological Officers (ALGAO), Chartered Institute for Archaeologists (CIfA), Federation of Archaeological Managers and Employers (FAME), Archaeological Archive Forum (AAF), and the Society for Museum Archaeology (SMA). It would likely be welcomed by all stakeholders (McNulty 2017; Southport Report 2011).

Archiving charred, mineral replaced, calcium carbonate materials and dry archaeological palaeoenvironmental remains

Amongst the corpus of published material regarding environmental archaeology, advice on the storage of archived charred, mineral replaced, calcium carbonate materials and desiccated archaeological palaeoenvironmental remains, or, for the sake of brevity, the 'dry' archives, have been relatively scant (Utriainen *et al.* 2007). In the examples that have contended with the topic, such as Brown (2011), and the recently published SMA (2020) guidance, the information can be regarded as being variable in scope. The SMA guidance is an informative document detailing the curation of archived palaeoenvironmental remains. When surveyed, 71.5% of the museum partners claimed that they require greater assistance with their palaeoenvironmental archives and 57% believe that they do not have, or are unsure if they have, the correct controlled environments to store palaeoenvironmental remains. This was before the SMA 2020 standards were published, and these results may now be different in the face of improved guidance. Regardless of the uncertainty regarding the requirements for additional guidance, the project's aim is to use existing publications to identify gaps in knowledge and recognise areas of best practice. The following section, therefore, sets out to determine what controlled environments and storage vessels in dry archived remains should be maintained to promote long-term storage. Recommendations have been achieved by consulting practices in natural history museums and examining standards adhered to in the UK, Europe, and the United States. Once the optimum environmental conditions and standards of vessels have been established, a range of real-world examples will be consolidated to determine if there are any threats to ongoing conservation and how they can be prioritised and addressed.

Incorrect storage can degrade palaeoenvironmental remains, making them unsuitable for research purposes (Brunning and Watson 2010; Brown and Brown 2011; Burrell *et al*. 2015; Charles *et al*. 2015). Degradation is regarded as being problematic, as well-preserved remains are necessary for many research applications, and researchers Charles *et. al* 2015; M Wallace 2020 personal communication 13 January; L Lodwick 2018 personal communication 01 January) have expressed the need for remains conducive to morphometric, isotopic, and genetic analysis. Samples being damaged or decaying post museum deposition can lead to frustrations experienced by researchers who exhaust unfruitful hours spent in museum stores searching through unsuitable remains (L Lodwick 2017 personal communication 25 September; Jarman *et al.* 2019). Further challenges regarding incorrect storage emerge when we consider the future opportunities to repeat experiments on items that have been isotopically or genetically analysed. If analysed and then reintroduced into an uncontrolled environment or incorrect container, acids and proteins may degrade in the years subsequent to the original analysis. Uncontrolled storage introduces differential decay and presents significant challenges for the unbiased re-testability of archaeological remains.

The post-depositional effects on palaeoenvironmental remains have received a reasonable amount of academic consideration (e.g., Fraser *et al*. 2013; Styring *et al.* 2013). Hartman *et al.* (2020) revealed the effects of post-depositional microbial decay by comparing laboratory samples with examples from archaeological samples. In this example, Iron Age I contexts excavated at Tel Dor, Israel, shed light on post-depositional effects on charred lentils (*ibid*). The Hartman *et al.* (2020) study used a combination of pXRF, FT-IR, DNA extraction and PCR amplification to examine degradation and concluded that bacteria in post-burial environments could be detrimental to the survival of nucleic acids and isotopic proteins. Using research on post-depositional effects and research into natural history methods of storing biological remains, it is clear that microbial and fungal agents pose significant threats to palaeoenvironmental remains. Degradation can be hastened by fluctuating or incorrect relative humidity and temperature and exposure to too much light, which encourage fungal attack and microbial action (Hubbard and al Azm 1990; Campbell *et al.* 2011). Incorrect containers can also be detrimental to the condition of palaeoenvironmental remains. Off-gassing from plastic containers can, for example, contaminate materials and non-rigid vessels, allowing exposure to mould, rot, mechanical stress, and damage.

Plant remains

Charring is the most common process that preserves archaeological plant material (Charles *et al.* 2015). Charring of archaeological remains can have occurred through the burning of items in domestic settings such as hearths and ovens (Berihuete-Azorín 2019; van der Veen 1998), through fires that engulf grain silos (Ansari 2020.), and accidental and the misfiring of industrial apparatus such as corn dryers and kilns (Van der Veen 1989; Huntley 1996; Monk and Kelleher 2005). Experiments have shown that the charring of cereals induces Maillard reactions, a process that occurs between proteins and sugars through exposure to heat (Arnaud 2019). Maillard reactions can convert cereal proteins and starch into melanoids (Styring *et al.* 2013). The absence of proteins and starch means that fungal and microbial attacks are arrested and result in relative stability (Styring *et al.* 2013).

Footnote 2 – pXRF = Portable X-Ray Fluorescence; FT-IR = Fourier-transform infrared spectroscopy and PCR amplification = polymerase chain reaction

The charring of plant remains such as cereal and weed seeds, legumes, chaff (figure 3) (includes lemmas, paleas, rachilla, awns and glumes), and wood occurs through exposure to the exclusion of oxygen, which are quickly extinguished or exposure to low temperatures for extended periods prior to being cooled, which permits carbonisation but not destruction and conversion to ash (Boardman and Jones 1990). The finely balanced conditions required to char but not destroy botanical remains favour more robust items than the smaller, fragile ones such as chaff, which are more likely not to survive the charring process than seeds (Hillman 1981; Van der Veen 1999). The carbonisation process can result in distortion and compromise external morphometric features and internal data such as DNA and stable isotope research (Boardman and Jones 1990). Therefore, some researchers that require morphological, isotopic, or genetic data may benefit from having the condition of charred materials included in collections management systems or museum databases to support archive search efforts (L Lodwick 2019 - Academic Researcher at the University of Oxford - personal communication 28 January.).

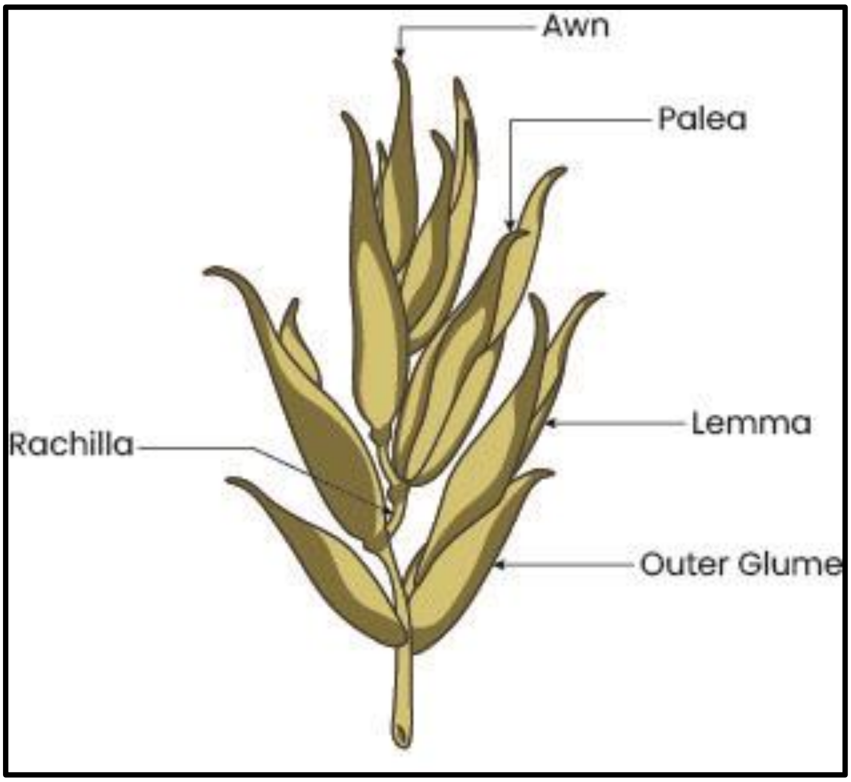


Figure 3. Illustration of chaff elements of cereal grains.

Less common methods of preservation include mineral replacement and desiccation (McCobb et al. 2001). Mineral replacement occurs through the partial or total replacement of degrading organic content with leaching chemical solutions in soils and sediments that are in proximity to organic remains (Anheuser and Roumeliotou 2003; Cartwright 2015). The chemicals that replace decaying organic content derive from corroding metal artefacts and the presence of salts such as potash, calcium carbonate, calcium phosphate and gypsum in soils and sediments (McCobb *et al.* 2001; Solazzo et al. 2014). Replacement can also occur through phosphatisation, the process whereby ions from phosphate-rich material, including faecal matter, food remains, and faunal remains, decay through the movement of subsurface hydrological motion (McCobb et al. 2001). The chemicals that have led to the replacement result in organic remains becoming either partially or fully replaced casts (Gillard et al. 1994).

Phytoliths

Phytoliths are microscopic deposits of silica minerals found in plants (Mulholland and Rapp 1992). They are robust items and survive well in the archaeological record in some geographical areas (Piperno 2006). Phytoliths can be used as palaeoenvironmental indicators and, when combined with other proxies, can provide palaeoclimatic records throughout the Quaternary period (Blinnikov *et al.* 2001). Phytoliths are extracted from sediment and mounted on slides for analysis (Alexandré 1997). After extraction from sediment, they can be maintained as part of a wet archive or be placed into a vial and dried at 80°C for 1 to 2 days until dried (Morris 2008). Once dried, phytoliths can be stored in a dry powder form (Integrated Archaeobotanical Archive 2010).

Mollusca

Terrestrial gastropods and bivalve mollusc shells consist of layers of calcium carbonate coated with a periostracum membrane, which decays rapidly except in waterlogged environments (Canti 2017; Storch 1987). Rapid drying of shell can contribute to degradation of the calcium carbonate layers and expose delicate and breakable layers (Child and Buttler 1996). Consequently, there are varying qualities of the shell that have been recovered and varying qualities of shell archived in museum stores (see page 62-64).

According to Shelton (2008), Carter (2000) and Geiger *et al.* (2007), shell remains should not be maintained in cardboard containers and should be in non-reactive metal cases, glass, or gelatine caps. The type of glass should be considered in advance of selection. Shell can also succumb to 'glass disease', the phenomenon whereby sodium hydroxide present in the glass can interact with a combination of atmospheric moisture and the calcium carbonate within the matrix of the shell, creating sodium carbonate (Birch 2000). Sodium carbonate can lead to the degradation of the shell (Birch 2000). To circumvent glass disease, low sodium hydroxide, high sodium carbonate glass and gelatine caps are preferred (Geiger *et al.* 2007). Where possible, only stable plastics should be selected and plastics prone to off-gassing should be avoided to prevent chemical contamination of the shell. Off-gassing is the process whereby volatile compounds are omitted by a range of solids and liquids stored in ambient environments (Alvarez-Martin *et al.* 2021). Plastics prone to off gassing and emitting volatile compounds and acids can have a detrimental effect on items contained within the plastic containers (Mazurek *et al.* 2019; Donnelly-Symes 2020; Pasiuk 2004). Off-gassing can be mitigated by leaving the lids off new plastic boxes for approximately four weeks to allow vaporous volatile compounds to disperse (Tsukada *et al.* 2012; Donnelly-Symes 2020). Allowing time for boxes to off-gas is a sensible strategy that can have beneficial effects, but for the storage of materials susceptible to Byne's disease – the process whereby formic and acetic acids emitted by resins, wood, cardboard and in particular plastics react with micro-shell molluscs (Cavallari *et al.* 2014). Plastics should therefore be avoided in the storage of malacological collections and archives (Sturm *et al.* 2006). Metal and glass and gelatine caps are preferred, but gelatine capsules must be supported in conditions that prevent exposure to fluctuating temperature and humidity, which can dissolve them (Tirlea *et al.* 2018; Geiger *et al.* 2007).

Microfauna

Ostracoda

Ostracods are microscopic bivalved crustaceans that are found in a diverse array of semi-terrestrial and aquatic environments that support carbonate and calcium water chemistry (Likens 2009). Ostracods' ability to adjust to changes means they can be identified in most aquatic environments except for non-water and brackish water, permitting them to be used for the reconstruction of palaeoenvironmental models (Rodriguez-Lazaro and Ruiz-Muñoz 2012). The shell is robust enough to survive for millennia in archaeological and geological strata (Horne 2012). Ostracods are routinely mounted on microscope slides to be identified and counted but should also be maintained in an unmounted state (Namiotko 2011; Horne 2012). Separate ostracods can be dissolved in liquid and analysed using ICP-AES and ICP-MS to examine oxygen and carbon stable isotopes and magnesium, uranium, boron and strontium trace metals and amino-acid-racemization to contract palaeoenvironmental reconstructions (Walker and Lowe 2007; Holmes and De Deckker 2012).

Ostracods can be maintained for long-term storage in either wet or dry states. If stored in a dry state, on account of their small size, they should be kept in glass vials rather than plastic options, as plastic can lead to the build-up of static electricity and cause the shells to leap out of the container or become stuck to the side of the vessel and difficult to remove (Horne and Siveter 2016).

Foraminifera

Planktonic foraminifera are microscopic single-celled organisms and mostly range from 1mm in length to 100µm with tests that consist of layers of calcium carbonate coated with a periostracum membrane, making them robust and able to survive in buried environments (Haywood *et al.* 2009; Gehrels 2013). The 50,000 known species of foraminifera that have so far been identified occur across the majority of marine environments, with certain species preferring marine niches, including salt marshes, others intertidal, others estuarine environments making them an attractive proxy for archaeologists to use for palaeoenvironmental reconstruction (Smith 2017; Lamb *et al.* 2006; Storme *et al.* 2020; Scott and Medioli 1978; Gehrels *et al.* 2002; Kemp 2009).

Environmental Control

The next section examines the environmental controls and suitable containers, packaging, and shelving recommended for curating palaeoenvironmental archives. Finally, examples of best practices and guidance for the curation of palaeoenvironmental materials from across the domains of archaeology and natural history will be compared with real-world examples from a range of museums to demonstrate the experiences of museum curators, identify a set of priorities and possible guidance that may be required to ensure the ongoing preservation of the dry palaeoenvironmental resource.

The process that has resulted in the preservation of dry remains has made them partially resistant to deterioration, although, since their recovery from the buried environment, they have been exposed to decay caused by fungi and bacteria (SMA 2020). Microbial and fungal attacks can never be prevented, but they can be arrested by maintaining the remains in an environment as similar to the buried environment as possible (Campbell *et al.* 2011). A suitably controlled environment for the long-term preservation of dry palaeoenvironmental archives requires three factors: a stable temperature, limited exposure to ultraviolet light, and maintaining the correct humidity (Geyh *et al.* 1974; Museum and Galleries Commission 1992; Shelton 2008; Mecklenburg 2007). In addition, unsuitable packaging and uncontrolled environments can hasten attack by undesirable factors such as bacteria (Hubbard and al Azm 1990).

Relative Humidity

Relative humidity (RH) is defined as the quantity of moisture which is in the air *relative* to the amount that the air is capable of holding (water quantity in a specific air quantity ÷ highest water quantity that air can retain in this temperature × 100%) (Lindblom-Patkus 1999; Pavlogeorgatos 2003). Dry items in a store that increases in RH will experience an increase in the quantity of water, no matter how small, within the stored item (Utriainen *et al.* 2007). Each class of material should therefore be maintained in an environment that encourages a stable RH and temperature that best suits the needs of their physio-chemical composition (Palfreyman 1998). Palaeoenvironmental remains will suffer in a RH that exceeds 55% as insect, pest activity and acid hydrolysis are promoted in such conditions (Museum and Gallery Commission 1992). A RH that exceeds 60% can quickly encourage mould and microbial attack (Lindblom-Patkus 1999). Low RH – a value lower than 30% – is too low and can lead to shrinkage and cracking (table 3) (Sharif-Askari and Abu-Hijleh 2018).

Botanical remains should be stored in an environment that does not exceed 45-55% RH (SMA 2020), and mollusc shells should be between 45% and 50% (Shelton 2008). Dried wood will react to the surrounding environment and will contract and expand according to the moisture in the air and should therefore be maintained consistently at 45–55% RH (Cabello 2011)

No literature indicates what RH silica and mineral replaced remains should be stored at. Silica remains are particularly robust and will not be compromised if exposed to fluctuating RH (Integrated Archaeobotanical Archive 2010). Since mineral-replaced items are likely to have a high concentration of calcium carbonate, they are recommended to have the same RH as molluscan and microfauna remains which physio-chemically comprise mainly calcium carbonate. Further research is required to determine the treatment of mineral-replaced items.

Archived material	**Recommended relative humidity**	**References**
Charred botanical remains and charcoal	45-55%	SMA 2020
Mollusc and microfauna	45–50%	Shelton 2008
Phytoliths	Robust enough to survive fluctuating humidity	Integrated Archaeobotanical Archive 2010
Mineral replaced	45–50%	Shelton 2008
Dried archaeological wood	45–55%	Cabello 2011

Table 3. Recommended RH for dried archaeological palaeoenvironmental materials

Due to factors such as height above sea level, local weather conditions and the air temperature outside the building, relative humidity is not constant across a single storeroom and can vary depending on the proximity to the roof, the floor, walls, corners of rooms, sources of ventilation and the containers themselves (Utriainen *et al.* 2007; Fairnell *et al.* 2020; Brown and Rose 1997; Hu *et al.* 2015; Schulze 2013).

Humidity and temperature can be managed through heating, ventilation, and air conditioning (HVac) systems (Neuhaus 2013). Adopting HVac systems has benefits as individual rooms and microclimates within rooms can effectively be managed by installing sensors that detect temperature and humidity, dehumidifiers, heating, and air conditioners (Broström *et al.* 2013). Despite these apparent benefits, there are arguments against the use of HVac systems. Neuhaus, for example, has observed that these systems do not always operate following the design specifications and can create an environment that is more harmful than if the system was not used (Neuhaus 2013). Incorrect design can also lead to higher costs that increase the running costs of a HVac system (Neuhaus 2013). For many museums, even small increases to running and utility costs can result in a museum's annual budget being exceeded (D Fox 2018 City Art Gallery and Museum personal communication 24 September).

The running costs of a HVac system do not have to be expensive, but they do need to be correctly designed and monitored using a thermohygrometer or hygrothermograph linked to dataloggers to ensure that they are running efficiently (Ferdyn-Grygierek 2020; Shelton 2008). Costs can be further reduced and mitigated against rising energy costs with the adoption of solar power (Ryhl-Svendsen 2013). Running HVac using energy efficient solutions has been achieved at the Museum of South-West Denmark storage building at Ribe (Ryhl-Svendsen 2013). The results reported on by the Museum of South-West Denmark have largely been successful, although considering factors such as having sufficient space to mount solar panels and having backup power for situations when adequate power cannot be generated (Ryhl-Svendsen 2013). Attempts have been made to make buildings efficient and achieve the correct storage environments without using traditional HVac systems (Utriainen *et al.* 2007). This 'passive' method of managing temperature and humidity requires buildings not to have super-insulated walls but be built from materials that contain little moisture; concrete used in the roof should not exceed more than 15% of the total used in roof construction, and the floor built of concrete poured on-site (Klem 2013). Buffering, whereby materials such as wood and unfired brick and clay are used in the floor and roof to allow for thermal inertia, can create a storage environment with an appropriate RH (Liuzzi 2013; Schulze 2013; Ryhl-Svendsen 2013). Other methods of maintaining a more manageable temperature and RH are minimizing the amount of outside wall being exposed to direct sunlight, not overpacking storerooms with too much material, and using the microclimate of a storeroom to store appropriate materials in the correct part of the store (Utriainen *et al.* 2007; Fairnell *et al.* 2020). Finally, it has been suggested that packaging archives and collections can assist with the challenges of RH and temperature. Utriainen *et al.* (2007) suggest that artefacts should be stored in porous paper bags to allow for moisture and vapour transfer and be placed in cardboard boxes that can act as a buffer. This suggestion may be viable for storing certain archaeological archives, but porous containers may be inappropriate for palaeoenvironmental remains. Farnell *et al.* (2020) concluded that for the storage of zooarchaeological remains, using porous containers would stabilise microclimate RH and reduce the chances of mould but could increase the risk of insect attack. A solution was sought via the application of humidity indicator strips which allow for monitoring of each sealed box of faunal remains. It was determined that sealed boxes in a store that maintains a relatively low RH should arrest the development of mould. Indicator strips will signal unwanted shifts in RH, which can then be counteracted with localised measures. However, silica gels should not be used with charred archaeobotanical remains, and if used in proximity to gelatine capsules, they should only be used as a temporary measure; otherwise, they will dry out the capsules (Tirlea *et al.* 2019).

Temperature

It has been well documented that storage temperature can affect the condition and health of biological specimens (Carter 2000; Pavlogeorgatos 2003; Broda and Hill 2021; Knight and Thickett 2007). Biological materials can be affected by relatively modest temperatures; a rise in only 5°C, from 15°C to 20°C, for example, can increase the degradation of cellulose in wood by up to 250% (Pavlogeorgatos 2003). Incorrect temperatures can encourage microbial and fungal attacks and pests, and fluctuating temperatures can quickly lead to detrimental effects such as cellular collapse (Melin and Bjurman 2017; Fairnell *et al.* 2020; Werz and Seemann 1993).

Following the advice provided by Natural Sciences Collections Association (NatSCA), shell is recommended to be maintained at 20°C (Carter 2000). Mollusca and microfauna should therefore be stored at 20°C. The storage of mineral-replaced remains has received very little consideration, and there is a dearth of published materials regarding this matter; given that the typical composition of mineral-replaced remains are calcium phosphate and calcium carbonate in nature, it seems prudent at this stage to recommend similar conditions to mollusc shell. This is a topic that could warrant further research in the future. Phytoliths are robust and will not be affected by the environment's temperature (Carruthers and Smith 2020; Integrated Archaeobotanical Archive 2010). Freeze-dried wood should be maintained between 19°C - 24°C (Cabello-Briones 2011).

Archived material	Recommended storage temperature	Additional points of interest	References
Charred plant remains and charcoal	-	N/A	Integrated Archaeobotanical Research Project (2010)
Mollusc and microfauna	20℃	A stable temperature must be maintained and free of fluctuations (Carter 2000)	Carter (2000)
Phytoliths	-	N/A	Integrated Archaeobotanical Research Project (2010)
Mineral replaced items	20℃	N/A	N/A
Freeze dried wood	19℃-24℃	N/A	Cabello-Briones (2011)

Table 4. Recommended temperature for dried archaeological palaeoenvironmental materials.

Light

Harmful agents such as bacterial and fungal growth can be arrested by reducing the amount of light that archived palaeoenvironmental remains receive (Pavlogeorgatos 2003). Research by Wohlfarth *et al.* (1998) revealed that dry botanical items could have microorganisms, or fungal strands, growing throughout the specimen whilst being stored prior to processing. This research revealed that fungal growth could redistribute carbon within the specimen. Reducing light can slow the growth of fungal hyphae and other intrusive agents such as algae which can grow and provide erroneous radiocarbon dates (Campbell *et al.* 2011). Further research is required to determine the duration of which these processes continue to affect botanical remains in a post-depositional environment and to what extent they can damage archived remains. Consequently, many museums and repositories need to keep archaeological archives in appropriate light environments for storage and display.

Light exposure in museums and archives is measured as infrared light, visible light and ultraviolet (UV) light, all three of which are detrimental to the health of all biological specimens (Ajmat 2011). To discourage growth of microorganisms, all three spectral light categories must be minimised to prevent harm to palaeoenvironmental remains. Illuminance, or the light that falls on a surface of an object, is measured in lux. The lower the recommended lux, the class of objects should be exposed to less light (Garside *et al.* 2017). Regarding luminescence, there are three categories that museums follow for display purposes: i) insensitive materials: 300 lux, ii) sensitive materials 200 lux, and iii) very sensitive materials 50 lux (Sharif-Askari and Abu-Hijleh 2018; Thompson 1978).

Botanical specimens are susceptible and should be maintained below 50 lux (Museums and Galleries Commission 1992). Mollusc shell is susceptible to risks such as Byne's disease, which can lead to significant degradation of the surface of the shell and should therefore be regarded as sensitive to light (Shelton 2008; Museums and galleries of NSW). Fluctuating visible light and UV levels, along with other factors such as temperature, humidity and general neglect, can contribute to shell decay (Carter 2000). Microfauna has been extended to be included in the same group as mollusc shell. Dried wood can also be regarded as sensitive and should not be exposed to an environment that exceeds 200 lux (Museums and Galleries of NSW; Museums and Galleries Commission 1992).

Ultraviolet light (UV) can be characterised as the amount of light emitted, and in the case of museum curation, relates to the in-door lights used. This is measured in microwatts per lumen (Michalski 2018). Ultraviolet radiation is measured in UV per lumen of visible light. The display and sustained exposure of charred plant remains, mollusc and microfauna, mineral replaced items, freeze-dried wood, and phytoliths should not exceed 75µW/lumen (Museums and Galleries Commission 1992; SMA 2020).

Archived material	**Lux**	**Lumen**	**Sensitivity group**	**References**
Charred plant remains and charcoal	<50	75	Very sensitive	Museums and Galleries Commission 1992; SMA 2020
Mollusc and microfauna	200	75	Sensitive	Museums and Galleries Commission 1992; SMA 2020; Carter 2000
Mineral replaced items	200	75	Sensitive	Museums and Galleries Commission 1992; SMA 2020; Carter 2000
Freeze dried wood	200	75	Sensitive	Museums and Galleries Commission 1992; SMA 2020
Phytoliths	300	75	Insensitive	Museums and Galleries Commission 1992; SMA 2020

Table 5. Recommended light conditions for dried archaeological palaeoenvironmental materials

Storing palaeoenvironmental archives in low light conditions should not pose any significant challenges for museum and repository staff as items can be placed in boxes that do not allow the penetration of light. However, exposure to light should be considered when being analysed and displayed. If items are selected for analysis, materials should be retained in a closed non-transparent box until the point of analysis and then returned to these conditions immediately after research has concluded. Compact fluorescent or white LED bulbs should be used for display purposes to maintain the 75-lumen maximum exposure (Druzik and Michalski 2012).

Dry palaeoenvironmental remains in context

The partner museums were surveyed to determine the conditions for storage and establish if they have the proper facilities to store palaeoenvironmental archives. No definition was provided of what constitutes 'correct' conditions as the question was dually establishing curator attitudes towards their standards. The results of the survey demonstrate that 43% of the 14 respondents believe that they have the correct standards, 21% were unsure, and 36% did not think that they operate with the appropriate environmental control to store palaeoenvironmental remains. Of the 36% of respondents believed that they did not maintain the correct standards, and were concerned that factors such as temperature fluctuations and uncontrolled environments could potentially place the stored items at risk.

Using examples provided by the museum partners, it becomes clear that the temperature and relative humidity experienced across the museums in England vary. At the Museum of North Lincolnshire, for example, the industrial unit that archaeological archives are stored in, in an average year, experiences temperature fluctuations from 3℃ to 32℃ and relative humidity fluctuations ranging from 30% RH to 88% RH (R Nicholson 2018 Collections Manager for North Lincolnshire Museum Service personal communication 21 August). In the store that Yorkshire Museums Trust used until moving to a new unit in 2021, a record low temperature of 1℃ was measured (A Parker 2020 Assisstant Curator of Archaeology at Yorkshire Museum personal communication 21 January). These fluctuations in temperature and RH are sub-optimal and are not ideal for the long-term curation of palaeoenvironmental archives. In contrast, the newer facilities, such as the Somerset Heritage Centre store, maintain temperatures between 18℃ and 24℃ and relative humidity between 40% RH and 60% RH and experience low levels of fluctuation (A Khreisheh 2019 Curator of Archaeology personal communication 10 September 2019). Although the Somerset Heritage Centre example can maintain stable temperature and humidity. Although there are no examples amongst the visited museums of dedicated space for palaeoenvironmental remains, there are international examples where such practices are observed. At the provincial Depot of Bodemvondsten, Noord-Brabant in 's-Hertogenbosch, Holland, the facility has eight storage rooms maintained at different temperatures and relative humidity. This is in addition to the main store that is maintained at 18°C and has a RH of 50% (+/-5%), which is used to store shells, phytoliths, freeze-dried wood, wood charcoal, insects and microfauna; an additional storeroom is maintained at a temperature of 6°C and does store charred plant macrofossils and charcoal (M Meffert 2021 - Content Management Provincial Depot Soil Finds Noord-Brabant pers comm 10 November). The Noord-Brabant example demonstrates that a facility with dedicated stores for dry palaeoenvironmental archives can be designed and maintained, but there needs to be space and enough funding to be able to introduce the heating, ventilation and air conditioning required to sustain the right conditions. This will be further explored in the following chapter.

Containers and packaging

To determine where improvements need to be made for the containers and packaging, various recommendations and guides have been consulted to produce comprehensive standards for the correct containers and packaging for archived palaeoenvironmental remains. These standards will be compared to examples provided by museum partners to establish what priorities need to be made to ensure the long-term preservation of existing palaeoenvironmental archives.

The methods of long-term storage for dry archaeobotanical archives are promoted by organisations such as the Society for Museum Archaeology (2020), English Heritage (2011). The Society for Museum Archaeology and the Archaeological Archive Forum recommends that bulk finds and dried residues be packaged in durable paper or suitable polyethene bags (SMA 2020; Brown 2011). As highlighted by Fairnell *et al.* (2020), the idea of using porous bags such as paper may prevent the development of microenvironments and allow moisture transfer, but sealed plastic has more benefits such as preventing insect attacks; plastic is therefore preferred. Samples that are regarded as sensitive should be stored in boxes or bags and, where necessary, have padding to resist vibrations and prevent movement in the box (SMA 2020; Brown 2011). Archaeobotanical remains are not explicitly referenced and fall within these recommendations. Taking a view from the standards of handling dry botanical specimens from Kew, the recommendations are focused on using plastic and glass vials with polypropylene lids (Gold and Manger 2014). For long-term storage of modern palaeoenvironmental materials, practices within natural history collecting revealed that glass vessels are preferred over plastic, as glass will not degrade and in gaseous form potentially contaminate the sample, and glass will not encourage the build-up of static electricity, resulting in the specimen leaping from the vessel (Tirlea *et al.* 2018; Waller *et al.* 1996; Horne and Siveter 2016). In terms of a stopper, polyethene is the preferred material over rubber or metal as it will not degrade over time, and vials should be supported in upright polystyrene holders (Levi 1966; Simmons 1995). Compared to seeds, the storage of archaeological charcoal has received little attention, and few publications deal with the matter. In place of specific data about the long-term storage of charcoal, the data in this chapter seeks to use existing broader guidelines and observations to provide useful recommendations.

Phytoliths

Dried powderised phytoliths should be maintained in glass vials rather than plastic to avoid static build-up (Horne and Siveter 2016; Integrated Archaeobotanical Archive 2010). Wide glass vials with plastic polyethene stoppers should be stored in upright polystyrene vial holders.

Charred botanical remains

Observations from museum stores revealed that charred botanical remains are stored in various ways, some of which are aligned with accepted standards and others that fall outside. In examples from York Museum Trust and the Wiltshire Museum, Devizes stores, there are instances where charred remains are stored upright in glass vials with plastic stoppers meeting the standards outlined above.

Plate 1. Charred plant remains from Stanwick stored York Museum, York

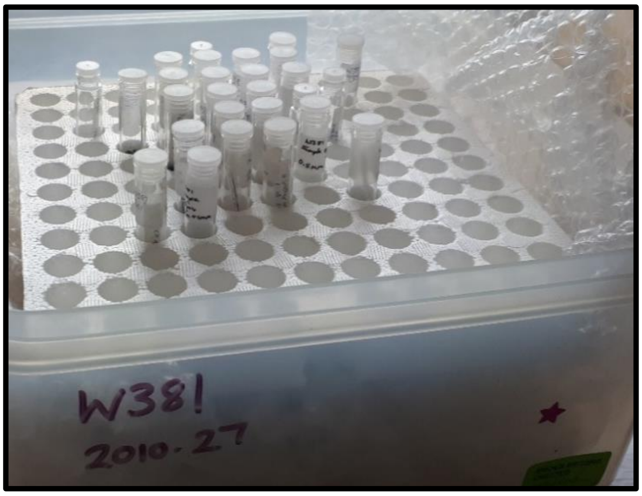


Plate 2. Example of plant macrofossils from the 1990 excavations at Market Lavington in glass vials being maintained in upright polystyrene vial racks at the Wiltshire Museum, Devizes

In addition to the examples of good practice, there are legacy archives with charred botanical remains contained in the same vessels that appear to have been conveniently on-site or on hand to the specialist at the time of analysis. Containers often relate to tobacco and smoking paraphernalia, such as match boxes, tobacco tins and cigar cases, examples of which are the Meare East excavations of 1966 (plate 3 and 4). In another example from Meare Lake Village, boxes of charred plant remains have been stored directly in cardboard boxes. These stored boxes contain a mix of dried sediment, and an abundance of charred plant remains (Plate 5). The condition of these remains has been revealed as being variable. Examples include cotton wool in boxes that have snagged shell remains leading to breakages and seeds that have become damp and mouldy. Assemblages in inappropriate packaging would benefit from repackaged and stored in correct vessels.

Plate 3. Matchboxes and tobacco tins from Meare Lake Village East which contained charred plant remains.

Plate 4. Archived charred Bronze Age seeds from Meare Lake Village East in a tobacco tin

Plate 5. An example of the partially processed plant remains from Bronze Aged contexts at Meare Lake Village East being stored in cardboard boxes.

Charcoal

Charred remains are delicate and are susceptible to being crushed (Ngan-Tillard *et al.* 2015). They should therefore be maintained in suitable rigid containers that prevent the risk of being compromised (Integrated Archaeobotanical Archive 2010). Upon inspection, charcoal was found to be contained in a variety of conditions. In an example from the Wiltshire Museum store, charcoal was recovered and stored in glass jars with metal and plastic screw lids (see plate 7). From a cursory visual inspection, these samples did not demonstrate any apparent signs of abrasion. Compared to an example of charcoal stored in the York Museum Trust store and collected from the 9 Blake Street, York, excavations, the charcoal was maintained in paper bags in cardboard archive boxes. A rapid assessment of the Romano-British charcoal from the excavations revealed that the charcoal had become broken and abraded since the archive was in the store. In the example of context 2129 (see plate 6), the charcoal sample has been snapped and broken into several pieces, with the abrasions demonstrating evidence of being broken recently (Caromano *et al.* 2014.). This would have been prevented if it had been stored in a glass vessel.

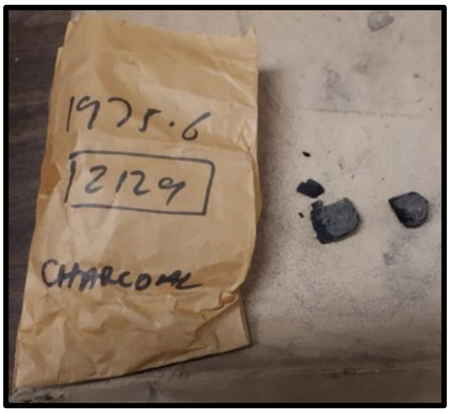


Plate 6. Charcoal from Blake Street, York, currently stored in Yorkshire Museum Trust store

Plate 7. Charcoal recovered from1990 excavations at Market Lavington, currently stored in glass jars in Wiltshire Museum

Shell remains

As highlighted earlier in the chapter, the shell should be maintained in glass rather than plastic vials. The stoppers and lids used pose more of a challenge given that anything but ridged plastic stoppers - such as cork or rubber - can perish and do not provide airtight conditions (Hanlon and Kelsey 1998; Schauff 2001). Given shell's sensitivity to plastic, the selection of stopper creates something of a conundrum. The risk of the stopper becoming compromised or decaying and resulting in a total loss is regarded as more of a threat than off-gassing. In place of a better solution, plastic stoppers are regarded as the best solution available. Examples of the use of plastic containers and stoppers can be seen in plate 8.

Plate 8. Shells in glass vials with plastic stoppers in the North Lincolnshire Museum store

In the example of the Wilsford Shaft excavation archive, currently stored at the University of Reading, the shell remains have been stored in various types of containers, which for the most part, can be regarded as being of a high standard. However, in an example from the Wilsford Shaft, a matchbox with cotton wadding has been used to store a complete shell. Ideally, this should be transferred to a larger glass vessel with a plastic lid.

An example observed in the York Museums Trust store showed that mollusc shells from the 1975 Blake Street excavation were stored in paper bags in cardboard boxes (plate 9). However, organic and inorganic palaeoenvironmental remains are at greater risk of developing mould and succumbing to rot than stable ‘cultural’ remains. Cardboard boxes will soak moisture and allow the materials inside to develop mould spores and rot. In the Yorkshire Museums Trust store example, the shell had developed mould due to the wet cardboard. Shell also became abraded due to the absence of a rigid container that could adequately protect the samples.

Plate 9. Mollusc shell from the Blake Street excavations, York contained in brown paper

Plate 10. Shell that has become abraded, damp and mouldy.

It is recommended that glass vessels with plastic lids are used and stored on lower shelving rather than on high shelves where they are exposed to factors such as leaks or condensation. Although no archived items should be exposed to moisture, some items are more robust and forgiving than organic/inorganic archaeological palaeoenvironmental remains.

The curation of fluid-preserved archaeological archives

England's waterways, river terraces, fens, wetlands, peat bogs, and coastal fringes encourage the preservation of palaeoenvironmental remains and ecofacts through waterlogging (French 2017; Holden 2006; Brunning 2012). Enhanced levels of preservation afforded by waterlogging can lead to a greater range of materials being preserved than charred and mineral-replaced remains (Werz and Seemann 1993). Small and fragile items, such as leaves, pollen, mosses, plant fibres, cordage, insects, parasites, fungi, skin, and hair fibres that do not have a robust structure would likely be destroyed in the charring process, are only likely survive in waterlogged contexts (Ashbee *et al.* 1989). Waterlogging is beneficial for the preservation of external morphological features (Ismail-Meyer 2017). In addition to preserving external features, internal features such as soft tissue, protoplasm, nucleic acids, proteins, and lipids are also preserved, which can offer genetic and isotopic data (High *et al.* 2016; Brown and Brown 2011).

Sediments more susceptible to waterlogging are often located in floodplains, wetland organic clays and peats, marine environments, and lakes, all of which encourage the preservation of archaeological materials (Holden 2006). The conditions necessary for waterlogging can also be identified in dryland archaeological sites in features that extend into organic soils, or sediments, or beneath the localised water table (Historic England 2018b). These could include wells, shafts, deep-cut pits, and ditches (College 1988; Green 1986). Being constantly submerged in water, they are deprived of oxygen, and bacterial and fungal microorganisms struggle to survive and attack organic remains (Retallack 1984). The pH of the sediments and water can also influence the preservation (Caple 1994). Alkaline to neutral conditions promotes the survival of plant fibres and bone, whereas acid to neutral pH encourages the preservation of keratinous material such as horn and animal fibres (O' Connor *et al.* 2015; Historic England 2018b; Watkinson and Neal 2001). Items including waterlogged wood, insects, plant remains, molluscs, diatoms, foraminifera, pollen, and spores are robust materials that can survive in various pH conditions (English Heritage 2008; English Heritage 2011).

The delicately balanced hydrological conditions and chemical composition of sediments mean that they are at risk from intrusive activities such as dewatering, deep ploughing and building developments, which can irrevocably alter the stability of these deposits and result in the degradation of palaeoenvironmental remains (Coles and Hall 1997). Activities potentially detrimental to palaeoenvironmental materials include the process of archaeological excavation itself and, if not conducted correctly, can damage waterlogged remains. Once removed from the delicately balanced waterlogged sediments and introduced to an oxidising environment, palaeoenvironmental remains instantly begin to suffer (Kaye *et al*. 2000). Consequently, waterlogged items, either hand-collected or recovered from environmental samples, need to be maintained in an environment which replicates the one in which they were discovered (English Heritage 2011). This requires remains to be immediately suspended in clean water and where practicable, maintained at a stable temperature between 0℃ and 10℃ in a store with limited exposure to UV light (SMA 2020).

Once analysed, relevant stakeholders need to consider which items should be selected for long-term storage (Brown 2015). Selecting waterlogged remains for long-term storage is complicated by museum policies, which regularly state that they will not accept waterlogged remains (see West Berkshire Museums and Reading Museum collecting policies for examples) due to the intricacies associated with curating wet archives. The decision to refuse wet archives may prove regrettable given the decline in wetland resources due to increasing global temperatures, which will likely lead to a scarcity of such resources (Moomaw *et al.* 2018; Marte *et al*. 2003). Furthermore, levels of detail, including shape, size and colour, are not distorted in the same way as they would be if they were charred, providing greater insight into topics such as comparative anatomy, taxonomy, and evolutionary biology (Austin and Melville 2006; Werz and Seemann 1993).

Genetic Research

An additional benefit of deposits becoming waterlogged can be the preservation of palaeoenvironmental remains and their internal features, such as genetic material (Brown and Brown 2011). Although the waterlogging of sediments is not *guaranteed* to preserve palaeoenvironmental remains, circumstances such as the movement and percolation of water can be detrimental to the survival of palaeoenvironmental remains; these environments can be vital to the survival of these remains and internal features (Parish et al. 2008). Genetic material's survival may prove vital for future archaeological research. Ancient DNA (aDNA) has, for almost 30 years, provided an insight into the evolution, use and exploitation of plants and animals (Higuchi *et al.* 1984; Slatkin and Racimo 2016). In the last five years, extracted aDNA has proved remarkably successful at the recovery of genetic material from archaeobotanical remains and evidence of palaeoenvironmental items that have degraded from a physical state into a chemical state, leaving residues preserved in sediment (sedDNA) (Gutaker and Burbano 2017; Brown et al. 2021; Di Donato 2018; Estrada 2018; Smith *et al.* 2015).

Nucleic acid (includes DNA and RNA) extraction followed by focused downstream sequencing of preserved palaeoenvironmental remains can provide insights into past diets, plant and animal domestication, and the adoption and importation of exotic plants (Lever *et al.* 2015; Downes 2021). Techniques such as Polymerase Chain Reaction (PCR) provide greater levels of sophistication and detail but over the last 37 years, since the first aDNA has been extracted, the development of aDNA research has been complicated by erroneous results (Rizzi *et al.* 2012). Notorious examples include the much-heralded extraction of what was believed to be dinosaur DNA but was revealed to be human DNA that contaminated the sample (Hedges *et al.* 1995). Other examples of DNA analysis conducted in the 1990s include cases where results could not be replicated independently in different laboratories and were discounted (Sidow 1991). Because of the unsatisfactory results, the methods and techniques employed in ancient DNA research are under scrutiny (Poinar and Cooper 2000). This level of scrutiny extends beyond the laboratory methods used for extraction and covers the methods used to conserve and store specimens in advance of genetic research and how these specimens are treated after analysis to ensure there is recourse to repeat the results (Hofreiter 2012).

Genetic research requires the presence of sufficient base pairs for analysis (Ciftci *et al.* 2019). The four bases (A, G, C and T(U)) form two whole groups of base pairs that must make up the necessary elements of nucleic acid and allow for the transfer and replication of genetic information (Hirao *et al.* 2012). The presence of available base pairs required for analysis is made more complex by the rapid degradation of genetic material after death (Burrell 2015). Take, for example, the plant *Arabidopsis thaliana* (L.) (rock cress) – a living sample that will possess over 100 Mb (100,000,000 base pairs). Once deceased, the effect of oxidation encourages the attack of microbial enzymes, which quickly erode tissue, and cells, and will be further degraded by endogenous nucleases, leading to hydrolysis and base-pair corruption (Hofreiter *et al.* 2001; Bennett 2003). In many examples of DNA extraction from archaeobotanical remains, base pairs have fragmented and rarely occur in less than a thousand base pairs (Wales *et al.* 2014). Short molecules can be amplified to extract enough information (Wagner *et al.* 2020). In addition to the decay to chain length, aDNA is prone to miscoding lesions (Fattorini 1999). These can be characterised as variations in the DNA template, which are affected by modifications in the guanine, cytosine, adenine, and thymine base during sequence amplification (Warren 2019). Post-analysis degradation can occur for various reasons, including post-excavation modifications, oxidization and drying during analysis and the incorrect use of chemical fixatives and preservatives used in the conservation process (Bernick 2011). The following section examines the methods employed to stabilise waterlogged remains for long-term storage. To preserve waterlogged remains for long-term storage, there are two routes to achieve proper conservation; the controlled drying of items and maintenance in a waterlogged state using a combination of preserving fluids (Tredwell 2006; Moore 1999; Broda *et al.* 2021).

Controlled Drying of palaeoenvironmental remains for Long-term Conservation

Controlled drying of waterlogged palaeoenvironmental remains can sustain their health and eliminate the need to use fluids for their conservation. As observed by the York Archaeological Trust (see page 81 in this chapter), the constant monitoring of fluid collections can be problematic given their susceptibility to evaporation if not correctly monitored, leading to disintegration. If left to dry without assistance, waterlogged materials will distort, crack, curl, and internal features will degrade (Senge and Carrlee 2013; Hosaka and Uno 2011). Analyses of modern entomological (insect) specimen, internal features and DNA have been shown to significantly degrade within a single day of drying and being exposed to air (Bisanti 2009). Whilst it is unclear if analogous archaeological remains would similarly degrade, care should be taken to not allow remains to dry until further research has determined the effects of uncontrolled drying may have on remains. The undesirable effects of uninhibited air drying can be countered using controlled air drying, freeze-drying and chemically assisted drying procedures (Broda *et al.* 2021; Fejfer *et al.* 2020).

Freeze-Dried wood

Unless preserved through charring, archaeological wood from British archaeological contexts is only identified in waterlogged anaerobic environments (Pedersen *et al.* 2021; Rich *et al*. 2016). It requires drying in controlled conditions to stabilise waterlogged wood and make it both storable and presentable in museum display (Florian 1990; Pedersen *et al.* 2021; Watson 1987). The most common form of conservation used in archaeology is freeze-drying, bulking agents, and wax impregnation (Ambrose 1990; Schindelholz *et al.* 2005). Dried wood should be packed in individual wooden containers that can act as a buffer to allow for external fluctuations in relative humidity (see plate 11). Sealing wood in polythene without a permeable buffer between the surface of the wood and plastic is not recommended (English Heritage 2010). Instead, large timbers should be cushioned with acid-free paper and, where necessary, supported using plastic or foam (National Museum of Iceland 2012). Items must be flat on a solid surface in an environment that promotes the correct unfluctuating temperature and RH (Harvey and Freedland 1990).

Archaeological wood is conserved using freeze-drying with the addition of polyethene glycol (PEG), a bulking agent that is water-soluble and impregnates the wood to replace the decomposed cellulose and prevent mechanical stress caused by drying (Fejfer 2020; Shaozhi 2016; Florian 1990). PEG has proven to be an effective method of preserving waterlogged timbers for long-term storage and display (Broda *et al.* 2021). However, although regarded as an effective conservation technique, PEG can cause shrinkage, distortion, reduced strength and stiffness (Lechner *et al.* 2013), although recent research has revealed that PEG preservation does not affect anatomical structure and techniques such as Computerised Tomography scans can still identify the species (Rankin *et al.* 2021).

Plate 11. Freeze dried wood packed in individual rigid plastic container at the Yorkshire Museums Trust.

Freeze Drying Invertebrates and Plant Remains

Freeze drying is a tried and tested method of drying waterlogged palaeoenvironmental remains (McCobb 2001; Jones 2009; Tirlea 2015). The freeze-drying process requires items to be frozen and then sublimated ice crystals, which are slowly transferred into water vapour (Hasley and Oetjen 2018). This process skips a liquid state, removing surface tension and minimising cell damage (Adams *et al*. 2015; Hangay and Dingley 1985). Although cell damage is minimised, there is still a certain degree of unwanted consequences such as shrinkage and distortion (Broda *et al.* 2021). Other problematic outcomes associated with freeze-drying include specimens becoming very brittle and requiring a great deal of care when being handled and, also, internal components such as nucleic acids, proteins, and lipids being destroyed (Walker *et al.* 1999).

Freeze drying in natural history began to gather traction as a conservation method in the 1950s and has come to be commonly employed in preserving insect larvae, and plant remains (Danilevskii 1950; Harris 1964; Bogs 1976; Morris and Seifert 1978; Gilkeson 1990). The freeze-drying of archaeological remains similarly began in the 1950s but focused more on archaeological timbers (Van Zeist *et al.* 1976). The conservation of archaeological remains has focused on the timber remains rather than insects and plant remains, but advances are ongoing, and improvements are constantly being made (I Panter 2021 – Head of Conservation – York Archaeological Trust personal communication 15 November; Broda and Hill 2021; Enevold *et al.* 2019).

Critical Point Drying

Critical point drying (CPD) was initially conceived as a method of preparing wet samples to be mounted for examination with a scanning electron microscope (SEM) (Bhattacharya 2020). SEM analysis requires specimens to be dried and coated in palladium or gold before mounting. Once achieved, SEM can produce detailed images of plant and insect surface morphology (Bomblies *et al.* 2008). The benefits offered through CPD are that the technique prevents specimens from collapsing on themselves whilst the specimens retain a certain level of flexibility that freeze-drying does not allow for, although the use of CPD can result in the dulling of colours of the specimen. Critical point drying was not originally intended to act as a tool to enable conservation, but its benefits were realised, and it is now used to conserve archaeological specimens for long-term storage (Kaye *et al.* 2000; Broda *et al.* 2021).

The critical point is the temperature at which a substance exists either in, or on the cusp of three states – solid, liquid or gas (Baskin *et al*. 2014; Historic England 2018b). Firstly, a specimen must be fixed (see page 74 for more details regarding the fixing process) using ethyl or methyl alcohols (Talbot and White 2013). Once fixed the specimen is introduced to a transitional fluid such as Freon, liquid CO_2, or carbon dioxide at its critical point, and then the temperature increases to reach a vapour state under a vacuum (Kaye *et al.* 1998). The use of Freon or liquid CO_2 under a vacuum means that a specialist with the correct facilities can only undertake the process, and the process can be expensive (Bhattacharya 2020; Bernick 2011).

Natural history practice has used critical point drying to great success with conserving mealy bugs, thrips, aphids, Diptera and Hymenoptera (Walker *et al.* 1999). The specimen's relative flexibility post drying suits insects, and their fragile appendages do not become too brittle. Additional benefits include low shrinkage levels; if prepared and fixed appropriately, tissue shrinkage can be as little as 8% (Talbot and White 2013). Specimens conserved using critical drying point techniques have demonstrated a relatively high yield of genetic data, especially in short and abundant DNA such as ribosomal and mitochondrial DNA (Austin and Dillion 1997). Archaeological practices forays into critical point drying have been concerned with conserving wood rather than invertebrates, or plant remains (Broda *et al.* 2021). To date, there has been limited experimentation with archaeological remains, and further experimentation is recommended to identify how archaeological remains behave when conserved through critical point drying.

Cryopreservation

Initially developed in the 1950s as a method to preserve biomedical samples, cryopreservation has been adopted to preserve biological materials in diverse fields (Baust 2009). Cryopreservation is where tissues and cells are stored in sub-zero temperatures to completely arrest biological activity and preserve specimens for future use (Iussig 2019). Samples can be thawed and refrozen through repeated cycles without affecting genetic data or internal structure (Ryding 2019). Over the last few years, influenced by the outcomes from reports such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment Report, cryopreservation techniques have been used with greater frequency by museums, herbaria, biobanks, and biorepositories around the world to preserve plant tissue and genetic data in the face of extinction (Funk *et al.* 2017; Pavid 2018; Shabihkhani *et al.* 2014; IPBES 2019). As with freeze-drying and spirit protocols, natural history museums extract genetic code and bank this with Genbank prior to long-term conservation (Martin 2006).

Liquid nitrogen (LN2) is a common material used by institutions to sustain genomic, germplasm, transcriptome, and proteome information in a range of plant materials to allow for the future propagation and species resurrection if a plant is lost due to extinction (Pence 2014; Shabihkhani *et al.* 2014). Realising its potential for preservation, natural history collections adopted the use of ultracold temperatures to bank specimens to preserve global biodiversity and, as asserted by Hagedorn *et al.* (2018), allow for the following five key outcomes:

> 1 - large samples of preserved and protected gene pools to 'seed' shrinking populations, even to 'resurrect' extinct species
>
> 2 - easy and inexpensive transport of genetic materials among living populations, such as small populations in zoos
>
> 3 - access to quality biomaterials for scholarly research
>
> 4 - invaluable opportunities to maintain individual genomes of rare species; and, most important,
>
> 5 - the capture and distribution of genetic diversity.

Within archaeology, not all the above points are necessarily relevant, but applications 3, 4, and 5 do bear relevance. As a means by which to allow access to biomaterials, maintain the genomes of rare species and capture the distribution of genetic diversity, cryopreservation should be considered for its use in the long-term preservation of archaeological palaeoenvironmental remains. To determine how cryopreservation could be used in archiving palaeoenvironmental remains, a short overview of its potential as a conservation tool and possible disincentives are provided.

The cryopreservation of palaeoenvironmental remains could be considered for the conservation of, for example, early instances of domesticated taxa or landraces, particularly rare findings or other significant discoveries. To date, however, cryopreservation is not routinely used in archaeology, unlike in natural history and biosciences. Within natural history practice, samples have genetic material extracted, the information is made available and stored on Genbank, and then the specimen is placed at ultracold temperatures (Zimkus and Ford 2014). A selection of museums and repositories around the world possesses the facilities and in-house specialisms that allow for localised management of cryopreserved specimens, making access for specialists working in that discipline and institution practical and streamlined (see Natural History Museum, ZSL Institute for Zoology and the Smithsonian Institute for example). However, unlike the natural history sector, cryopreservation is not a process available 'in-house' within archaeological/heritage organisations (in England), which significantly reduces opportunities for the medium's consideration as a conservation method (Angela Middleton 2020 - Senior Archaeological Conservator, Historic England - personal communication 8 August).

Further impediments likely include the financial costs of controlled drying techniques for archaeological palaeoenvironmental remains. In terms of financial cost, liquid nitrogen is relatively inexpensive, but the supporting equipment required to maintain a cryopreservation laboratory is more costly. Tools such as laminar flow hoods, PCR machines, centrifuges and supporting equipment, including glassware and the cryovats, freezers, and oxygen monitors can become expensive. In the case of the Natural History Museum in London, in 2002, the cryopreservation laboratory cost £67,500 to set up and £10,000 a year to run in terms of material and utility costs (Martin 2006). In addition to these costs, specialist-trained staff are required to operate the equipment, handle hazardous materials, and deal with potentially complex health and safety challenges (Talbot *et al.* 2013; Kulus 2019).

Finally, there is a dearth of information regarding what effects such extreme temperatures could have on palaeoenvironmental remains. The preservation of internal features, acids and proteins is known to be encouraged by cryopreservation, but what about remains that are damaged to the cellular level after centuries or millennia in buried contexts? Can ultracold temperatures have detrimental effects on external morphologies? Do palaeoenvironmental items require fixing in advance of cryopreservation? Perhaps then, a way forward could involve a scheme of research that can determine if cryopreservation is an application that carries little to no risk for the safety and security of the archived resource. Then, crucially, the *need* for cryopreservation within archaeology should be assessed. Is there, for example, enough material to warrant archaeology-focused cryopreservation? If so, then perhaps a small-scale laboratory could be considered. Such a resource may influence future decisions to use cryopreservation as a conservation method. If cryopreservation is identified as a conservation method, it should not be used to conserve palaeoenvironmental remains with DNA potential, which is expected to be accessed later. If an item or items have significant potential for genetic research, this should be extracted and barcoded before freezing. Additional research into this topic is required.

Spirit

The use of spirit to preserve biological collections can remedy some of the issues that can make drying a difficult or impossible decision. Spirit collections have a long history of experimentation and have proven to be cost effective and effective at preserving the specimen's shape, colour, and genetic material (Moore 1999; Historic England 2008). The use of spirit collections in archaeological and natural history museums needs to be considered for two essential reasons. Firstly, the utility of spirit collections for future archives and the management of legacy archives.

Spirit collections – also known as wet or fluid preserved collections – have been used to preserve plant and animal remains for future studies for over 300 years (Stoddart 1989; Tredwell 2006). The work of pioneers such as Robert Boyle and William Croone developed the practice of hermetically sealing vials with brine and ethyl alcohol to preserve biological specimens (Mathias 1990). These 17^{th}-century experiments revealed that correctly managed spirits could maintain a specimen in the state it was either recovered in or at the point of death by preventing dehydration, decay, swelling and diminishing shrinkage (Tredwell 2006). These collections have proved invaluable data sources over the last three centuries and have assisted in taxonomic studies that have been re-evaluated for enquiries into biodiversity and, more recently, have been able to contribute to genetic/phytogenetics (Marte *et al.* 2003). As scientific techniques such as DNA studies have developed, the sophistication of the spirits and mixes of spirits have evolved and adapted to meet the needs. The following section briefly examines the methods, techniques and spirits implemented in today's standards and those used in recent history. Spirit-based preservation uses two critical processes and related spirit mixes; fixation and preservation (Perry *et al.* 2016; Panzacchi *et al.* 2019).

The fixation process prevents autolysis, whereby post-death degradation occurs and arrests putrification, consequently preserving carbohydrates and proteins within the composition and architecture of cells within the tissue (Thavarajah *et al.* 2012; Perry *et al.* 2016). Fixation occurs through a physicochemical process that allows the fixative fluid to penetrate and harden the tissue and arrest the decomposition and putrefaction processes at the cellular level and greatly diminish microbiotic agency internally and externally to the specimen (Singh 2019). Although regarded as an essential stage in natural history collections management, the fixation process for archaeological remains is a topic that has received little to no research. This is a likely consequence of the fact that archaeological remains have been deceased for hundreds or thousands of years and will have had their cellular details altered by the taphonomic processes (M Carnal 2021 Oxford University Natural History Museum Collections Manager personal communication 25 August). On the face of it, this means that the fixation process does not affect archaeological remains. However, there are two key reasons why the fixation of archaeological remains requires consideration – i) its application as a method of removing biological agents that threaten palaeoenvironmental items and ii) understanding how to deal with historic archives that have been preserved using fixation techniques. This second point requires a review of the materials used in the fixation process to determine how these can be dealt with if encountered in archival stores.

The ideal fixative has yet to be identified, as each fluid used in the process carries with it some potential risk, or chance of modifying chemical and physical properties (Thavarajah *et al.* 2012). Many fixatives are toxic, highly flammable, corrosive, or volatile (Perry 2016; Kothmaier 2011; Singh 2019). Amongst these options, formaldehyde and diluted derivatives such as formalin, with its cost-effective ability to permeate tissues and cell walls, have emerged as the most commonly selected fixative (Panzacchi *et al.* 2019). Formaldehyde was identified as an effective disinfectant in the 19th century and was adopted as a fixative and preservative by the end of the century (Schiller 2014). The benefits of formaldehyde were considered superior to ethanol as its evaporation rate is much lower than ethyl-alcohols and therefore requires less active management (Simmons 1999). However, the benefits were countered by early experiments which recognised the substance as toxic and museum workers commented on the abrasiveness of the liquid on exposed flesh (Schiller 2014). Formaldehyde is commercially sold as *formalin*, a mixed solution containing 10% methanol and 37% dissolved formaldehyde. The benefit of formalin use over pure formaldehyde is the addition of methanol which limits polymerization and oxidation of the fluid (Zhang 2018).

Formalin has a low pH and can embrittle protein and decalcify bone resulting in limited flexibility and the separation of the specimens. For its use as a fixative, formalin is buffered to neutralise the pH using 0.05 M sodium Glycerophosphate in either saline or deionised water as a buffer. A neutralised pH will prevent morphological distortions and, if suspended for no longer than two weeks, can prevent the leaching of amino acids and lipids (Moore 1999). In addition to M sodium Glycerophosphate, formalin/formaldehyde's ability to fix specimens can be further improved with the addition of Glutaraldehyde which is sometimes added to encourage the formation of covalent bonds that are fixed and cannot be rearranged (Alberch, 1985). Many other agents are used in material history collecting, each of which has their benefits and disadvantages. These are outlined in table 6.

Fixative	**Chemical Grouping**	**Fixing Role**	**Benefits**	**Disadvantages**
Formaldehyde	Aldehydes	Cross links proteins	-Very effective. -Widely used and experimented with. -Suits all biological materials.	-Highly toxic. -Difficult to dispose -Alters nucleic acids.
Glutaraldehyde	Aldehydes	Cross links proteins	-Glutaraldehyde is a good fixative for small specimens as it works fast but it doesn't penetrate far. -Is unacceptable for tissue blocks larger than about 1 cc in volume.	-Highly toxic and has been banned in hospitals for being too hazardous. -Difficult to dispose -Alters nucleic acids.
Osmium tetraoxide	Oxidizing agents	Cross links proteins	-Stabilise lipids	-Highly toxic. -Volatile
Potassium permanganate	Oxidizing agents	Cross links proteins	-Very good for plant remains.	-Not good for DNA preservation.

				-Rarely used in the last couple of decades. Volatile.
Methyl alcohol	Alcohol based	Protein-denaturing agents	-Preserve nucleic acids -Can be buffered and used as a fixative but it can lead to shrinkage and hardening.	-Removes lipids.
Ethyl alcohol	Alcohol based	Protein-denaturing agents	-Preserve nucleic acids -Can be buffered and be as effective as formalin (formaldehyde).	-Evaporates quickly
Acetic acid	Alcohol based	Protein-denaturing agents	-Prevents nucleic acid loss. -Speeds up fixation	-Evaporates quickly
Mercuric chloride	Metallic	Forms insoluble metallic precipitates	-Fixes nucleoproteins.	-Slow to penetrate -Highly poisonous -Corrosive -Expensive
Picric acid	Metallic	Forms insoluble metallic precipitates	-An excellent preserver of glycogen.	-Highly flammable. Must be kept damp to prevent explosion. -Does not preserve DNA

Table 6. Chemicals typically used as fixatives and their benefits and disadvantages

In addition to the complications presented by the toxicity of formaldehyde and formalin, their use is harmful to the preservation of DNA (Haque *et al.* 2020; Vincek *et al.* 2003). After one year in formaldehyde, freshly deceased specimens can be found to have DNA compromised by formaldehyde (Taleb-Hossenkhan *et al.* 2013). Formaldehyde creates DNA protein cross-links - where endogenous genetic material responds with a pair of nucleotides and becomes covalently trapped, creating artificial linkages between DNA and protein (Fang *et al.* 2002; Tretyakova 2015). Cross-links make the extraction of genetic information complex and time-consuming, but in some cases, successful extraction has been achieved (Taleb-Hossenkhan *et al.* 2013).

In archaeological examples, the base pairs that are required for analysis have degraded (Dabney *et al.* 2013). Base pairs measuring more than 194 kb (194,000) have successfully been extracted from decades-old museum collections fixed in formalin, although these were from specimens that were freshly killed before fixation (Fang *et al.* 2002). Savioz *et al.* (2997) amplified an impressive 838 base pair long fragment from a 46-year-old sample, proving that in some cases, formaldehyde fixation can preserve samples. Finding well preserved base pairs in decades old samples is seemingly rare. How formaldehyde can negatively alter nucleic acids has been examined by Schander and Halanych, who highlight the work of Crisan & Mattson (1993), who Identified five factors.

1) The chemical composition of the fixative
2) The duration of fixation
3) The duration of tissue hypoxia (which is proportional to the amount of DNA degradation)
4) The size of the specimen and its permeability to the fixative
5) The length of storage time.

Given the small, or microscopic, size of archaeological palaeoenvironmental remains destined for long-term storage, samples that have been fixed or otherwise suspended in formaldehyde-based solutions for more than a year are likely to have compromised genetic material. Although there are occasions where DNA has survived in a specimen in formaldehyde, such as the example provided by Savioz's *et al.* (1997) successful extraction of sufficient base pairs from a 46-year-old sample, these are rare. Attempts to retrieve genetic material stored in formaldehyde using silica column-based extraction are far from guaranteed success (Katevatis *et al.* 2017; Lee *et al.* 2010). It is therefore recommended that in the case of extracting ancient DNA for archaeological analysis, the DNA must be clear of contamination, presenting further complexities for the use of formalin-fixed specimen (Wales 2014).

Despite the fact it is a poisonous carcinogen and damaging to DNA, formaldehyde and formalin continue to be recognised by some organisations, such as Kew Gardens, an institution that uses formalin in their 'Kew mix' (5% formaldehyde solution (38% w/w), 53% Industrial Methylated Spirit (98/99% total alcohols), 5% glycerol; formaldehyde-fixative and 37% water) (Criscuolo 1994; Prakash 2019). Its continued use is a consequence of its cost-effectiveness and efficiency in its ability to permeate cells and tissue quickly and fix comprehensively (Notton 2010). Although world-renowned institutes such as Kew still use formalin for fixation, many institutions are becoming uncomfortable about holding hazardous materials on-site (Zhang 2018). Other solutions used in the fixing process, such as glutaraldehyde, osmium tetraoxide, potassium permanganate, mercuric chloride and picric acid, are also detrimental to human health and dangerous to store, and their use should be limited. The use of ethyl and methyl alcohols has proven to be effective fixatives if used in the correct concentrations (Rolls 2012). The search for a safe alternative has found solutions such as a 70% ethanol buffered with phosphate (Panzacchi *et al.* 2019). This fluid has been found to provide the same benefits as formaldehyde-based fixatives, with the advantage of not being carcinogenic (Perry *et al.* 2016).

Once the fixing is complete, items need to be transferred from the fixative to preservative, or in the case of freshly excavated archaeological remains that have been adequately handled during assessment and analysis, can be added straight into a preservative fluid (Harris 1990). Most frequently used are methyl and ethyl alcohols, including propylene phenoxetol and isopropanol (Notton 2010; Schiller 2014). A variety of preservatives have been identified, to provide subtly different results. The correct preservative therefore needs to be selected to suit the material and the intended environment for storage (Moore 1999).

Transferring to preservatives

If previously fixed or suspended in formaldehyde, items must be staged through a concentration ladder to remove trace amounts of fixative solutions (https://conservation.myspecies.info/node/33). The staging process is vital in the conservation process and can prevent the effects of chemicals from the fixation leaching into the preservative and causing acidification and other effects that can compromise the remains. Staging firstly requires washing the fixed specimen with distilled water under a fume cupboard to provide a ventilated barrier between the user and the dangerous chemicals potentially used in the fixation process (Fischer *et al.* 2012). Ideally, the item should be placed in distilled water and lightly agitated for an hour (Simmons 1999). Once washed, the sample should be suspended in clean distilled water, which is tested for acidity using pH strips, or a pH meter (Rolls 2012; Simmons 1999; Srinivasan *et al.* 2002). A pH lower than 5.5 will require further neutralisation. This can be achieved by mixing a solution comprising 1L of distilled water with 17g of Potassium Phosphate [K2HPO4]. Items can then be suspended in the solution for six hours (depending on sample size). Specimens, whether having required neutralisation or not, can then be placed in a 20% ethanol mix for 24 hours and then staged through 10% increments each for 24 hours until the desired concentration is achieved (Simmons 1999). If cleaned sufficiently, the containers can be reused.

Preserving fluids

In advance of adding palaeoenvironmental remains to preserving fluids, consideration should be given to factors that may be lost through long-term storage. Colour can be lost over time, and glycerine can produce a thin film that causes reflection and can make it more challenging to photograph items that have been conserved for an extended period (Jacomet and Kreuz 1999). If there are specific features that are deemed to be significant, they should be photographed or micro-photographed in advance of preservation. Once satisfactorily recorded, remains can be conserved using fluids.

The use of alcohol as a preserving fluid has been understood for centuries (Marte *et al.* 2003). Today, the use of dentured alcohol - industrial methylated spirits (IMS) - is recommended for use in conservation (Moore 1999). IMS is considered a high-quality preservative as it prevents shrinkage and discolouration of materials as diverse as animal fur, fly pupae, complete animal specimens, and plant remains (Moore 2010). However, as a preserver of genetic material, the effectiveness of methylated spirits has still to be reliably proven and requires further research (Carter 2003).

The evidence from conserved samples indicate that those suspended in a stronger alcohol concentration and maintained in a low temperature environment will have better results (Notton 2010). An additional benefit of using IMS as a preserving solution is its ability to reduce the leaching of fatty acids, amino acids and lipids that may have begun during the fixation process or their in-situ degradation (von Endt 1994).

The concentration of IMS can vary from 74 Over Proof (74 OP), which is 99% industrial methylated spirit (IMS) and can be diluted to any mix. For the conservation of archaeological palaeoenvironmental remains, using 74 OP IMS would require dilution with a pure mix leading to the erosion of carbohydrate elements and embrittlement (Moore 1999). General recommendations such as those from the American and Canadian museum services and NatSCA, suggest a dilution should fall between 70% to 96% for the long-term preservation of biological specimens depending on the material (Moore 2010). Plant remains should be maintained in the ‘Copenhagen mix’, a combination comprising 70% IMS and 2% glycerol. The Copenhagen mix is also used by Kew as a mixture to transport specimens and to suspend them whilst being researched (Funk *et al.* 2017; NatSCA 2019). This mix has been proven to maintain the integrity of specimen whilst being analysed and can be more beneficial than using clean water.

For preserving insects, pupae and larvae, and animal skin, ethanol is preferred over IMS (Carter 2003). Introducing IMS to these materials can cause dehydration and should be avoided (Hendry 1999). For insect remains, a mix of ethanol that ranges between 90% and 94% to a respective 10% to 6% distilled water is recommended for a preservative (Schauff 2001). For some insects, such as mites, aphids and fleas, a dilution of less than 90% strength can be detrimental to DNA, but a concentration of 95%-100% will better preserve genetic material (Schauff 2001). Experiments have identified that 95% and upward can make specimens brittle and problematic for future use (Marquina 2021; Frampton 2008). A sensible solution to this conundrum is, on a case-by-case basis, using a system whereby a sub-sample is preserved in a 95% - 100% mix and maintained strictly for genetic research. Skin and hair should be maintained in 70% ethanol (Perry *et al*. 2016). The taxa of non-pollen palynomorphs (microscopic remains that appear on pollen slides such as flatworms, roundworms, testate amoebae, tardigrades, Ascomycetes, Zygomycetes, green algae) are too wide-ranging in their composition to be given a single comprehensive recommendation and need to be considered on a case-by-case basis (Shumilovskikh and Geel 2020).

Other than ethyl and methyl alcohols, preserving fluids used in natural history collections, biosciences and medical sciences include propylene phenoxetol and isopropanol (Winsor 1991; Williams 2007; Schauff 2001). Unfortunately, these fluids in their undiluted form and in composite fluid mixes have not been experimented with to conserve archaeological remains. The following section examines the pros and cons of using propylene phenoxetol and isopropanol to determine if their use should be considered for future conservation.

Mixes that comprise propylene phenoxetol, formaldehyde and propylene glycol do have low evaporation rates and could therefore be seen as beneficial, but many museums still prefer the use of ethyl-alcohols as maintaining balanced mixes in perpatuity can prove complex. (Walker *et al.* 1999; Pickering 1997). Propylene phenoxetol has been used in natural history collecting and medical science and has proved efficient as a preserver and maintaining the flexibility of specimens such as marine invertebrates and human anatomical samples (Winsor 1991; Hill 1966; Frølich 1984; Williams 2007; Schauff 2001). Unfortunately, historic collections that have used propylene phenoxetol show deterioration (Crimmen 1989).

Isopropanol alcohol has also been used as a preservative for insects in natural history collections as it demonstrates a slightly lower evaporation rate than other ethyl and methyl alcohols and can make specimens easier to mount (Levi 1966). However, Isopropanol has been found to make specimens brittle and hard to manage (King and Porter 2004; Lord and Rodriguez 1989.). This has proved particularly challenging for items with delicate appendages, which are at threat of snapping off (Moore 1999). Brittleness has been counteracted by mixing it with ethyl alcohols, thus creating a mixture that can preserve genetic and internal features and create a degree of flexibility (King 2004). This mix needs to be maintained and protected against differential evaporation of ethyl alcohols resulting in an undiluted isopropanol mix and creating brittle specimens. A further disadvantage of isopropanol is that it can form reactive peroxides that bleach and deform specimens (Clark 2001).

Propylene phenoxetol and isopropanol benefit the preservation of insects and invertebrates in natural history collections, especially if we consider the lower rates of evaporation, but many of these factors are not necessarily achievable or desirable for archaeological palaeoenvironmental remains, especially if they can make items brittle. An ethyl isopropanol mix could provide flexibility, but the relative complexity of the mix and the management that would be required make the use of propylene phenoxetol and isopropanol less than ideal for archaeological use.

Topping up

Fluids suffer from the debilitating factors of evaporation (Bocaege *et al.* 2013). Without monitoring and topping up, these factors can lead to drying out and total decay of the remains. In the case of the insect assemblages from the Coppergate excavations, York, these have regrettably not been actively curated and since their analysis in the 1970s, have decayed. In the statement provided below by York Archaeological Trust's post-excavation officer Nienke Van Doorn, the processes that led to the decay of the assemblage are outlined.

Insects and insect remains were recovered from soil samples from Coppergate, one of the largest and most stratified archaeological excavations in York. Pests such as weevils and grain beetles, as well as fleas and lice, and even honeybees, were recorded by external specialists, preserved in solvents, and later returned after a long period of the research being concluded.

The state of the insects had thus been changed from a wet in-situ like storage environment in soil samples to a more specialised solvent-based storage. Something that the stores were not equipped for, and no maintenance protocol came attached. Subsequent staff turnover caused the knowledge of the state of these samples to be lost. The solvent evaporated. The samples dried out. Likely this could have happened even before the samples were returned, as evaporation can happen rapidly.

Insect remains are rare, especially from a large and important site as Coppergate. Thankfully these remains were recorded prior, but with ever-developing research methods, we may miss out on samples being available to be re-evaluated in the future.

It can be difficult for smaller, single institutions to maintain caring for such highly specialised sub-collections. On some occasions, subcollections were returned after knowledge exchanges (long-term research projects, for instance) or otherwise acquired in the past, but the guidance of how to look after them has not been passed on. The storage methods, the chemicals needed, and appropriate safety measures, all should be requirements in a transfer or deposition, particularly if the storage method has been changed (wet to dry, dry to wet, etc).

Without careful documentation and handover, specialised subcollections may be at danger of being overlooked in stores where the specific care and training for maintenance quickly becomes too costly, especially for long-term care. With such specialised subcollections in a larger storage depot without ubiquitous knowledge for highly specialised care in-house, there exists a need for detailed instructions to correctly care for the contents or alternative methods. Storage methods could involve fewer specimens requiring solvent based-treatment, by selection, or changed to those that would allow the specimen to be kept at ambient temperature or otherwise in a way that requires fewer interventions during long-term storage, such as freeze-drying a majority selection.

This statement highlights the factors leading to wet archives becoming neglected and drying out. To determine how such occurrences can be avoided in the future, understanding the factors that cause evaporation and identifying repeatable methods for recognising evaporation, the dilution of preservatives and topping up protocols are outlined below.

The evaporation of methyl and ethanol preservatives is influenced by multiple factors, including the interface between liquid and air and liquid and vapour, the concentration of above surface vapours and the differential vapour pressure of the mixed chemical components (Leighly 1937; Tao *et al.* 2018; Compernolle *et al.* 2015; Cai *et al.* 2015). Should the relative humidity become high, water will be absorbed from the atmosphere, and ethanol will begin to escape. In practical terms, in a store with 50% relative humidity, a mix comprising 70% ethanol to water would likely lose the vapour equivalent to approximately 95% ethanol (Waller and Strang 1996). The evaporation of ethyl-alcohol over the water is further encouraged by the positive deviation from Raoult's Law which dictates that water to ethanol mixes will have a higher rate of evaporation than if they were isolated unmixed

(Notton 2010). The differential evaporation of ethanol in the ethanol-water mix can dilute the mix. The topping up of the fluid mix may therefore require topping up with a stronger concentration of alcohol to make up for the diluted mix.

In the event that evaporation occurs, and the vessel requires topping up, fluid strength needs to be calculated to make up for the evaporated alcohol content. A method proposed by Notton (2010) requires knowledge of the volume of the vessel filled with fluid and the strength of the fluid. Table 7 demonstrates the concentration of fluid that should be used to maintain the correct strength and ensure that the remains continue to be adequately preserved.

		Initial proportion of jar containing preservative																		
		0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
Initial concentration of alcohol	100.0	70	70	70	70	70	60	60	60	50	50	40	40	30	20					
	97.5	70	70	70	70	70	70	60	60	60	50	50	40	30	20	10				
	95.0	70	70	70	70	70	70	60	60	60	60	50	50	40	30	20				
	92.5	70	70	70	70	70	70	70	60	60	60	50	50	40	30	20	10			
	90.0	70	70	70	70	70	70	70	70	60	60	60	50	50	40	30	20			
	87.5	70	70	70	70	70	70	70	70	60	60	60	60	50	50	40	30	0		
	85.0	70	70	70	70	70	70	70	70	70	70	60	60	60	50	50	40	20		
	82.5	70	70	70	70	70	70	70	70	70	70	70	60	60	60	50	50	30	10	
	80.0	70	70	70	70	70	70	70	70	70	70	70	70	70	60	60	60	50	30	
	77.5	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	60	50	30
	75.0	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
	72.5	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	88	88	96	
	70.0	80	80	80	80	80	80	80	80	80	80	80	80	88	88	88	96			
	67.5	80	80	80	80	80	80	80	80	80	80	88	88	88	96	96				
	65.0	80	80	80	80	80	80	80	80	80	88	88	88	96	96					
	62.5	80	80	80	80	80	80	80	80	88	88	88	96	96						
	60.0	80	80	80	80	80	80	80	88	88	88	96	96							
	57.5	80	80	80	80	80	80	88	88	88	96	96								
	55.0	80	80	80	80	80	80	88	88	88	96	96								
	52.5	80	80	80	80	80	88	88	88	96	96									
	50.0	80	80	80	80	80	88	88	88	96	96									
	47.5	80	80	80	80	88	88	88	96	96										
	45.0	80	80	80	80	88	88	88	96	96										
	42.5	80	80	80	80	88	88	96	96											
	40.0	80	80	80	80	88	88	96	96											
	37.5	80	80	80	88	88	88	96	96											
	35.0	80	80	80	88	88	96	96												
	32.5	80	80	80	88	88	96	96												
	30.0	80	80	80	88	88	96	96												
	27.5	80	80	80	88	88	96													
	25.0	80	80	80	88	88	96													
	22.5	80	80	88	88	96	96													
	20.0	80	80	88	88	96	96													
	17.5	80	80	88	88	96	96													
	15.0	80	80	88	88	96														
	12.5	80	80	88	88	96														
	10.0	80	80	88	88	96														
	7.5	80	80	88	88	96														
	5.0	80	80	88	96	96														
	2.5	80	80	88	96	96														
	0.0	80	80	88	96	96														

Table 7. Notton chart (2010) provides quantitative details that can be utilised to identify the amount of dilution that has likely occurred and indicates what strength of spirit should be introduced to ensure the correct balance is achieved.

Wet archives need to be monitored to determine the localised evaporation rates (Notton 2010). The recommendations Notton (ibid) suggested a repeatable and straightforward way to monitor and top up wet archives. However, if a wet archive has not been sufficiently monitored and factors such as the proportion of jar filled and the concentration of alcohol used in the fluid are unknown, the recommendations are rendered ineffective. It is recommended that materials should be transferred to a suitable vessel with a known concentration of spirit, which should then be appropriately monitored. Monitoring can be achieved by filling the jars with an established quantity of fluid and checking the vessels with a dipstick marked off in tenths and held to the outside vessel (Notton 2010). Monitoring should be undertaken every six months following recommendations advocated by NatSCA (Walker *et al.* 1999; Moore 1999; Tredwell 2006).

To prevent drying out, a plan should be introduced that assigns staff members to monitor the wet archive and explains how to monitor the drying out of spirit. The monitoring of wet collections could be undertaken at the same time as the monitoring of small finds and metal work which will likely have a scheduled monitoring plan in place with time and staff assigned to it. Levels of spirit should be monitored, and when these are observed to be dropping, should be topped up.

Historic archives that have not been adequately labelled to indicate what combination of fluids have been used, could prove hazardous to the health of anyone exposed as the mix could contain a derivative of formaldehyde, or compounds such as mercury and arsine gas (Moore 1986, Moore 1990). The potentially hazardous activity of appraising historic or unmonitored wet archives should therefore be undertaken in a fume cupboard to prevent the inhalation of toxic airborne compounds (Moore 1999). Drying out is a relatively common occurrence in English museums and has been experienced by several curators from the consulted museums, including examples in the Corbridge Roman Town store (plate 12) and the Leicester County Museum store (plate 13).

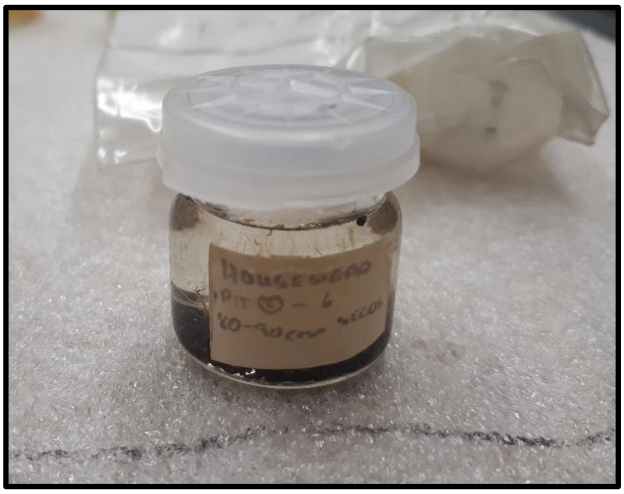


Plate 12. Beetle remains from Corbridge Roman Town

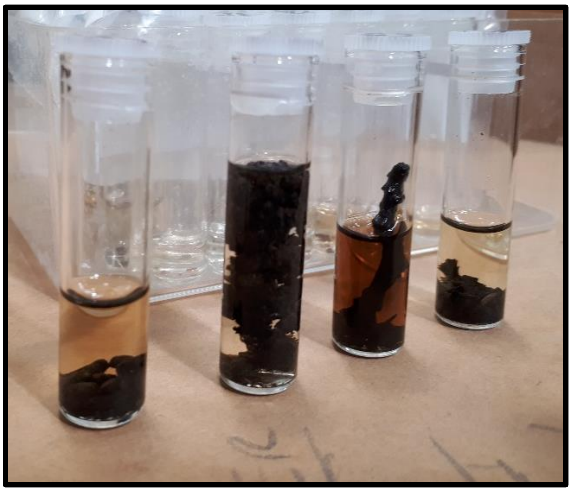


Plate 13. Plant remains held in Leicester Museum store.

To determine what concentration of fluid has been used, it is recommended that a digital density meter (the Anton Paar DMA 35N is suggested) is used (Notton 2010). If it cannot be determined what fluid has been used or the sample has dried out to the degree that a quantity of fluid cannot be extracted for analysis in a density meter, it may be worth transferring the sample to a new vessel with the addition of a known fluid mix and filled proportion. This can be achieved using the fixative to the preservative staging process. If the fluids used cannot be determined, it should be assumed that formaldehyde or a derivative has been used, and appropriate health and safety procedures should be followed.

Materials

Vials and jars for long-term preservation

The following section highlights information regarding the best size and construction materials and vessels required to preserve wet archaeological palaeoenvironmental archives. Vials and jars used for spirit collections should be flat bottomed, straight-sided, and ideally made of glass (Walker *et al*. 1999). Plastic containers can leach and potentially affect the chemical balance of the preservative and, compared to glass, can hasten evaporation (Tétreault 2018; Simmons 1999). A disadvantage of using glass vessels is that they can be more expensive than plastic options. Recently, the price of vials has been proven to fluctuate, with the recent Covid 19 global pandemic pushing the prices of medical glassware higher (see https://www.washingtonpost.com/business/2020/07/13/coronavirus-vaccine-corning-glass/). Therefore, it would be prudent for museums and contractors to buy large supplies of glass vials when the prices are low and maintain a surplus. Some researchers have advocated cheaper options such as Le Parfait glass jars as they are easy to use but the seals are permeable and would allow for evaporation (Notton 2010). Seals made of rubber, cork, metal screw caps and neoprene have all been experimented with and have allowed evaporation. Polyethene stoppers are the most efficient lids that prevent evaporation, but their long-term effectiveness and propensity for leaching are still unknown (Levi 1966; Simmons 1995). Some museums have recommended using cotton wool or conservation grade padding to act as an additional bung (Allington-Jones and Sherlock 2014). The use of additional padding and wadding has been dismissed as its porous nature will offer little protection against evaporation (Walker *et al*. 1999). Lining jars with cotton wadding can safeguard against total evaporation by trapping solution in the material, but having material that can catch or snag specimen appendages on the wool could prove more detrimental. If managed correctly, the need for padding is redundant (Allington-Jones and Sherlock 2014).

Size and Standardised jar and vial size

An institution should use a standardised series of vials and jar sizes (Notton 2010). If jars and vials of standard size are used and use polyethene stoppers, the evaporation rates can be monitored, and patterns should emerge and become easier to handle and manage (Schiller *et al.* 2014). Using standardised containers can help with monitoring and deciding how to top up with the correct concentration. The fewer sizes used, the more control the institution can have over the wet archive.

The size of containers needs to allow for a ratio of at least twice the volume of remaining available space to the specimen's volume. Specimens should easily fit into the jar or vial and not be squeezed or forced in (Simmons 1999).

Labels

The paper used for labels must be of a standard and quality that can withstand the immersion in preserving fluids (Snyder 1999). Experiments with Resistall paper and Goatskin Parchment paper have identified that Resistall paper with a minimum of 100gsm (weight of paper) is the optimal material that will withstand long-term immersion in fixatives and preservatives (Carter 1996). As a result, Resistall has been adopted as the material of choice for wet collections in museums worldwide (see Bates *et al.* 2005). The outside of jars and vials can be labelled using tie-on labels or can be placed inside polythene bags that have relevant information handwritten on the outside using permanent ink, with an additional Tyvek or Resistall label inside the bag. Prepared labels should not be attached to the outside of the jar or vial using adhesive labels or tape (Brown 2011).

Inks used on the labels must be resistant to long-term immersion in chemical mixes (Zala *et al.* 2005). Labels should be printed using a computer to ensure that the text is legible. Carter (1996)'s label and ink experiments determined that PermaDri ink was the best ink and had the best potential for long-term storage in the fluid. Carter's experiments involved the boiling of printed labels and the close monitoring of the submerged labels over three weeks. Three weeks of storage is perhaps not enough time to accurately measure the effectiveness of long-term storage, and the monitoring of label conditions should be conducted simultaneously as preservative levels are monitored. The label should, at minimum, include site code, context number, sample number, and taxa (Brown 2011).

Labels contained with jars and vials within legacy archives may fade and require replacement. Old labels should be retained to provide recourse to tracing the history of the sample (Hawks and Williams. 1986). If a label is found in a legacy archive that has faded and appears unreadable, it needs to be replaced. Exposing the label to infrared light can be used to make faded ink legible once again (Carter & Walker 1999).). If the paper has become embrittled, it can be de-acidified using methanol with a 1% mix of barium hydroxide (Walker *et al*. 1999). Old labels should be preserved in a folder designated for old labels using acid-free sleeves (Simmons 1999).

Environmental control

Once remains are adequately prepared for storage, they must be maintained in a controlled environment supporting their long-term conservation (Historic England 2018b; Sharif-Askari and Abu-Hijleh 2018). A vital aspect of the long-term storage of wet archives is that the temperature and RH are maintained at suitable and consistent values (Vaught and Henderson 2011). Temperatures that exceed recommendations will lead to a faster deterioration process, resulting in the unwanted extraction of proteins, acids and lipids into the fluid and encouraging increased evaporation rates (Moore 1999). The following section highlights the ideal environments for the long-term storage conditions of preserving fluids.

Fluid	**Molecular formula**	**Recommended store temperature**	**Chemical Safety**	**Flashpoint**	**Boiling point**	**Density g/ml**
C_2H_60	C_2H_60	0–25°C	-Flammable	20°C	>35°C	0.89 g/ml
IMS 99% (74 OP)	C_2H_60	15–25°C	-Highly flammable -Irritant	13°C	78°C	0.8 g/ml
Ethyl alcohol	C_2H_60	12–15°C	-Highly flammable	12°C	78°C	0.78 g/ml
Methyl alcohol	CH_4O	12°C–15°C	-Flammable -Toxic	40.6°C	143.5 at 760 mmHg	0.79 g/ml
Isopropanol (Isopropyl alcohol)	C_3H_8O	15–25°C	-Flammable -Irritant	11.8°C	180.5 °F at 760 mmHg	0.79 g/cm^3
Propylene Phenoxetol	$C_9H_{12}O_2$	12°C–43°C	-Irritant	98.30°C	240.62°C at 760 mmHg	1.05 g/cm^3
Formaldehyde /formalin	CH_{2O}	0°C–28°C	-Toxic	60°C	97°C	1.083 g/ml

Table 8. This table highlights the store temperature, flashpoint, chemical safety, boiling point and relative density of chemicals typically used in wet archives.

Temperature

Wet-preserved plant remains should ideally be suspended in 70% IMS and maintained at a consistent temperature (SMA 2020). A consistent temperature will maintain internal and external features for an extended period, slow the evaporation process, and consequently require less topping up (SMA 2020).

Insect remains should be suspended in ethanol and ideally suspended in 90–94% ethanol and maintained at temperatures between -20°C and -30°C. Unlike adult insects, pupae and larvae need to be conserved in an ethanol concentration between 70–80%. Research has indicated that temperatures between −25°C and +24°C have little bearing on the preservation of larvae (Adams and Hall 2003; Niederegger 2021). In freshly killed specimens, temperatures higher than 6℃ can have – albeit slight and dependant on the larval stage – effects on the size and can lead to distortion (Bugelli *et al.* 2017). Temperatures <6°C are unlikely to distort archaeological examples which have been deceased for centuries or millennia and have essentially become quasi-fixed. Therefore, rather than storing such remains in temperatures requiring refrigerated temperatures and requiring staged acclimatisation, it is recommended that pupae and larvae are stored in the recommended storage temperatures between 12–15°C.

Pollen, non-pollen palynomorphs (NPPs), and diatoms recovered from archaeological contexts are routinely mounted on slides for study (Marret *et al.* 2021; Mannion 1987; Chambers *et al.* 2011). For long-term storage, the mountants and sealants must be considered to prevent factors such as swelling, growth of microbial decay and destruction of the pollen (Daniau *et al.* 2019). Mountants are best made from phenol rather than glycerine and glycerol as any residual water would cause swelling, and phenol will act as a preservative (Cushing 2011). The ideal sealant is a conservation grade adhesive/polymer Acryloid as it will not be detrimental to micro-remains, unlike alternatives such as nail polish (Vinçotte *et al.* 2019). If maintained at room temperature, micro-remains mounted on slides should be adequately conserved (Integrated Archaeobotanical Archive 2010). Removing mounted archaeological remains cannot easily be achieved, and should the occasion arise where there is value in preserving pollen and diatoms so they can be further analysed in the future, they should be preserved in sediment. Having additional material accessible in archived sediment could allow for the measurements of equatorial and polar areas of grains which may not be available in slides (Moore *et al.* 1999). The rationale for retaining unprocessed samples in any kind of quantity would need to be strong, as it would be unreasonable for archaeological archives to store unprocessed samples. Sediment must be maintained at a stable chilled temperature (Tirlea *et al.* 2015).

Most plant remains and Chrysophyta can be maintained at a temperature between -20℃ and -40℃ to preserve DNA, and if there is a suspected desire to preserve remains for future genetic research, a sub-sample could be maintained at lower temperatures (Kelly *et al*. 2018). Kelly *et al.* (2018) recommends that if diatoms are expected to be placed in long-term storage for genetic research in the future, photomicrographs should be taken in advance of storage. In the case of non-pollen palynomorphs (NPPs), a simple set of recommendations is challenging to suggest, given the variability of the materials. NPPs number over 1300 and comprise a diverse range of taxa such as Cyanobacteria, flatworms, testate amoebae, Ascomycetes, tardigrades, and rotifers (Shumilovskikh and van Geel 2020). A diverse range of taxa requires a diverse range of recommendations, and in the occurrence that NPPs require archiving, further research into the particular items should be conducted to identify the best method of conservation.

Archaeological pollen can be preserved in sediment cores and preserved for future use (Chevalier *et al.* 2020; Kelso *et al.* 1995). Sediment cores require cold storage to adequately preserve micro and macrofossils suspended within them (Tennant *et al.* 2022). With capacity at a premium and cold store space particularly difficult to source, it is hypothesized that freeze-drying can preserve sediment cores to preserve the contents. Experiments on the freeze-drying of sediment for pollen preservation are ongoing and remain inconclusive (Enevold *et al.* 2019). Further elucidation of this topic may prove fruitful for preserving micro remains in the future.

For the curation of parasites and parasite eggs, these should be stored in 70% ethanol within the range of storage temperatures of 12–15℃ (Sepulveda and Kinsella 2013). In addition, animal skin, fur and hair should be maintained in 70% ethanol within the recommended ethanol temperature range of 12–15℃ (Perry *et al*. 2016).

Temperature Staging

A sudden shift in temperature could be detrimental to the health of archived remains, and when samples are removed from their store, they may require temperature staging prior to analysis (Zimkus and Ford 2014). Although this is a topic that has received relatively little published research for the management of archaeological palaeoenvironmental archives, the use of temperature buffer rooms is practised in some museums stores that hold archaeological archives, such as the Provincial Depot Bodemvondsten Noord-Brabant in 's-Hertogenbosch, the Netherlands (M Meffert 2021 - Content Management Provincial Depot Soil Finds Noord-Brabant personal communication 10 November). Samples that have been frozen will survive the rapid thaw and re-freeze, but for plant remains maintained in IMS at <10℃ and ethanol in 12–18℃ these would be best staged to acclimatise (Museum and Galleries Commission 1992; M Meffert 2021 - Content Management Provincial Depot Soil Finds Noord-Brabant personal communication 10 November). If space for researchers is maintained at 20℃ and 50% RH, for samples maintained in ethanol at 12–15℃, this shift in temperature is acceptable. IMS samples are maintained at <10℃, and 30% RH should be transferred to 12–15℃ and 40% RH for 24 hours and then moved to the study space (Daffner 2003).

Relative humidity

High humidity can encourage mould, low humidity can encourage drying out, and fluctuating humidity can hasten evaporation and lead to the oxidation of lipids (Moore 1999). Compared to dry archives, wet archives experience fewer shifts in relative humidity regarding the materials as the storage environment, and the containers play a more significant role in influencing long-term conservation. A consistent unfluctuating RH maintained at 50% should slow evaporation (Museum and Galleries Commission 1992; Schauff 2001).

Light exposure

Wet archives being overexposed to light can lead to drying out and bleaching (Moore 1999). However, like relative humidity, the exposure to light that wet palaeoenvironmental archives can safely receive is more uncomplicated than managing dry archives. Wet archives can be maintained in conditions that receive no more than 200 lux luminescence and 75µW/lumen UV (Museum and Galleries Commission 1992).

Rehydrating

If a sample has dried out, it can be hydrated, but careful consideration needs to be given to whether this is a worthwhile activity (Moore 1999). The process of rehydration is complex, and it is not guaranteed to work, occasionally destroying the sample (Simmons 1999). Rehydration can cause the degradation of genetic material, and if it has become completely dry, retaining it in its dry state may be preferable to subjecting it to the stresses of rehydration (Carter 2003; Brown and Brown 2011). If a sample is only partially dried out and morphological features are yet to distort due to the effects of drying, rehydration should be considered and can be achieved through the use of various rehydrators. For macroscopic palaeoenvironmental remains, the method advocated by Singer (2014), Moore (1999) and Simmons (1999) is recommended. These methods of rehydration are based on biological museum samples and represent rare published examples of repairing macroscopic biological remains. This method requires the sample to be placed on a staging platform within a large glass jar that can be tightly sealed. Warm deionized water should be introduced into the jar to a level just below the staging block, with antifungal agents such as Thymol crystals added to the liquid. Condensation within the jar will slowly rehydrate the sample, and the antifungal agents should sufficiently remove any fungal acidity that has developed since the sample has dried. Given the small size of most palaeoenvironmental remains, samples should be left in the chamber for up to 2 days. If the water becomes discoloured, it should be changed. After two days, samples should be placed in pure deionised water and then staged in ethanol up to the desired concentration in 10% increments.

Specialist equipment

The volatile nature of fluid collections means measures must be taken to store the chemicals safely (Tétreault 2008). Advice is provided by the Health and Safety Executive (HSE) for storing flammable liquids in containers. The HSE safety document relating to the safe storage of flammable chemicals is HSG51 and is supplemented with *Safe use and handling of flammable liquids* (HSG140) and the *Storage of flammable liquids in tanks* (HSG176). The two key themes within the HSE documents are the adherence to Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR), which provides a pathway to construct risk assessments for the workplace (HSE 2015). DSEAR provide recourse to monitor and measure the following:

- control measures
- mitigation measures
- general safety measures
- emergency procedures to be implemented in the event of an incident.

To meet the needs of DSEAR, a convenient solution to meeting the requirement is using flame-resistant cupboards. Flame-resisting cupboards and bins can hold up to 100 litres whilst being covered by DSEAR principles. Storing dangerous and flammable substances in a flame-resistant cupboard constructed to the correct standards provides a barrier between the fire risk and the workplace. The metal that is used to construct the cupboard must be at a 750°C-melting point. If a cupboard can meet these criteria and a fire were to break out during work hours, the barrier would provide extra time for evacuation (HSE 2015). Containers and vials within a cupboard should be stored either in a metal drawer or in easy-to-handle, open-top polypropylene boxes. A raised lip on the shelves can prevent the contents from sliding off the edge of the shelf (Moore 1999). It is sensible to ensure that the room containing the spirits is uncarpeted and has close access to a sink or drain in case of any accidents (Moore 1999). The use of cupboards provides dark environments that arrest evaporation and reduce exposure to UV light. The environments that cupboards are maintained in should be well-ventilated (Howie 2014). An example of best practice in storing flammable material can be observed at the Bristol Museum, where the curator has procured and installed a flame-resistant cupboard to maintain the 1–2 Redcliff Street, Bristol, site archive (G Boyle 2018 - Senior Curator of Archaeology at Bristol Museums, Galleries & Archives - personal communication 1 October). This is a rare example of an archaeology curator developing a capacity for wet archaeological palaeoenvironmental archives.

Plate 14. Flame proof cabinet currently excavations installed at Bristol Museum

Plate 15. Waterlogged samples from the Redcliffe Street suspended in 70% IMS fluid within the cabinet.

Botanical samples that require storage at 12℃–25℃ should have frame-resistant apparatus stored in a room that can maintain the desired temperatures. For insect samples and sub-samples maintained at sub-zero temperatures, they should be maintained in spark-free freezers (Notton 2010).

Chapter Summary

It is clear from the standards gleaned from various sources and the current practices regarding the curation of palaeoenvironmental remains that there are areas where challenges can be identified. Challenges include drying out wet archives, using fluids that are potentially damaging samples, using fluids that are potentially damaging to health, and using incorrect containers that can hasten the decay of samples. Throughout this chapter, there were examples of how these challenges can be addressed and the curation of archived palaeoenvironmental remains can be improved. However, how can these suggested improvements translate to actual examples? The following case study will examine how these challenges can be overcome.

Chapter 4 - The Wilsford Shaft, Wiltshire

Introduction

In the summer of 1960, excavations directed by Edwina Proudfoot commenced on two bowl barrows (No. 1 and No. 33) and a pond barrow (No. 33a) located on Normanton Down near Wilsford, Wiltshire (fig 4) (Ashbee *et al*. 1989). Rather than the shallow depression enclosed within a ditch and bank typical of a pond barrow, the excavation of pond barrow No. 33a revealed an inverted conical-shaped feature of considerable size, which was filled with chalky rubble material (Bell 2017; Grinsell 1953; Cole 1997). The feature revealed as a weathering cone gave way to a large pit later identified as a shaft (Ashbee *et al.* 1989). The work required to excavate the shaft meant that works could not be completed within the summer season. In 1961 and 1962, Paul Ashbee directed fieldwork, revealing a >30m deep vertical shaft dug into the chalk substrate and extending below the water table, allowing for the waterlogging of the basal 2.1m of fill. Radiocarbon dates deriving from human and faunal remains revealed that the weathering cone filled during the Iron Age, between 760–400 BC (Ashbee *et al.* 1989). The earliest date obtained from lower fills was 3630–3105cal BC, although this was almost certainly erroneous, given multiple other dates from the lower fills that range from 1515–1400 BC. The shaft appears to have filled quickly, with the weathering cone filling in after an interval of 700-1000 years.

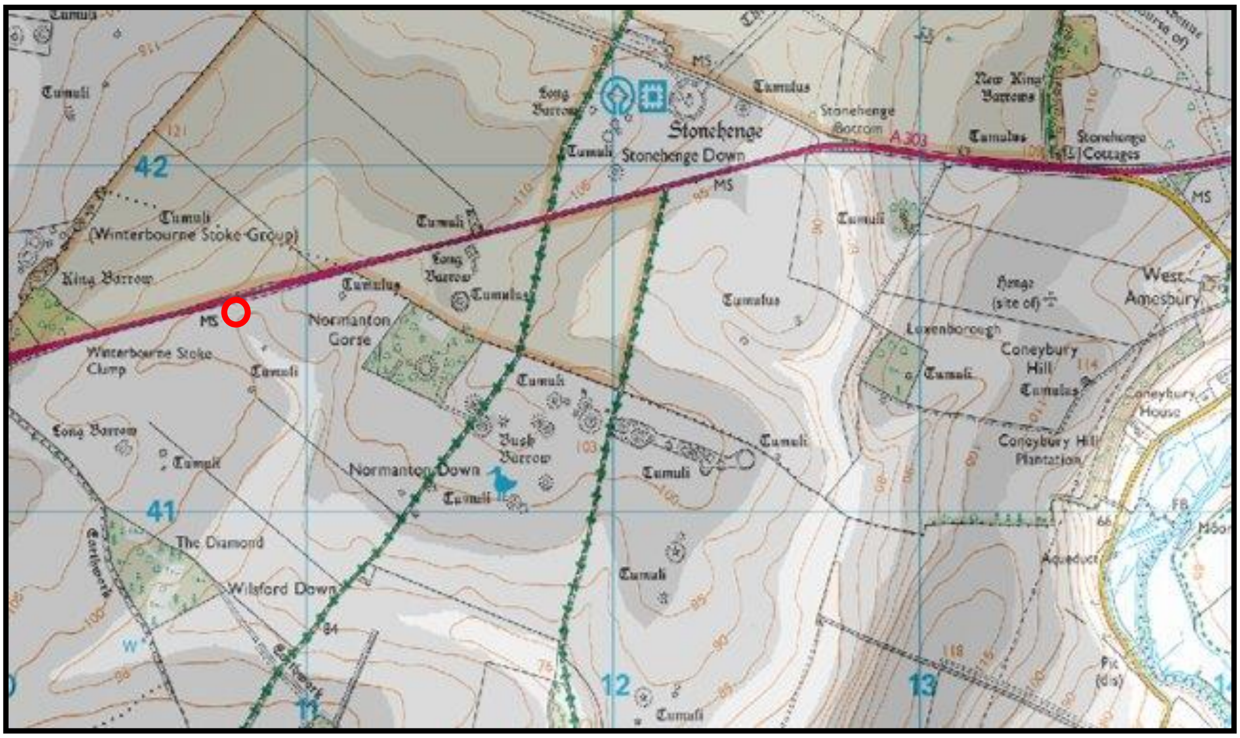


Figure 4. The location of Pond Barrow 33a - The Wilsford Shaft – is highlighted in the red circle (relief map created by the author - licensed under the Ordnance Survey Limited Educational User Licence - 1:50 000 Scale Colour Raster [TIFF geospatial data], Scale 1:50000, Tiles: su04_clipped, Updated: 16 August 2022, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service, <https://digimap.edina.ac.uk>, Downloaded: 2022-09-17 15:15:38.384)

Numerous prehistoric shafts have been identified across England, including i) Eaton Heath, Suffolk (Darvill 2010; Wainwright and Donaldson 1972), ii) Swanwick in Hampshire, iii) Calke Wood, Wattisfield, (Wacher 1958), iv) the Monkton-up-Wimborne complex on Cranborne Chase in Dorset (French *et al*. 2007), v) Fir Tree Field, Dorset and vi) Down Farm in Dorset (Green and Allen 1997), but none of these was equal to the depth of the Wilsford Shaft. Shafts such as these have received a range of interpretations, with some researchers favouring a ritual use, whilst others prefer more practical applications, such as a well that can facilitate crop and livestock management (Green and Allen 1997; Wainwright and Donaldson 1972). The Wilsford Shaft monograph (Ashbee *et al.* 1989) discusses the potential for both ritual and more utilitarian interpretations, and although reports and articles that discuss the Wilsford material that has been published from the 1990s onwards are more likely to refer to the shaft as a well, the debates continue (see Robinson 2013a; Robinson 2013b; Green and Allen 1997).

Once excavation had concluded in 1962, finds and environmental samples were transferred to the Ancient Monuments Laboratory, Fortress House, London, where Mr Leo Biek undertook a staged evaluation. From here, analysis was recommended, and samples were distributed to specialists. For example, botanical samples were sent to the Institute of Archaeology, London, and beetle samples to the University of Birmingham. Post-excavation progress stalled, and in 1985, the Backlog Working Party of English Heritage - set up under the chairmanship of Professor Barry Cunliffe - reviewed the situation, and Dr Martin Bell, formally of the University of Lampeter - and now the University of Reading - was appointed to oversee the palaeoenvironmental aspects of the research. He worked with a team of specialists, some of whom already had material, and found specialists to report on other materials. The samples were transferred from Fortress House and elsewhere to the University of Wales, Lampeter and later when he moved to Reading University. The report on the archaeological investigation and the environmental analysis was published (Ashbee *et al.* 1989). However, before publication, some samples at the Institute of Archaeology could not be found despite a careful search. The archive was discovered in a locked cupboard in 1997, eight years after the reports was published and transferred to Reading University but not included in the published monograph and has not been evaluated or analysed.

Given the waterlogged conditions of the sediments within the Wilsford shaft, it allowed for the preservation of a wide array of organic remains, most of which were palaeoenvironmental in nature (Ashbee *et al*. 1989). A list of the materials, corresponding specialists conducting the analysis, and the monograph page are supplied below.

- Pollen. Analysed by G, W Dimbleby pp. 72
- Seeds and plant macrofossils by M Robinson pp. 78
- Plant fibres by P Tomlinson pp.90
- Cordage by P Walton pp. 92
- Buds by C, A Keepax pp. 92
- Wood identification by J, P Squirrell pp.93
- Charcoals by M, Taylor pp. 94
- Fungi by D, N Pegler pp.94
- Mosses by G, W Dimbleby and E, C Wallace pp.95
- Biochemical studies by G Hendry pp.96
- Insects by P, J Osbourne pp.96
- Land snails by M, G Bell pp.99
- Small vertebrates by P E Yalden pp.103
- Possible skin and hair fibres by M, L Ryder pp.121
- Other animal hairs by P Tomlinson pp.124
- Parasitological studies by AKG Jones pp. 124
- Plant microfossil analysis (herbivore dung) by P Tomlinson pp.126

The basic pH of chalk substrates, such as those within the Stonehenge World Heritage Site, generally only preserve remains such as charred and mineral-replaced remains bones, molluscs, foraminifera, and ostracods (Williams *et al*. 2016). Therefore, the excavation of the Wilsford Shaft can be regarded as a significant discovery and phase of work in the *corpus* of environmental archaeology conducted in England.

The Archive

At the time of excavation and analysis, the Wilsford Shaft was within the collecting area of Salisbury Museum. The museum's collections policy stated that they did not accept wet archives. Consequently, the artefactual archive, latex impressions and freeze-dried PEG timbers were transferred to the museum, but the wet remains were refused (Ashbee *et al*. 1989). Although not all the organic archive was wet – approximately 29% of the non-documentary archive was recorded as wet - it has been kept together as a cohesive environmental archive. The Wilsford Shaft archive primarily comprises palaeoenvironmental remains but also contains 15.6% of non-palaeoenvironmental remains such as non-organic heavy residue samples that comprise gravel and stone (representing 7% of the total undeposited archive), chalk fossils (representing 3% of the total undeposited archive),' tank sludge' – the material retained from the base of the Siraf tank (representing 0.7% of the total undeposited archive), iron concretion (representing 0.8% of the total undeposited archive) and unprocessed soil and sediment samples (representing 4% of the total undeposited archive). The undeposited archive was gathered from various specialists after analysis and maintained at the University of Wales, Lampeter and later moved to the University of Reading, where it remains.

A recent dialogue with Salisbury Museum's Director and Collections Manager has been productive, and they are now keen to receive the archive (M Berrisford 2020 – Salisbury Museum Collections Manager – personal communication 12 November). However, the museum is reticent about taking charge of the processed wet remains and is unsure how to manage such a resource. The outcome of this case study will inform the museum of the requirements needed to manage the archive effectively.

The Wilsford Shaft monograph does not explicitly state why the biological archive was retained beyond its analysis. The reason for the omission is the result of a combination of factors, primarily that material was excavated between 1960 and 1962 and analysed over 25 years, meaning the archive needed to be maintained for an extended duration. Another factor influencing the long-term storage of the remains is its significance in the history of English environmental archaeology, with the Wilsford Shaft excavation representing one of the first extensive Coleoptera analyses in England. Some of the Coleoptera taxa identified are extinct in Britain, such as *Onthophagus verticicornis* (Hoornmestkevers) and *Aphodius quadriguttatus.* Plant remains such as opium poppy (***Papaver*** *somniferum* L.*)* were also recovered during the excavation, the first time such a discovery was made in a British archaeological context (Tomlinson and Hall 1996). In addition to the rich diversity of significant material in the shaft, the condition of remains was considered mostly outstanding, warranting retention of the archive. Finally, some samples were not examined as part of the earliest phase of analysis and were retained for future research. Due to a likely combination of these factors, the entire biological archive was retained.

In total, 897 containers of biological archaeological remains in 17 archive boxes were kept for the intervening period. Most of this material is palaeoenvironmental in nature. The containers used were on-hand at the time of analysis and range from small glass vials with stoppers made from plastic, cork, or metal to matchboxes and large plastic tubs with plastic screw tops and sealed plastic bags. The wet archive has been preserved in spirit, although it is not entirely clear what spirits and combinations of spirits are present in each of the containers. There is mention in the monograph that some of the wet archives have been preserved in a solution composing 30 parts Industrial Methylated Spirit, 60 parts glycerol, and ten parts 40% aqueous formalin solution (Ashbee *et al*. 1989). Discussion with the monograph co-author Professor Martin Bell revealed that the Environmental Unit advised the fluid mixture used at the York Archaeological Trust (M Bell 2020 personal communication 2 November). Initial observations have revealed that the evaporation of the spirit has occurred. The degree of evaporation appears to have varied across the archive, depending on the container and stopper (Schiller *et al*. 2014). The methylated spirit will have evaporated faster than the glycerol and Formalin, resulting in a solution of unknown composition (Notton 2010).

Aims of the Case Study

This case study has two central aims, firstly, the assessment of the 'health' (condition) of the biological remains and secondly, to establish the archive's potential for research using techniques that were not available at the time of analysis, consequently demonstrating the utility of retaining such an archive.

Using standards established by natural history museums and in archaeological practice, the health of the biological materials will be examined to determine if it is in a condition that is suitable for re-use or if it requires further work and, if so, what that work entails. This assessment will prove valuable for achieving deposition of the materials in the Salisbury Museum but will also likely be beneficial for other similar archives stored in England, and the recommendations could prove wide-reaching. In addition, these results could be used for future archiving practices and ensure that palaeoenvironmental remains are appropriately curated.

The original analysis of the Wilsford Shaft material was instrumental in providing information regarding the Bronze Age environment and land use. Since the excavation and subsequent analysis, new techniques and avenues of research can reveal previously inaccessible information. The current research potential of the archive will be established by cross-referencing the array of materials with a recently published research agenda that covers the Stonehenge World Heritage Site to see how the archived material can contribute to modern research. Most notably, techniques such as isotope and DNA analyses in archaeology have only developed since the 1970s and the 1990s, respectively (Fiorentino *et al.* 2015; Poinar *et al.* 1998).

Fundamentally, the case study aims to identify areas where items may be at risk and require remedial measures to ensure long-term conservation. Potential solutions are forwarded, but it is beyond the scope of this research project to identify funding bodies and agencies that can contribute towards materials or staffing required to meet the needs of the work.

The current condition of the biological archive materials

The Wilsford Shaft wet archive has jars and vials in various states. Due to evaporation, some are nearly entirely dried out, and others are partially dried. Topping up is complex as it is not entirely clear what combination of spirits has been used to preserve the archive. There is mention in a report of 'glycerin – meths – formalin', although it is unclear which samples had this mixture added. There are multiple ways in which spirit mixes can be determined, but the simplest is to use a density meter. However, in the Wilsford Shaft example, determining relative proportions is a moot point; given the mix of glycerine, and meths, Formalin is more typically used as a fixative and requires transference to a preservative. The items which have nearly entirely dried out, may have been exposed to microbial attack and may require re-fixing before transference. Again, this could be achieved using a formalin mix or non-formaldehyde solutions.

Although the mixture used for the Wilsford Shaft is reminiscent of a fixative solution, it was likely devised as a well-meaning all-purpose long-term preservative. If the fluid is treated as a fixative, standard methodologies can be followed to transfer the materials into a preservative solution. This can be achieved by transferring the remains through various staged concentrations of ethyl-alcohol until it reaches the desired concentration for preservation.

Wilsford Shaft Appraisal Methodology

The 17 boxes of stored remains contain a varied quantity of individual vials, jars, bags of sediment and residue and containers. Each jar and vial was inspected to observe the palaeoenvironmental remains, levels of spirit, and labels to record their respective conditions. The wet material was assessed to determine if the spirit was present in enough quantity and record its condition accordingly. It was also assessed to determine if the containers need to be changed to meet the correct standards. The dry palaeoenvironmental material was assessed to determine if the containers were appropriate and met the correct standards. Labels that appear in vials and on jars has also been assessed to determine the degradation of the label and make judgements regarding a replacement. The criteria for the scoring system are outlined below.

A four-point scoring system was devised to assess the organic and non-organic remains was applied to the following:

- Spirit archive. This includes the physical remains and their containers.
- The labelling that accompanies the wet items.
- Dry archive. This includes the physical remains and their containers.
- The labelling that accompanies the dry items.

Each of these four areas has been graded with a corresponding score from 1 (good condition) to 4 (poor condition) (table 9). In addition to assessing the condition of archived remains and labels, the score reflects the priority with which the remains need to be treated to ensure their continuing preservation. A score of 4 indicates that the items require attention as a priority to ensure their continuing preservation.

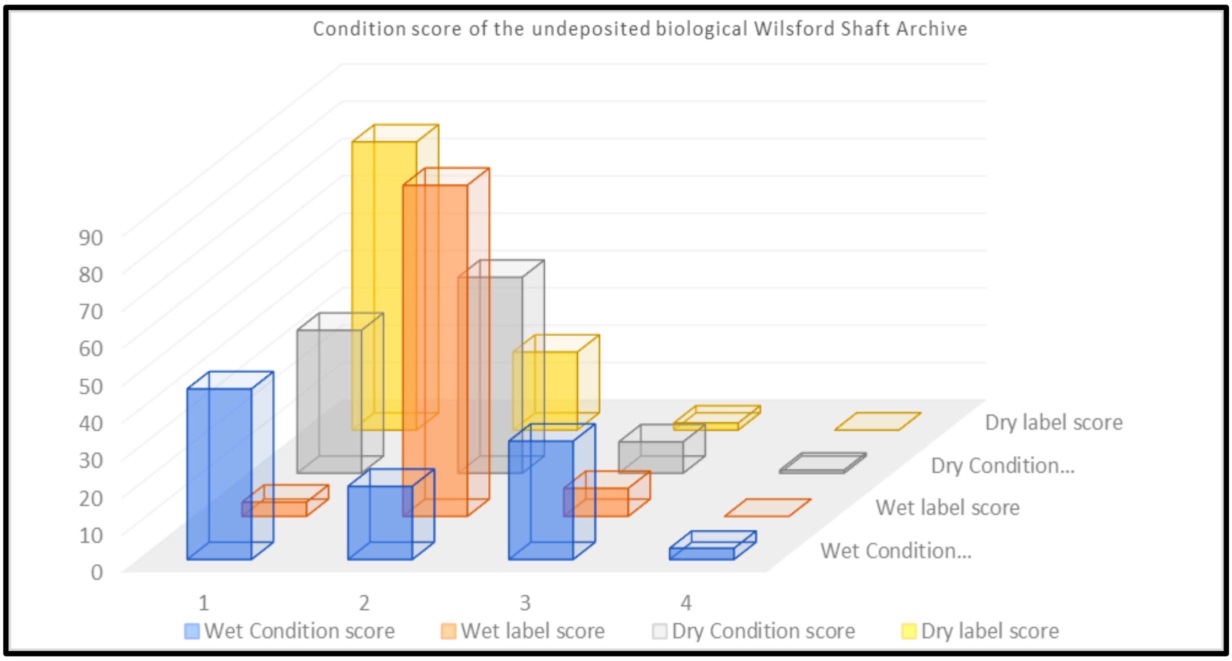
Score 1			
Spirit Archive		**Dry Archive**	
Spirit Archive Condition	**Spirit Archive Label Condition**	**Dry Archive Condition**	**Dry Archive Label Condition**

Initial observations revealed that no vials had the optimal amount of spirit. Therefore, score 1 includes adequately submerged items in spirit that have depleted. Each item requiring testing with a density meter should be transferred into a suitable preservative. The vessel and stopper are considered to be of an adequate standard and do not need replacing.	They are in good condition and are legible but ideally need replacing with printed labels.	The items are in appropriate containers and have plastic stoppers. These samples do not require any further work.	They are in good condition and are legible but ideally need replacing with printed labels
Score 2			
The spirit is drying out and requires attention. First, the item needs to be transferred into a preservative. The preservative could either be an ethyl-alcohol or methyl-alcohol. The vessels and stopper are likely to be adequate, but there may be an occurrence where the stopper needs replacing.	Labels are becoming faded and need to be replaced. Stuck on the outside and need to be removed.	Dry items are in good condition but are loose and ideally need to be moved to upright polystyrene holders.	Labels are becoming faded and need to be replaced. Stuck on the outside and need to be removed.
Score 3			
Spirit that has almost completely evaporated. Given that the remains have been exposed, they should be assessed for signs of decay. Whilst being staged, the remains will need to be closely monitored. Vessels are sub-standard and have used either rubber, metal or cork stoppers and need to be replaced.	Labels are decipherable but in poor condition and need to be replaced.	Dry samples that scored 3 need to be moved to more suitable containers. At present, stoppers include cork, rubber or metal materials.	Labels are decipherable but need to be replaced.
Score 4			
The spirit has evaporated, and the sample is exposed. The individual remains have been exposed to oxygen and may have begun to rot or be exposed to bacterial decay. These remains may benefit from re-fixation, which will disinfect the remains. Rather than using a formaldehyde derivative as a fixative, a buffered ethyl-alcohol should be used. Not using a carcinogenic chemical will prove safer for human health and requires less effort to transfer into the preservative. Wet samples with plastic vessels or inappropriate stoppers, such as those made of cork or rubber, need to be moved due to their failure to slow evaporation.	Labels with a score of 4 require new labels. The label may require infra-red light to decipher the information. All labels need to be retained. New labels must be computer printed on Resistall paper with PermaDri computer ink.	The dry archive is in inappropriate containers such as matchboxes or paper and needs to be transferred to suitable vessels. Inappropriate containers could range from matchboxes, plastic tubs, jars, or degraded stoppers.	Labels with a score of 4 require new labels. The label may require infra-red light to decipher the information. All labels need to be retained. New labels need to be computer printed on Tyvek with PermaDri computer ink.

Table 9. The scoring criteria that have been used to grade the condition of the Wilsford Shaft archived remains.

Results

Overall, the undeposited biological Wilsford Shaft material can be considered relatively 'healthy', with the most common score for the dry and wet remains and dry labelling scoring being 1 or 2. The dry condition score is good, with 38.3% of the number of samples in the dry collection scoring one. This means that the archived remains do not require any further work (graph 1). In addition, the labels with the dry archive are in good condition and are legible. Ideally, the labels could be replaced with computer-printed labels, but this is not essential if budgetary constraints exist.



Graph 1. Graph 1 demonstrates the condition of the undeposited biological Wilsford Shaft. The raw quantities are expressed through mean averages to make the results between the wet and dry archives comparable.

45.7% of the wet archive scored 1, meaning it is submerged in spirit and can be regarded as being at low risk and a healthy condition. Although they are at low risk, they need more fluid and, rather than using the formalin mix, should be submerged through various stages of concentrated ethyl-alcohol into an appropriate preservative. There are relatively few labels associated with the wet archive that are in good condition, 3.8%. Ideally, these should be replaced so as not to contaminate the newly transferred samples with the formalin mix. New labels should be created with computer-printed labels on >100gsm Resistall paper using PermaDri ink.

A total of 38.3% of the dry archive scored 1. These remains are at low risk of suffering from degradation and are stable. The containers they occupy are sufficient, the lids and stoppers are suitable, and they are maintained upright in polystyrene vial racks. These samples do not require any further work and can be transferred to the museum in their current state. Dry labels scored 77.2%, meaning they are legible and in good condition. The labels should be computer-printed to ensure that the archive remains usable for future use.

There are relatively few examples of the wet archive that scored 2 (19.6%). These examples require more urgent attention than those scoring one but are still relatively stable. These samples require additional fluid as they have almost dried out. They should be transferred to a suitable fluid akin to a preservative that can better sustain nucleic acids. There may be examples where the containers, lids and stoppers need to be changed to something more suitable. 88.7% of the wet archive labels scored 2, meaning they are beginning to deteriorate and becoming difficult to read. The labels ideally require replacement with computer printed >100gsm Resistall paper and PermaDri printer ink.

The 52.5% of the dry archived remains that scored 2 are in a reasonable condition and are not at significant risk but require attention to bring them up to the correct standards. They are loose in boxes and must be stored upright in polystyrene vial racks. The containers have adhesive labels on the outside and therefore do not meet the widely accepted archival standards. The labels adhered on the outside, and in occurrences where labels have been included in the container, have become worn and difficult to read. They should be replaced to prevent them from becoming more eroded and harder to decipher in the future.

31.7% of the wet archive scored 3 and can be regarded as high risk due to near-complete drying out. The remains may have been partially oxidised and suffered from microbial attack. Therefore, these samples require close examination before the transfer to a suitable preservative. If there is evidence of microbial attack, the samples may require re-fixation to stabilise and disinfect before immersion in the preservative. Samples that scored three may also be in a poorly suited container and require new vials or lids. The labels are in poor condition and must be replaced with some urgency to prevent them from decaying any further and losing the relevant contextual information.

8.4%. of the dry archive scored a 3. These archived remains fall short of the accepted standards of use. They include rubber seals and cork stoppers and must be replaced before they are deposited in the museum. Dry labels that scored 3 are in poor condition, becoming frayed, ripped, or worn to the point of being near indecipherable. These must be replaced in advance of the transfer to the museum.

4% of the wet archive scored 4 and will require urgent attention. The materials that scored four are listed as being

- Plant material and moss
- Sediment (x2)
- Soil samples (x3)
- 'Tank sludge' (sediment from the flotation tank that has been retained)

If we were to take our influences from natural history practice, dried samples would be rehydrated. The 'plant material and moss' sample could be rehydrated. The sediment and 'tank sludge' need to be processed to justify their retention and deposition. No wet labels scored 4.

Only 0.8% of the dry samples scored 4. These are in containers considered to be very poor such as matchboxes, and need to be replaced as a priority. No dry labels scored 4.

Significance of results

Besides the potential degradation of internal features, the archive's health can be considered good to moderate quality. The dry archive requires little work to bring it up to a high-quality standard. Some containers need to have the labels removed, the stoppers replaced and, in some cases, such as the samples in matchboxes, be changed entirely. These tasks do not require many resources or time to resolve. The labels should be printed using Tyvek and PermaDri computer ink if possible. This is not regarded as an immediately important task, but if undertaken, it will ensure that the archive is prepared for long-term storage and will not need to be replaced again for some time.

The wet archive requires more detailed work to meet an acceptable standard than the dry archive. It would not be possible to freeze-dry any of it, as past experiments have proven unsuccessful in drying fluid collections and archives. In instances where historic wet collections have been dried, issues have led to the degradation of various elements of the specimens and are therefore recommended against. In the example of the Wilsford Shaft, continued maintenance in spirit is the most appropriate option.

The wet archive items that scored 1 and 2 require topping up, although it is recommended that these are not topped up with the Formalin, IMS, and glycerine mix but are transferred to a composition that is less likely to harm internal features, genetic material, or human health (Schiller2014). For example, the plant remains should be transferred into a 70% ethanol and 2% glycerine mix, animal tissue should be transferred to 70% ethanol, and insect remains should be transferred to a 90% ethanol mix. These fluid combinations will ensure that the internal features are best preserved and will bring the remains into the globally accepted methods of storage/preservation (Chieco *et al.* 2013; Talbot and White 2013; Prentø and Lyon 1997; Simmons 2014; Bayless and Shepherd 1993; Natsca 2019).

Transfer to a more appropriate preservative needs to occur in stages. Firstly, the items must be extracted from the container using tweezers into distilled water and mildly agitated for an hour. Next, the remaining mix should be tested for acidity using a pH meter or pH strips. If the pH is lower than 5.5, the acid will require neutralisation in a solution comprising one litre of distilled water mixed with 17 grams of Potassium Phosphate [K_2HPO_4]. Given the size of the individual items within the Wilsford Shaft archive, immersion in the basic solution will not require more than six hours (Bayliss and Sheppard 1993). If the pH exceeds 5.5, or the neutralisation process has been completed, each item can be transferred into the preservative. Transfer occurs through the introduction to ethanol starting with 20% dilution to then be staged in increments that increase by 10% in each stage, each immersed for 24 hours until the desired final concentration is achieved. Finally, the same containers can be cleaned and re-used. The process, from initial extraction from the formalin mix to the final staged flush, should take place in a fume cupboard to prevent inhalation and exposure to the Formalin (Simmons 1999). If vessel stoppers are found to be inappropriate, they should be changed for ribbed plastic stoppers.

Samples that scored 3 have become oxidised and exposed, which means they have potentially been susceptible to microbial attack. Each sample should, therefore, depending on size, require careful examination using a low-power microscope, hand lens or high-power microscope to observe signs of decay. Where decay is detected, re-fixation should be considered. Methods of re-fixation depend on the material. Insect remains, for example, can be staged up to 90% ethanol using 10% increments for 24 hours per increment, which will sufficiently act as a fixative and a preservative. For plant remains, re-fixation and transfer to preservative can be achieved by transferring to distilled water, with the formalin mix being tested for pH and accordingly moved to a basic solution or a 20% ethanol mix for the staged flush. These samples should then be staged up to 75% ethanol with the final 25% consisting of glacial acetic acid and, depending on the taxa, immersed for 0.5–3 hours (see Sharma *et al*. 2011 for details). After this process, the remains will be fixed, and the item can be transferred into the desired preservative without staging. Animal tissue and hair should be staged up to a 70% ethanol buffered in phosphate and maintained for 2–4 hours but given the size of the Wilsford Shaft remains, this will require no more than 2 hours. The samples then need re-staging from 20% ethanol to a 70% concentration for preservatives. In instances where lids and stoppers are insufficient, they should be changed to ribbed plastic options.

The wet material that scored 4 ideally requires rehydration. The possibility of rehydration is made difficult as there is no precedent for the rehydration of archaeological sediments and soils, samples of which are in this category. It is proposed that a sub-sample of the materials is retained for long-term storage, and the rest should be processed through wet sieving. The 'plant remains and moss' sample should be rehydrated and examined for signs of decay or microbial attack; if detected, re-fixation should be considered.

Once wet materials have been appropriately stabilised, they must be kept separate from dry materials, and all remains need to be transferred into plastic boxes for transportation. Once transferred to the museum, the dry matter needs to be maintained in a controlled environment outlined earlier in the chapter, while wet materials should be maintained in a flame-resistant cupboard and kept out of direct sunlight. To preserve genetic material, insects should be maintained at a minimum of -20^{o}C and ideally at -70^{o}C. Attaining low temperatures for most museums is unrealistic with basic equipment such as domestic fridges and freezers and would require the investment of a laboratory freezer, which is financially prohibitive (Deborah Fox 2018 – Senior Curator Museums Worcestershire – personal communication 24 September). The Wilsford Shaft example presents complications in determining if achieving these temperatures is worthwhile, given that the Formalin may have degraded genetic material. If this is the case, maintaining minus temperatures is a moot point. If remnant genetic material can be detected, then the archive must be placed in minus temperatures to save this resource.

Following recommendations advocated by organisations such as the Natural Sciences Collections Association (NatSCA), the archive should be monitored every six months (Walker et al. 1999; Moore 1999; Tredwell 2006). A plan should be introduced that delegates members of staff with the task of monitoring the wet archive and provides a prescriptive method that explains how to monitor the drying out of spirit. The monitoring of wet collections could be undertaken at the same time as the monitoring of small finds and metal work which will likely have a scheduled monitoring plan in place with time and staff assigned to it. Levels of spirit should be monitored, and when these are observed, dropping should be topped up. As the samples require topping up, a minimum of 80% ethanol should be used (Notton 2010). The stronger mix of ethanol will account for the evaporation of the alcohol and the gradual dilution of the fluid. To assist with handling and topping up, the containers should have small, coloured dots that indicate what fluids are included within the vessel.

Overall, the dry labels are in a reasonable condition, and most of them could be maintained for transfer to the museum. However, a small number requires changing onto Tyvek and should be computer printed using PermaDri ink. Ideally, all the labels from the wet archives should be changed. Changing the labels in the wet archive will prevent residual Formalin from contaminating the new fluid. These should be computer printed using PermaDri ink on 100gsm Resitall paper. Where possible, all the original labels should be washed, dried, and retained in a dedicated folder.

Wilsford Shaft undeposited archive research potential

There are countless avenues of specific research that the Wilsford Shaft could contribute towards. For example, researchers engaging in the redating of sediments and features within the environs of the shaft using contextually secure palaeoenvironmental remains and radiocarbon dating (^{14}C) technologies that have advanced since the excavation of the shaft (Plicht *et al*. 2020). Other areas of research that could use the physical remains include insect extinctions, palaeoclimatology and plant and animal domestication. However, rather than listing all the possible research that the archive can contribute, a more focused approach is taken, identifying substantial and relevant research areas as expressed in research frameworks.

In 1986, areas including, and surrounding Stonehenge and Avebury were designated as UNESCO World Heritage Sites (WHS) (Darvill 2005). The Stonehenge WHS designation incorporates the monuments surrounding Stonehenge, such as Vespasian's Camp, Bush Barrow, the Stonehenge Cursus and Avenue, King's Barrow and the Wilsford Shaft. To ensure that efforts are appropriately focused and coordinated, research agendas have been produced for many of the geographical regions of England. These have been supplemented by period or landscape-specific frameworks, a variety of which have focused on the Stonehenge landscape. The most recent is the 2016 *A Research Framework for the Stonehenge, Avebury and Associated Sites World Heritage Site* (Leivers and Powell 2016). The 2016 research framework covered the World Heritage Site designation and was drafted following the recommendations of UNESCO to ensure that a unified approach to managing the discrete sites is undertaken (Leivers and Powell 2016). The framework was produced in partnership with local and national authority staff, university academics, museum curators, individual researchers and the wider heritage community that were invited to contribute through public consultation—the document intended to direct researchers to the most crucially important areas of current and significant research.

The shaft was almost entirely filled in by the fifth century BC, indicating that the shaft was constructed and predominantly used throughout the Middle Bronze Age (Ashbee *et al*. 1989). To determine how the palaeoenvironmental remains from the shaft can be re-used for new research, it needs to be established what potential the remains have for reanalysis. The Middle Bronze Age research themes were consulted in the *Research Framework for the Stonehenge, Avebury and Associated Sites World Heritage Site Research Agenda and Strategy* (Leivers and Powell 2016). Question K.9 focuses on agricultural strategies in the Later Bronze Age and is the most relevant to the Wilsford Shaft material.

Since the analyses of the remains from Wilsford have concluded, technological and methodological developments can use inter-ring analysis of wood to interrogate themes surrounding palaeoclimate (St. George and Esper 2019; Loader *et al*. 2003), animal diet, subsistence behaviour and land use through the application of ZooMS and MALDI-ToF (Sinet-Mathiot *et al*. 2019; Collins *et al*. 2010) and past cultivation practices using functional weed ecology and stable isotope analyses (Bogaard et al. 2016; Charles 1997; Velasco 2008; Fiorentino 2015). Using these technical developments, it is possible to identify three questions within the research framework that the Wilsford Shaft archive can contribute towards.

> **K.9. What was the character of the landscape during the later Bronze Age, and what effect did cultivation have on it, especially in terms of soil fertility and erosion?**

At the time of analysis, some of the most well-regarded specialists in the country used cutting-edge techniques to analyse the remains (Robinson 2013a). Cross-referencing the remains in the undeposited Wilsford archive with question K.9, it has been possible to identify areas of new research that can be undertaken. Following questions K.9, the research areas include cultivation techniques, cultivated taxa, land use and palaeoclimate.

The environmental reconstruction indicates that Stonehenge lay within an essentially grassland pastoral landscape with some woodland in the surroundings in the Neolithic, which had probably been largely cleared by the late Neolithic (Michael 1997). The surroundings of Stonehenge lack evidence of early (so-called 'Celtic') fields as mapped from the air by the Royal Commission on Historical Monuments (Richards 1979). Traces of fields come within about 500m of Stonehenge to its west on Stonehenge Down. Generally, however, the mapped blocks of ancient field traces to the north, west, and southwest are 1–2km from Stonehenge, indicating that even after Stonehenge's main active life, this remained a pastoral landscape from the early Bronze Age to the Romano-British period and beyond. Wilsford Shaft lies 1.55km southwest of Stonehenge. Air photographs reveal a palisade or ditch alignment about 400m southeast of the shaft, but the nearest mapped early fields are about 400m east and north of the shaft. Environmental evidence from the shaft implies that it was nearer to the boundary between arable and pasture in the middle Bronze Age. The field system and early landscape at Druids Lodge 700m southeast of the shaft have recently been investigated by a team from Historic England (Roberts *et al.* 2018). The Roberts *et al.* research concluded that the boundary ditches indicate an agrarian regime but disentangling the limits of agrarian practice and ceremonial activities, and the design of the monumental landscape is complex. Analysis of the Wilsford Shaft archive can contribute to understanding this topic.

Cultivation

At the time of the Wilsford Shaft's analysis, the techniques and methods used to understand Bronze Age cultivation and factors such as soil fertility, water status, manuring and soil disturbance levels were comparatively limited. Today, stable isotope analyses have a proven track record of investigating prehistoric husbandry practices (Charles *et al*. 1997). Watering status is determined by analysing stable carbon isotope values in pulses and cereals (Cernusak *et al*. 2013; Farquhar *et al*. 1982; Fiorentino *et al*. 2015; Fraser *et al*. 2011; Wallace *et al*. 2013). In arable habitats, variation in stable carbon and nitrogen isotope values in cereals and pulses have been shown to reflect water status and soil nitrogen composition, respectively, with implications for watering and irrigation strategies (e.g., Araus *et al.* 1997; Bogaard *et al*. 2007; Fraser *et al*. 2011; Wallace *et al*. 2013; Fiorentino *et al*. 2015). Water status and irrigation strategies can be determined by establishing the ^{12}C and ^{13}C ratios of preserved plant remains which provide a proxy for water availability during growth (Jones *et al*. 2021). At times of stress caused by limited access to water, plants can limit water loss by closing the stomata, restricting the amount of CO_2 available for photosynthesis (Osakabe *et al*. 2014). Stress caused by water shortages results in RuBisCo – the enzyme in plants that transforms carbon into sugars – using all available CO_2 rather than discriminating against the ^{13}C, the heavier isotope.

Consequently, a plant that has experienced optimal watering will have depleted $\delta^{13}C$ and more positive values of $\Delta^{13}C$. Conversely, plants that have suffered from water stress will have lower values of $\Delta^{13}C$ and have less diminished ^{13}C (Parry *et al*. 2002). The insight into potential irrigation strategies could inform the interpretation of the shaft and may indicate that a primary function of the shaft was for the extraction of water rather than for ritual functions.

Combining functional weed ecologies with stable isotope analysis can complement each other and provide evidence of the labour intensity and soil disturbance levels (Stroud *et al*. 2021). In order to detect the extent of past crop manuring, stable nitrogen values can be a proxy for the soil nitrogen a plant has used during its growth (Bogaard 2007). Analysis of cereal grains can identify if there is an enrichment of ^{15}N. The enrichment of ^{15}N can occur because of the introduction of ammonia as a consequence of manuring but can also be present as a consequence of waterlogging, salinity, microbial activity and aridity (Fraser *et al*. 2011; Handley *et al*. 1999; Hartman and Danin, 2010; Heaton, 1986; Senbayram *et al*. 2008; Yousfi *et al*. 2010). In the context of the Wilsford Shaft, aridity and salinity are unlikely to be causal factors for the enrichment of ^{15}N and waterlogging should be made apparent by the stable isotope analysis. Knowledge of past crop manuring can inform on the broader implications of soil fertility and crop rotation.

Soil fertility, soil disturbance and labour intensity of past agricultural regimes can be determined through crop stable isotope values combined with functional ecology analysis associated with weed taxa (Bogaard *et al*. 2016). The original Wilsford Shaft analysis uses the preserved weed assemblages to investigate past agriculture practices, an unusual approach for the 1970s and 1980s (Hillman, 1981; Knorzer, 1979; Willerding, 1980). The weed assemblage analysis refers to observations of modern taxa to make inferences regarding the phytosociology of the Bronze Age landscape (Ashbee *et al*. 1989). The use of modern taxa to make assumptions about past floristic composition is adept at providing general interpretations of prehistoric autecology. However, this approach has struggled to construct detailed models as this method cannot account for factors such as geographic distribution, watering and fertilising strategies which can influence floristic composition (Jones *et al*. 1995). Since the publication of the Wilsford Shaft monograph, methods that use modern weed taxa have improved by using the functional ecology of weeds rather than purely making inferences based on modern distributions. The functional ecology of weed seeds approach uses functional traits to understand a species' potential to grow in an environment and compares modern weed flora attributes with archaeological weed assemblages it can indicate different agricultural regimes (Stroud *et al*. 2021). Using functional attributes, a linear equation can be created using discriminant analysis accentuating extensive and intensive agricultural regimes (Green *et al*. 2018). Low-intensity agricultural regimes are indicated by weeds associated with low soil fertility, whereas high intensity is suggested by weeds associated with high fertility (Bogaard 2014).

Stable carbon and nitrogen isotope analyses could be conducted on cereal remain from the Wilsford Shaft. These analyses can inform the management of the watering and fertilising strategies of crops grown near the shaft. If the results indicate that watering consistently occurred on samples throughout the use of the shaft, it could demonstrate that the shaft was created to facilitate the watering of crops, consequently clearing up a debate that has existed for over 50 years. Additionally, the stable isotope and functional ecology analysis could inform the soil disturbance, soil fertility, and labour intensity of agricultural regimes surrounding the shaft. The reanalysis of the functional ecology of weed seeds does not require the physical remains, but this combined approach would assist in the accuracy of the outcomes. The weed seed analysis can be achieved using the results from the monograph and following a recently published methodology (see Bogaard *et al*. 2016; Stroud *et al*. 2021; Green *et al*. 2018; Bogaard 2014). These analyses would contribute toward understanding how cultivation affected the landscapes in the middle and late Bronze Age.

Stable isotope analyses of plant remains are, however, destructive. Destructive analysis will mean that the relatively few cereals that have been kept and not misplaced during the analysis by Peter Hawkes at UCL would be destroyed. Such a decision would require input from multiple stakeholders and should ideally not be undertaken until the archive has been reunited with the rest of the archaeological archive at Salisbury Museum. This would ensure that consistent decision-making is being made across the entire archive and guarantee that an approved process of determining the value of destructive analysis is undertaken.

Plant Domestication

The Wilsford Shaft monograph presents certain ambiguities regarding what was deliberately cultivated in the vicinity of the shaft. For example, the reason for the presence of opium poppy (*Papaver somniferum* L.) is uncertain, and it is unclear if the poppy was a non-cereal crop or if it was present in the shaft as an undomesticated weed (Ashbee *et al*. 1989). The cultivation of opium poppy could be for oil which can serve a medicinal or culinary purpose (Duke 1973). The opium poppy is thought to have been domesticated in the Western Mediterranean, is not a native British species and is very rare in prehistoric Britain; the Wilsford Shaft example is the only occurrence from Bronze Age contexts making it significant (Tomlinson and Hall 1996; Salavert 2018). It has been suggested by Robinson (in Ashbee 1989) that the presence of a poppy seed as being waterlogged rather than charred means is representative of disturbed ground rather than being deliberately grown as a crop. At the time of the publication of the Wilsford Shaft, morphometrics was not sophisticated enough to verify if *Papaver somniferum* L. represents a domesticated or wild variant. Recent developments in geometric morphometrics can now use descriptors, including the number and size of cells, to determine if a poppy seed is wild or domestic (Jesus *et al*. 2021). The archived opium poppy seed could be reanalysed to determine if the poppy grown at Wilsford was a domesticated strain and treated as a non-cereal crop or if it was present in the shaft as a weed and indicative of disturbed ground. The successful examination of the sample's morphology relies on the quality of preservation.

Additional methods of determining if ancient plant remains derive from a domesticated or wild species include the analysis of biomarkers deriving from extracted genetic information (Orlando 2021). Plant remains from archaeological sites successfully extracted nucleic acids from them, which have subsequently been analysed and compared against modern molecular markers and identify whether plants are domesticated or wild (Manen *et al*. 2003). DNA sequencing has successfully been used to track the introduction of *Lagenaria siceraria* from Asia into America in the early 8th millennium B.P (Schlumbaum 2013). To date, attempts to use DNA to discriminate between wild and domesticated opium poppy have not been successful, but the relative rarity of prehistoric opium poppy has meant that the pool of available data has been limited (Jesus *et al.* 2021). The Wilsford Shaft poppy seed could be analysed using ancient DNA studies and contribute to the broader genetic study, although it is questionable whether the extraction of genetic material will establish if the sample is domestic or wild (Gugerli *et al.* 2005; Jesus *et al.* 2021).

Given that there is only a single instance of *Papaver somniferum* L. recovered from the site, and it remains incredibly rare in British prehistoric contexts, a non-destructive form of analysis should ideally be sought. Presently, the least invasive DNA extraction methods, such as Polymerase Chain Reaction (PCR), are slightly destructive and unlikely to be applicable (Sharma *et al.* 2012). This, coupled with the fact that the Formalin erodes genetic material, means that the recently published developments in seed morphologies are the most appropriate methods of determining if the seed is wild or cultivated.

K.1.What was happening within and immediately around the Neolithic monuments at Stonehenge and Avebury during the Middle and Late Bronze Ages?

K.2. Does the present dearth of evidence for activity mean that these places were actually being avoided, possibly physically, or is it simply a question of lack of archaeological visibility?

Resolution of the themes raised by questions K1 and K2 is offered by the original Wilsford Shaft analysis. The analysis of the pollen and Coleoptera strongly indicate that there was no local tree coverage in the vicinity (Ashbee *et al*. 1989). This evidence, combined with data obtained from the weed seeds and animal dung, suggests that livestock grazing is likely to have occurred around the vicinity of the shaft and, by extension, the other monuments in the immediate area. The 1989 monograph, however, draws attention to potentially contradictory results such as the presence of buds, leaves and roundwood within the shaft, suggesting the introduction of fodder as part of the livestock diet, something that was not evident from the dung. This inconsistency could be resolved by firstly using ZooMS (Zooarchaeology by Mass Spectrometry) on the archived animal hair fibres to determine what species the hair originates from (Collins *et al*. 2010). As ZooMS is a non-destructive form of analysis, the samples could be further analysed using stable isotope techniques to establish the animals' diet and detect if they were fed grass or leaf fodder (Ehleringer *et al*. 2020). Single strands of hair can provide data about shifting diets leading up to the point of death and could therefore indicate if fodder contributed to diets or was perhaps exploited seasonally (Runge *et al*. 2021; Hollemeyer *et al*. 2012).

Using a combination of ZooMS and stable isotopes to understand more about the diet of animals could elucidate what has been described as "*a fluctuating boundary between pastoral and arable land and clear evidence that both regimes were present close to the shaft"* (Ashbee 1989 pg 129). The weeds informed evidence for the shifting borders between the arable and pastoral land, cereal remains, and entomological assemblage, respectively (Ashbee *et al*. 1989). A greater understanding of the pastoral strategies and seasonal changes from keratin within animal hair recovered from well-dated contexts can elucidate land use and activities that include foddering animals at the site (Ventresca-Miller *et al*. 2020; Baker and Worley 2019). This will inform on the organisation and use of space in the monumental landscape, farming methods, and food production (Portillo *et al*. 2020).

Identifying new avenues of research is encouraging, given that the generally calcareous well-drained sediments encountered within the Stonehenge World Heritage Site designation do not readily preserve organic remains such as those encountered in the Wilsford Shaft. Therefore, the remains from the shaft present a unique view into the Bronze Age environment and the lives of those who occupied the area surrounding barrow 33a and other barrows in the Wilsford Shaft area (Ashbee 1989). Since the shaft's excavation in the 1960s and subsequent analysis, analytical methods and techniques have developed in sophistication, accuracy, and cost-effectiveness (Van der Plicht *et al*. 2020; Akhter 2018). For example, stable isotope analyses, DNA analyses and advancements in morphometrics can allow for the detailed re-exploration of the archive, which can inform on important themes, including plant domestication and cultivation techniques. Although the significance of the archive and its potential for further research is indisputable, its ability to deliver on its full potential is called into question due to the conservation methods employed and the condition of some of the remains. For instance, the possibility that genetic material has been dissolved by the Formalin in the fluid potentially diminishes the archive's ability for future research.

On the other hand, there are examples in natural history museums where DNA has survived in specimens that were stored in Formalin for decades (Criscuolo 1994; Prakash 2019). In some of these examples, the reasons for the survival of nucleic acids are unknown, presenting hope that the Wilsford Shaft material has retained genetic material. Unfortunately, there is no way of determining this without testing a sub-sample of the material. Therefore, DNA analysis of the shaft's material is outside the scope of this project, although it is something that could be undertaken as part of another research project. Nevertheless, the outcome of DNA research will further inform on the destructive nature of Formalin and archaeological remains.

Chapter summary

The case study has demonstrated research that can be conducted using the Wilsford Shaft archive. There is no doubt many more examples where the archive can offer material for specific research, but the region's research framework (Leivers and Powell 2016) has shown relevant questions that the Wilsford Shaft can address directly. Storage of the archive in Formalin may have reduced the efficacy of the wet remains for genetic research, although this cannot be fully determined without testing. Except for the potential decay of nucleic acids, the undeposited archive health can be regarded as primarily good-to-moderate even though the material has not been actively curated. Components that require work to bring them up to a standard appropriate for long-term storage and safer for human health can be achieved using the methods described.

Above all else, this case study has highlighted that dry archive remains are simpler to curate than wet archives and spirit archives require time, effort, and resources to maintain effectively. However, the wet archive's benefits for future archaeological and ecological research demonstrate that waterlogged remains should be suitably archived. Given that most museums do not collect wet-preserved archives, this creates a challenge in identifying repositories that accept these remains. The following chapter examines potential solutions to these challenges.

Chapter Five. Local, Regional or National? A Comparison of Models for Future Storage Facilities and Archive Management.

Chapters three and four highlighted that archaeological archive repositories in England require improvements in the range and stability of controlled environments to adequately conserve archaeological palaeoenvironmental archives. To identify potential solutions, a combination of sources and concepts have been considered. Chief amongst these are the ongoing discussions regarding the development of regional archive repositories in England, repositories that if designed suitably, could appropriately curate palaeoenvironmental remains. As highlighted in chapter two, organisations such as RESCUE– The British Archaeological Trust, Historic England in their review of Mendoza report and special interest groups such as the Southport Group, highlighted the need for regional archaeological resource centres to alleviate storage pressures and allow archival materials to be linked to life-long learning programs (RESCUE 2011; Wills 2018; Trow and Sloane 2016). To examine how a system of regional resource centres could be introduced and investigate the associated benefits and disadvantages that such a system could offer archaeological palaeoenvironmental archives, the regional archaeological archive depots in the Netherlands is used as a comparison (de Grooth and Stoepker 1997).

Counter to the vision of regional archaeological archive repositories, are single national facilities used to store biological samples (Utriainen *et al.* 2007) such as environmental specimen banks in Sweden (Odsjö 2006), Korea (Lee and Kim 2012), America (Wise and Koster 1995) and Japan (Koizumi 2009). As explained by Koizumi *et al.* (*ibid*), *"an environmental specimen bank (ESB) is an organization and facility that is engaged in the systematic long-term preservation of representative environmental specimens. Specimens from ESBs have been used for retrospective analysis and evaluation for regulatory decision-making. As such, a well-designed ESB can be a valuable resource of specimens for real-time and retrospective monitoring."* The aim of an Environmental Specimen Bank is to provide material that can provide ecological materials to offer retrospective ecological monitoring, global marine monitoring, and wildlife and soils monitoring (Koizumi *et al.* 2009). National facilities such as these can provide centralised management of the complex curation needs of biological materials and can also provide recourse to set scientific and educational agendas (Odell 2017; Storms 2006; Utriainen *et al.* 2007). Perhaps then, the nature of the archaeological palaeoenvironmental components of the archaeological archives would suit a national facility rather than a regional system where resources, funds and expertise may be sparsely distributed. Ostensibly, a national repository dedicated for the curation of palaeoenvironmental remains may seem like a sensible solution, but there are challenges and disadvantages - such as splitting the palaeoenvironmental components from the rest of the archive, establishing changes in ownership and the removal of archaeological remains from the local community - that need to be considered (Edwards 2013; May 2020). The suitability of regional or national repositories for the storage and curation of palaeoenvironmental remains requires greater consideration in advance of the future decisions regarding developments in England's archive system.

The use of value-led archive appraisals is also examined as a potential solution. Archive appraisals can determine multiple factors such as identifying if any items are under threat from decay, establish conservation plans, update research agendas, and improve catalogues. Well designed and targeted appraisals can indicate what costs may be involved in re-packaging or conservation plans that can ensure that all remains are at least appropriately packaged and sealed. This is a measure, that with relatively little investment, may prove instrumental in the long-term conservation of these archives.

New Archaeological Archive Repositories for the Curation of Palaeoenvironmental Archives

As highlighted in Chapter Three, the controlled environments and facilities required to effectively curate archaeological remains are, in many cases, not sufficiently being met in English museums and repositories. As evidenced in Chapter Three, museums experience temperature and humidity fluctuations which potentially threaten palaeoenvironmental archives. The development of new repositories or a dedicated national repository equipped with the correct facilities and controlled environments would ensure that palaeoenvironmental remains are curated correctly. Dedicated archive repositories would offer multiple storerooms maintained at different temperatures and relative humidity. These could include a store for frozen genetic material, botanical remains at $<10°C$ as well as other dried remains and wet archives that can be stored in the desired environments. Such environments would allow for the conservation of a wider variety of remains to be selected and archived in perpetuity.

Most museums in England do not accept wet archives, consequently reducing the possibility that waterlogged remains can be archived (Society for Museum Archaeology 2020). Waterlogged items in many instances can be dried but this can lead to the degradation of genetic and isotopic material, meaning that options for archiving waterlogged remains should be considered (Brown 2011). A dedicated facility could rectify this by accepting wet archives, and crucially, it would have the expertise, tools and solutions required to accept and effectively curate them. A combination of refrigerators and freezers could be installed at varying temperatures to maintain archived palaeoenvironmental remains in the best possible conditions. Additionally, new repositories could include the equipment and expertise required to stabilise archived remains and fume cupboards that can allow for handling fluids.

A Background to the Discourse Surrounding New Archaeological Archive Repositories

Over the last decade, there has been discourse surrounding the development of additional storage capacity in England in the form of regional archive repositories. One of the earliest contributors to the topic was provided by RESCUE. Since its inception in 1971, RESCUE has lobbied local and national government to ensure that the planning process considers cultural heritage and archaeology (Ralston and Hunter 2006; Rahtz 1974; Everill and Ivring 2015). The need for new regional facilities to support archaeological archiving in England has been advocated by RESCUE, as highlighted in the following statement:

> *"We have long advocated improvements to the system of archive deposition in local and regional museums and the creation of regional depositories to hold archives from developer-funded and amateur/voluntary excavations in perpetuity. The funding crisis has only deepened the crisis surrounding the long-term curation of archaeological archives."* (RESCUE 2011)

The statement from RESCUE acknowledges that regional repositories would be a welcome solution, but also highlights a key challenge in the development of new repositories, which is funding. This statement was written in 2010, just after the Great Recession of 2008, an event that resulted in drastic cuts in government spending on the arts (Science and Technology Committee 2009; Verick and Islam 2010). Threats to funding have not eased and government figures indicate that museum funding in England for 2016 was 31% lower than in 2010. The reduction in funding resulted in museums closures, reduced opening hours and a reduction in skilled staff (Museums Association Review 2016). Regrettably, the ongoing Covid 19 pandemic is likely to divert further funding away from arts, culture, and heritage funding sources such as Community Infrastructure Levy, private giving, the National Lottery Heritage Fund, and partnerships in commercial projects (Banks and O'Connor 2021; Anheier *et. al* 2021). Consequently, the prospect of generating substantial quantities of funding from national or local government is likely to be challenging (Gross *et al.* 2021; Pye 2020).

In addition to the opinions provided by RESCUE, the need for additional archiving capacity has been examined by the Southport Group. The Southport Report was the culmination of the group's year long examination and critique of the 2010 Planning Policy Statement 5 (PPS5) which replaced Planning Policy Guidance 16 (PPG16) (Hinton 2013; Chitty 2011). In the same year as PPS5 was introduced, the government's Open-Source Planning Green Paper was published which, along with the Localism Act published the following year, heralded deregulation, and the shrinkage of funding for local and national government run organisations and museums (Bevan 2014; Hinton 2013). In response to the changing legislation and the outlook of government regarding the funding and management of cultural heritage, the Southport Group used this as an opportunity to critically re-examine legislation relating to archaeology. Regarding archaeological archiving, and the development of new archive repositories, the suggestions from the Southport Review relevant to this chapter are as follows:

- *A network of resource centres, related to existing museum structures and supporting appropriate expertise, that curate archaeology collections (records and material) and provide access to all types of information on the historic environment for a wide variety of users.*

- *The establishment of those resource centres as hubs for research, linked to life-long learning, schools, research interest groups, museums, other archives, online resources such as the Archaeology Data Service (ADS), planning departments and HERs.*

- *Provide information on potential areas where resource centres could be created. In some areas 'regional' repositories or hubs – such as the London Archaeological Archives Resource Centre (LAARC) – with access digitally through gateways at HERs and local museums would provide more cost-effective and better service for researchers.*

The authors of the report recognised that new repositories need to provide more than just storage capacity. The report acknowledges a need for new repositories to offer opportunities for access for all members of the community and lifelong learning. New repositories organised by English county and/or metropolitan or non-metropolitan district, could be designed to accept school groups and special interest groups and observe and handle artefacts, learn about the archaeological process and archaeological science. Opening up the archaeological process and archaeological science corresponds with the wider government aims to encourage public science engagement given that public trust in science and scientific governance is currently wavering, especially when compared to the historic high levels of confidence recorded in 2014 (UK Government 2020; Cheng and Hsiaw 2018; Castell *et al.* 2014). This growing distrust is exemplified by data which demonstrates that some voters are likely to distrust government officials and scientists (YouGov 2017). It is therefore important that there are discussions amongst stakeholders, academics, policy makers, assessment practitioners and, crucially, the public, to maintain, and where possible, enhance public trust and involvement in science and technology (Fosberg *et al.* 2015; Arnold *et al.* 2012; National co-ordination centre for public engagement 2014). Trust could be gained by increasing engagement in scientific processes and engaging with authentic artefacts.

Prioritising access can also ensure that archaeological archives are engaged with more frequently, consequently demonstrating societal need and, crucially, applicability for funding. As part of the Southport Group's deliberation, there is the suggestion that new repositories could qualify for funding through the Community Infrastructure Levy (Wills 2018). To attract funding through the Community Infrastructure Levy, the development of new repositories would have to demonstrate strong prospects for frequent access as well as clear societal benefit. Perhaps then, a clarification of *what* is expected from a repository in terms of access would be beneficial. The definition of a publicly accessible repository, as defined by the Society for Museum Archaeology (SMA) in the following statement:

> *An accredited repository for the collection, curation and safeguarding of archaeological archive material which is pro-actively managed and developed by staff qualified to ensure continued public engagement with, and the best possible access to the archaeological resource, for the purposes of enquiry, exhibition, learning, research, inspiration, enjoyment and general interest.* (SMA 2018 p 2)

The SMA statement succinctly qualifies what a repository should be aiming for in terms of access. Regarding *who* archaeological archives should be made available for, the Mendoza Review elucidates on public access and public value, as highlighted in the following statement published in Historic England's package of recommendations following the Mendoza report (Historic England 2018a).

> *"In addition to the importance of archaeological archives for professional archaeologists and academics, they also deliver key benefits for the public: allowing the periodic refreshing of front-of-house museum exhibitions; supporting primary and secondary, as well as higher*

education teaching; and enabling 'citizen science' and voluntary sector research initiatives." (Historic England 2018a pp 7)

The statement from the Mendoza Report highlights the significance of having appeal for professionals but also members of the public. Solutions that can regularly provide access for schools, higher education, and citizen scientists as well as researchers should be sought.

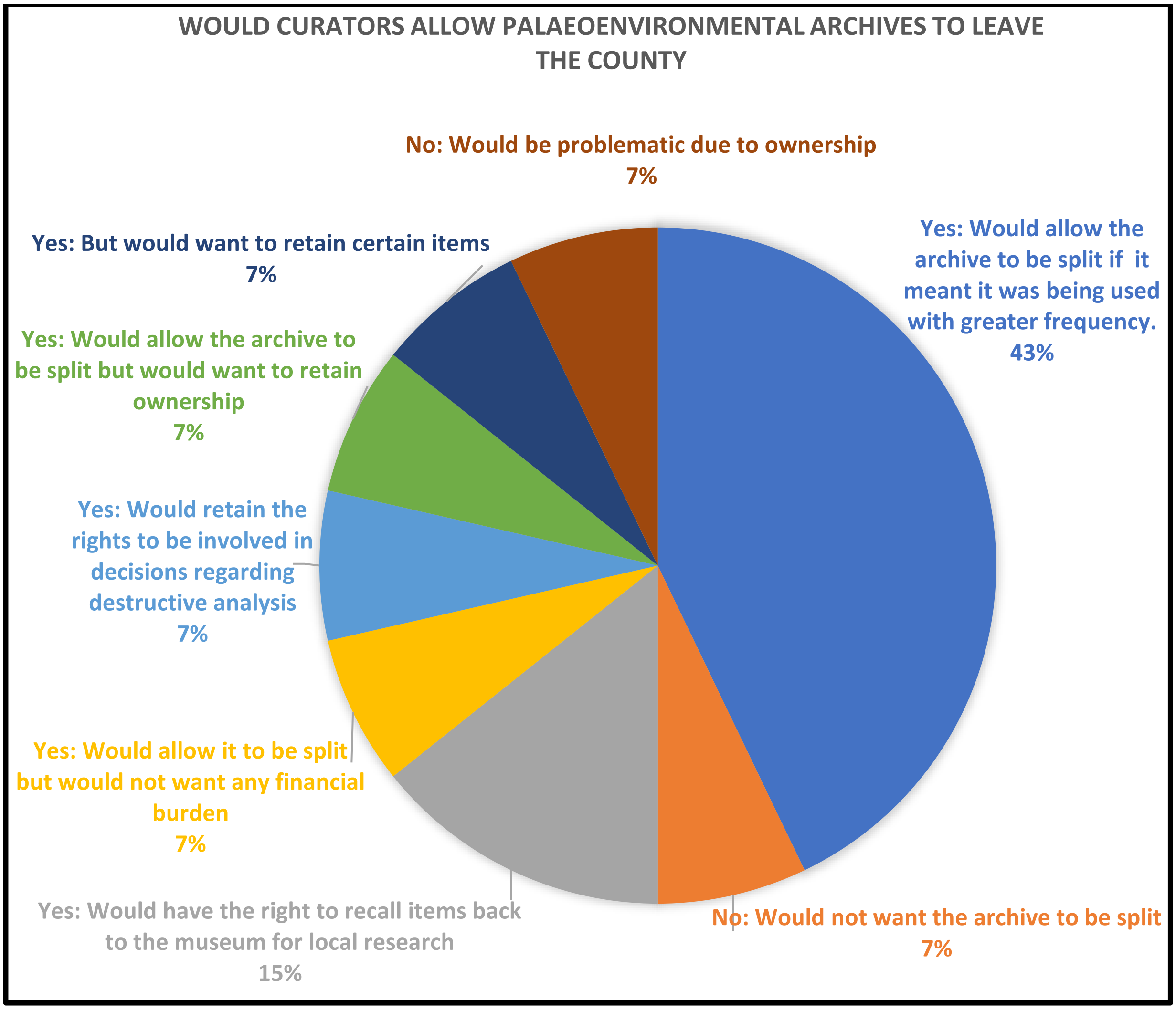
Opinions from the museum sector

The background provides an insight into what key factors need to be accounted for when considering the development of new archaeological archive repositories. Absent, however, are the opinions of museums curators regarding how palaeoenvironmental components of site archives should be managed if they were to leave their care and be curated in a separate facility. To rectify this absence, survey data collected from 14 museums is provided to elucidate on the opinions of curators. The relevant survey questions set out to establish if museums or a single museum could become centres for the curation of archaeological palaeoenvironmental archives. Also for consideration is the potential for an existing museum to potentially act as a dedicated repository that could, with investment, act as a specialised repository for archaeological palaeoenvironmental archives. To achieve this, an institution would need to accept archives from outside their collecting area and have sufficient space and infrastructure to allow for the development of climate-controlled storerooms and facilities. To understand if there is any likelihood that an existing museum could offer these necessary services, the museum partners were surveyed to determine if there is any potential.

Of the 14 participants, 93% responded that they would not collect outside of their collecting area due to contractual and ownership concerns and limitations to storage capacity. The single museum that did indicate that they would be able to find sufficient space and would be willing to accept another region's archaeological archives was Peterborough Museum. Peterborough City Council's culture, museums and leisure facilities are managed by *City Culture Peterborough*, an independent charitable non-for-profit organisation (https://cityculturepeterborough.org.uk/). City Culture Peterborough also manage Flag Fen Archaeology Park, a visitor attraction that welcomes the paying public, researchers, and school and education groups to experience prehistoric life, view archaeological artefacts and waterlogged remains and participate in nature walks. Flag Fen could provide the space necessary to support semi-permanent structures with reduced footprint that could be used to store palaeoenvironmental archives and crucially provide access to the public.

The survey responses also provided data regarding how museum curators would feel about the palaeoenvironmental components leaving their custody to be curated by a separate institution. The survey revealed that 43% of respondents claimed that they could not perceive any challenges with the archive leaving the county, 7% would not want the archive to be split, 15% reserve the right to have items recalled to the museum, 7% stated that they would be prepared to split the archive but would not want to incur financial burden that arises in the process of splitting the archive, 7% would want to retain involvement in decisions regarding destructive analysis, 7% responded that they would want to retain ownership of the archived remains, 7% would be allow for most of the archive to be split but would want to keep some items of local interest and 7% foresee challenges that may prevent the splitting of archives due to ownership (graph 2).

Of the 22% of the participants that responded that they had no issue with the material leaving their custody, a further questioning revealed that they did not feel that there was a regional cultural connection with the remains. This fact is concerning and demonstrates a clear lack of appreciation for the palaeoenvironmental resource in their care. Only a single respondent would not feel comfortable spitting the archive and would want to retain the palaeoenvironmental components. However, curators responded that they would be prepared to allow the archive's environmental component to leave their custody, especially if it means the archives will receive more use and better care. However, there are several potential barriers, such as ownership and local involvement in decisions regarding destructive analysis that need to be resolved. Museum curators also expressed an interest in being able to retrieve items if a local resident wanted to have access to the material. The museums would also not want to bear any financial responsibility for participating in the retrieval or relocation of archives.



Graph 2. The 14 museums were asked how they felt about splitting archives and having them leave their custody.

If regional facilities or a national facility was commissioned, the factors regarding ownership and local input regarding destructive analysis would need to be catered for. If these themes can be solved, the data indicates that museum curators would be happy to allow the majority of palaeoenvironmental archives to leave their care. To better examine how a system of regional archaeological archive repositories would operate, and to examine how challenges such as archive ownership would play out in real-world situations, a short case study using the Dutch system of regional archaeological archive depots is provided.

The results from these two survey questions indicate that current museums infrastructure, except for Peterborough City Council, is unlikely to be able to support a single specialised facility, and museums would be prepared to allow transfer to a new facility. Although indicative, it should be considered that the survey only considers the opinions of 14 museums and is not representative of the entire country.

Case Study - Regional Archaeological Archive Depots in the Netherlands

To examine the role those regional repositories could play, and how such facilities could benefit the curation of palaeoenvironmental archives, the Dutch system of regional depots is examined to provide comparative qualitative and quantitative data. The Dutch system of archiving was selected as a case study following a presentation to the Association of Environmental Archaeology given by Professor Hans Huisman (Huisman 2020). Professor Huisman's presentation focused on the system of regional archive repositories and some of the challenges that have been experienced such as the varying curation standards and a reticence of specialists to deposit palaeoenvironmental remains. There are no published works that specifically focus on palaeoenvironmental archiving in the Netherlands. In the absence of a specific documentation, this section draws publicly available data from the Ministerie van Onderwijs, Cultuur en Wetenschap (Cultural Heritage Agency – Ministry of Education, Culture and Science) website regarding the general museum practice and from more specific consultation with depot curators.

Since the early 1960s, archaeological archives in the Netherlands are managed through a system of regionalised archaeological depots (Willems 2002). The first depots were in provinces (broadly analogous to English counties). Dutch heritage law dictates that all archaeological samples, artefacts and documentation are deposited in a corresponding facility (see the 2007 Archaeological Monument Care Act). Given the similarities of archaeological deposits in the Netherlands and England and shared overarching European heritage legislation such as the European Convention on the Protection of the Archaeological Heritage (revised) of 1992 (Council of Europe 1992), the two countries are suitable for comparison. Also comparable is the Dutch experience of commercial archaeology, which formally became enacted into legislature in in 1992 and today approximately 90% of the archaeological investigations undertaken in Holland are commercial in nature, making the challenges for archiving comparable to the English example (Van den Dries et al. 2010; de Rijk 2008). A benefit that the example of the Dutch system of depot storage provides, is the decades of experimentation and the resulting challenges from years of administrative and legislative changes, and the examples of problem solving that have arisen. The experiences of establishing and maintaining regional archive repositories can assist with determining how a system of regionalised depots could assist with the long-term management of archaeological palaeoenvironmental archives.

When first established, the depots were assigned to each province, to accept archaeological finds. Each depot was under the care of the Rijksdienst voor Archeologie, Cultuurlandschap en

Monumenten (RACM) (previously the Rijksdienst voor het Oudheidkundig Bodemonderzoek (ROB)), a provincial archaeologist employed by the Dutch state. Prior to the 1961 Dutch Monuments Act, which led to the introduction of the provincial depots, the country's archiving systems followed a similar system to the one experienced today in England (de Grooth and Stoepker 1997; Waugh 2008). The decision to create the depots was not necessarily to solve the familiar challenges manifest in the archive curation but was to provide administrative separation between the museums and the developing commercialisation of archaeology. Freeing the museums of the duty of accepting and managing archaeological archives allowed for resources to be focused on increasing visitor numbers, a preoccupation that successfully saw the rise in museum visitors increase from 13 million in 1978 to over 20 million visitors by 1988 (Navarrete 2014). Regrettably, the attention given to the front of house, led to a dearth of attention being given to rear of house, and many artefacts suffered as comparatively little effort was being applied to their conservation (Navarrete 2014).

A significant development occurred in 1988, following the 1985 Museum Policy Document, decentralisation of museums and the revision of the Dutch Monuments Act (Bina *et al.* 2016). There were two main outcomes: the first was that a certain number of museums went from being subsidised by the government to being fully owned by the state, and the second was the creation of municipal (broadly analogous to English local authority districts and boroughs) depots. The municipal depots accepted artefacts recovered from the municipal area except for university run excavations and sites managed by the state which were sent to the provincial museums (Grooth and Stoepker 1997). Municipal depots ranged in size from single rooms located in museums to dedicated separate buildings managed in partnership with local provincial museums.

A pivotal moment in the management of the Dutch archived archaeological resource was privatisation of the museums in 1993 (Bina *et al.* 2016). Post privatisation, the state continued to own the properties and collections that were regarded as being of national importance, but the management of museums was transferred into independent foundations overseen by the Ministry of Education, Culture and Science (Bina *et al.* 2016). The privatisation of the museums led to something of an identity crisis between the museums and the depots in which numerous issues arose. Chief amongst these was the relationship between the depots and their partnering museums which has, at times, been contentious (Willems 2002). These contentious issues can be summarised as disputes regarding the roles and services that the depots should be offering, an absence of shared standards, and diminishing capacity for storage (Bruin 2004).

The Netherlands Archiving Standards

The pell-mell standards of conservation operated in museums and depots in the Netherlands were improved in 1995, with the publication of interim reports from the Delta Plan Project for Cultural Heritage in the Netherlands (Grooth and Stoepker 1997; Bruin 2004). The Delta Plan was an ambitious project that ran from 1990 to 2000 which used approximately £85M of government money to improve the conservation of materials in Dutch museums (Navarrete 2014). A key aim of the Delta Plan was to better understand what collections and archives existed in Dutch museums and devise an action plan that can better curate these items (Keene 2006; Alexander *et al.* 2017). The plan set out to make detailed inventories of backlogged items that require registration or conservation and eradicate any backlog and make improvements to storage environments to promote better conservation (Navarrete 2014; Keene 2006). The Delta Plan introduced the concept of preventative conservation and provided prescriptive methods of auditing collections and archives (Talley 1999; Keene 2006). The outcomes of the Delta Plan rarely cited the improvement of facilities and conditions such as introducing air conditioning and air purification to improve storage environments. Rather, the outcomes of the Delta Plan were wide ranging and conceptual (Bruin 2004; Van der Burg 1996). The main outcomes are as follows:

- developing standards for conservation
- educational work and promotion
- research into improving treatment methods
- improving the professionalism of staff of the institutions
- instituting training courses

Although aimed at the museums more than the depots, the Delta Plan also introduced the concept of Collectie Nederland (Collection Netherlands), a perspective that views all museum collections as telling a national story. This was only made possible by the large-scale audits of the museum stores which provided enough detailed knowledge of what exists in the store and how it can be leveraged for public engagement and scientific research. Consequently, the outcomes influenced the importance of conservation methods and selection criteria that can be operated in museum and depot alike. The Delta Plan rarely referenced the auditing and curation of palaeoenvironmental archives specifically but recognised that environmental conditions of the remains – especially delicate remains - needed to be improved (Grooth and Stoepker 1997).

The decentralisation of government services and the attempts to improve the standards and conditions of artefacts and samples such as those outlined in Delta Plan were further improved by the introduction of the Kwaliteitsnorm voor Nederlandse Archeologie (KNA) (Willems and Brandt 2004). The KNA is a quality assurance system that introduced legal requirements on the entire Dutch archaeological community (Waugh 2008). These requirements govern every stage of the archaeological process including the standards for creating, depositing, and managing archaeological archives (Willems and Brandt 2004). The KNA has received routine updates but there are few references of the archive standards needed to curate palaeoenvironmental archives, only packaging methods. It is, therefore, hard for each facility to understand and operate the correct curatorial standards. The next section examines what standards exist across the depots for the curation of palaeoenvironmental archives to determine if a similar system would satisfy the needs of palaeoenvironmental archives in England.

Facilities for the Curation of Palaeoenvironmental Archives

Today, there are 38 archaeological depots in the Netherlands. These include a corresponding depot for ten of the 12 provinces (North Holland, South Holland, Zeeland, Gelderland, Utrecht, Flevoland, Limburg, Nord Brabant, Overijssel), the Northern Archaeological Depot (includes Groningen, Drenthe, Friesland), and 28 municipal depots. To determine if the Dutch archive repositories possess the correct facilities and tools necessary to curate archaeological palaeoenvironmental archives, a selection of repositories were contacted and asked to describe what controlled environments and facilities they possess and what frequency of use the palaeoenvironmental component receives. The selected ten repositories (Amersfoort, Arnhem, Delft, Deventer, Het Valkhov, Hoorn, Noort Brabant, Maastricht, Overijssel and Utrecht) were chosen for survey as contact details that listed the curator directly were readily available rather than a council or online enquiry card. Other surveys conducted as part of the thesis found that email addresses not linked directly to the curator were slow to respond and reticent to engage with the project. Of the ten repositories contacted, eight replied - Amersfoort, Arnhem, Delft, Deventer, Het Valkhov, Noort Brabant, Overijssel and Utrecht.

All eight repositories replied that they had a general storage room (table 10). A general storage room is defined as a room that is maintained at approximately 18°C with a relative humidity (RH) ranging between 30% and 60%. In the instances of the Het Valkhov and Delft repositories – both of which are municipal - they only possess a single all-purpose room. Refrigerators and freezers are owned by Arnhem, Deventer, Overijssel and Utrecht. Noord Brabant does not own a freezer intended for genetic material and is maintained at -20 °C. Low humidity rooms intended for metalwork are included in repositories in Overijssel and Noord Brabant. Amersfoort and Arnhem have separate storerooms that are maintained at cooler temperatures and can support charred plant remains. Of the eight repositories, only two have storerooms dedicated to dry ‘ecological archives’ archives.

These stores are maintained at 18°C but with a lower RH, maintained at 50%. In addition to the dry ecological archives store, Noord Brabant has a wet ecological archives store. Noord Brabant also has a mounted slides room, a documentation room maintained at a temperature and RH to conserve the paper archive, a buffer room, and a wet archive room. The variability across the archive depots surveyed is significant and the standards of conservation of palaeoenvironmental remains is also likely to be varied.

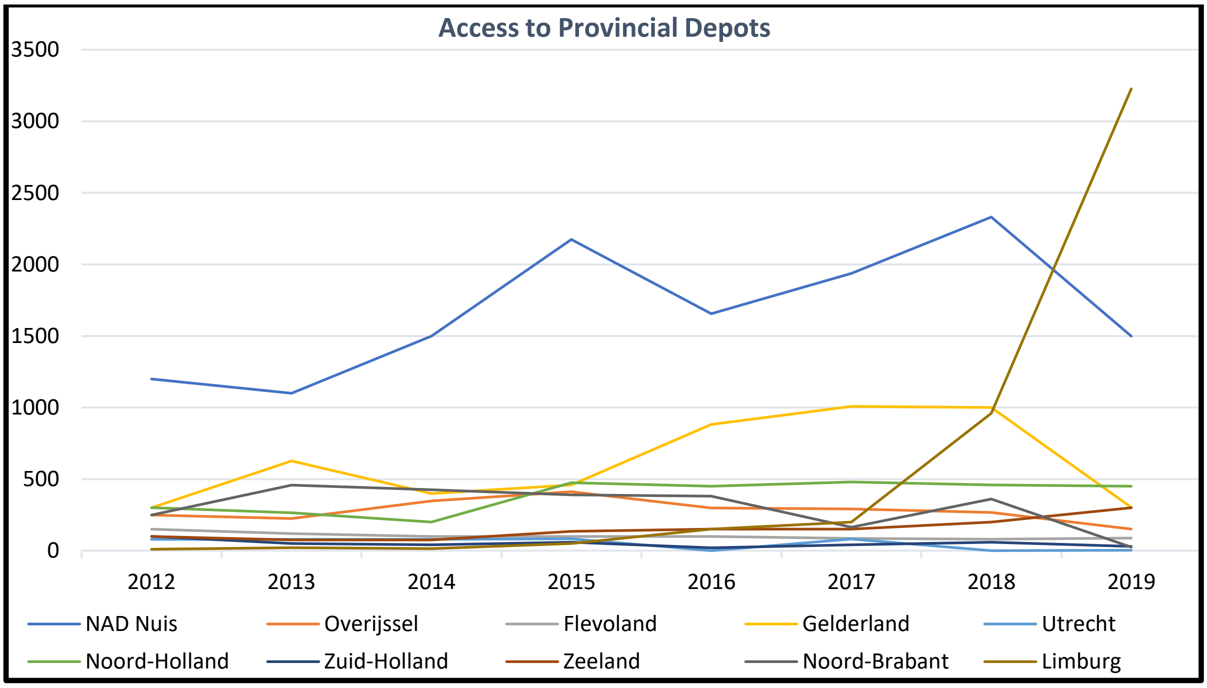
	Utrecht	Delft	Overijssel	Noord Brabant	Het Valkhof	Deventer	Arnhem	Amersfoort
Buffer Room				**X**				
Controlled/cooler room							**X**	**X**
Mounted slides room				**X**				
Documentation room				**X**				
DNA store				**X**				
Dedicated palaeoenvironmental store (Dry)			**X**	**X**				
Dedicated palaeoenvironmental store (wet)				**X**				
Low humidity room			**X**	**X**				
Refrigerators/freezer	**X**		**X**			**X**	**X**	
General storage space	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Table 10. Eight archaeological archive depots (two provincial and six municipal) responded to the question regarding the controlled environments they support.

Accessibility

People visiting the facilities to access specific materials or as part of school or lifelong leaning fluctuated over the years, with 2016 boasting an impressive 210,000 visitors to the depots. For reasons that are unclear, the overall visitor numbers have steadily declined, although some of the depots such as the Limburg provincial depot experienced a significant increase in visitor numbers. The depot that has received the largest visitor numbers is the Northern Archaeological Depot (NAD).

The NAD represents three regional depots that were merged: Groningen, Drenthe, and Friesland. These were situated in the museums of Groningen, Assen and Leeuwarden respectively, and were combined into a single purpose non-museum depot (van Wijk 2019). The NAD is the largest depot and, was the most visited depot between 2013 and 2018 in Holland (see graph 3). The number of visitors for the NAD has fluctuated between a minimum of 1100 visitors and a maximum of 2331 annual researcher visits and over an eight-year span, presents an average of 1675 annual visitors (Rijksdienst voor het Cultureel Erfgoed - eigen registratie. De Erfgoedmonitor 2022).



Graph 3. Data obtained from the Rijksdienst voor het Cultureel Erfgoed – Ministerie van Onderwijs, Cultuur en Wetenschap (Cultural Heritage Agency – Ministry of Education, Culture and Science) https://erfgoedmonitor.cultureelerfgoed.nl/mosaic/kerncijfers/. Visitor number data is obtained from the 10 provincial museums over an eight-year period.

The least visited archaeology depot is South Holland, which over an eight-year span welcomed 400 visitors, a mean of 50 visitors a year. This result may seem meagre when compared to the NAD, but when compared to the average number of visitors to archaeological archives and collections in England, which is 40 visitors a year, 50 visitors is still an improvement.

An estimation of archaeological archive users, as indicated by the Edwards, 2012 nationwide survey, highlights that the of 19 museums surveyed, there were 8,431 visits over a period between 2000-2012. This indicates that even for the Dutch depot that receives the fewest visitors, this single institute receives more visitors than reported visitors to archaeological archives in England. These results from a country which is 3.5 times smaller in area than England, demonstrates that the depot system of managing archiving archaeological remains is successful at providing and encouraging access.

Regarding the frequency of visits to research archaeological palaeoenvironmental archives, there is variation between the repositories. The Arnhem repository has, for example, received approximately 50% of the visitors to research palaeoenvironmental archives whereas the Het Valkhov repository has only received approximately two visits for palaeoenvironmental archives in the last two decades. The differences in interest in palaeoenvironmental archives is linked to the regional research foci. Arnhem, for example, is located on the confluence of the River Nederrijn and the River Ijssel and is 7km from the Rivers Waal and the Rhine and is also close to the large Roman site at Nijmegen. The riverine deposits, wetland heritage and the history of excavating waterlogged sediments in the region prompts greater levels of research.

The Netherlands' regional archive repository system demonstrably encourages greater use of archaeological archives than the system of storing archives in museum stores currently employed in England. It is suggested that discussions regarding the adoption of a regional system of archaeological archive repositories in England should consider the success of the Dutch depots. There are, however, lessons that can be learnt from decades of experimentation. For example, the combining of three provincial depots at Groningen, Assen and Leeuwarden to form the larger and frequently visited NAD, suggests that few and larger depots (rather than a repository for every county and district) would be a sensible option. The Dutch system has also demonstrated very variable abilities to effectively curate palaeoenvironmental archives. There are clear differences between Noord Brabant and other depots such as Delft and Het Valkhov and their ability to actively curate palaeoenvironmental archives. In effect, the Dutch system has replicated the same challenges and the variability is comparable to the challenges that are being experienced in English museums and as such cannot be viewed as a satisfactory solution to the challenges. For the conservation of archaeological palaeoenvironmental archives, as highlighted in Chapter Three, each repository would need to support suitable environments to accept all remains and adequately store them. To curate archaeological palaeoenvironmental archives in England, each new repository would need separate designated storerooms and refrigerators/freezers. Replicating the same systems would be costly. It would be beneficial to have a single store that can possess the items needed to sufficiently curate palaeoenvironmental archives. It is therefore argued that if a similar system were to be adopted in England, fewer, or a single specialised repository would be more cost effective for the management of archaeological palaeoenvironmental archives.

In terms of ownership, a similar system to the Dutch 2016 Archaeological Monument Care Act would ensure that remains are the property of the corresponding municipality, or province they were discovered in (Cultural Heritage Agency 2016). A repository dedicated to the maintenance of archaeological palaeoenvironmental archives would need to maintain close links with regional and local museums, while also developing frameworks for loaning material for local research or exhibition.

National Archive Facility

The review of the system of regional archaeological archive depots in the Netherlands has suggested that if a similar system were adopted in England, a host of familiar challenges would arise. Perhaps then, a dedicated national repository that could service archaeological palaeoenvironmental archives would be better suited. To determine how a newly developed archive repository could best serve archaeological palaeoenvironmental archives, the priorities identified by RESCUE. the Southport Group, Historic England and the SMA are used as criteria to identify potential solutions. To appreciate what the ideal facility may look like, two examples of existing facilities have been selected for comparison. Each of the examples have been assessed using five themes that have emerged from the repository discourse combined with the opinions of the museum curators and the vision of Historic England and special interest groups. The five themes are as follows.

Correct Controlled Environments and Facilities. There needs to be space to install, or already possess tools and resources, to effectively curate the remains. These include the following:

- Sufficient space for the accrual of future archives
- Sufficient space for multiple climate-controlled stores
- flame resistant containers for wet archives,
- cold stores, fridges, and freezers to manage various remains at different temperatures,
- chemical handling (fume cupboards and liquid nitrogen etc).

Accessibility. Accessibility is key for a new facility. Digital methods of promoting and sharing the resource will be covered in Chapter Eight, but the availability for researchers to be able to find and access material is vital for the success of a repository. Access for the public is also of importance. Public access could be facilitated by tours around the stores and the inspection of the full array of archived remains using microscopes.

Expertise and tools. The example needs to be assessed for its ability to provide specialist staff to monitor archive remains and ensure they are stable. The staff would need to field communications from researchers who want to access materials. The attending staff would therefore require the skills to assess factors such as condition, potential, quantity etc and provide information to the researcher. At least one high powered and low powered microscope would be required at the facility to examine archived remains.

Cost effectiveness. Cost effectiveness is a crucial factor for all stakeholders and is a vital consideration if the long-term management of such a facility is to be considered. Palaeoenvironmental remains require a certain amount of specialist tools and materials, but these need to be procured and managed in a cost-effective way. This would include materials and staffing.

These four criteria are applied to a national model, which assumes repositories are located on a regional basis and are shared with other archaeological archives and a national model, which assumes a single specialised repository that deals exclusively with palaeoenvironmental remains. The regional model compares an example from the Netherlands that has successfully developed regional depots for archaeological archives. Holland is 3.5 times smaller than England, but the model is regarded as being scalable and crucially, has comparable archaeological deposits and a history of environmental archaeology.

The national model examines the applicability of two sites, Flag Fen and Fort Cumberland. As identified, Flag Fen has the space and capacity to welcome visitors to ensure that public access can be met. Fort Cumberland, Portsmouth is home to Historic England's Fort Cumberland Laboratories, field archaeology team and archaeological archives team and clearly has the expertise and facilities that could effectively curate palaeoenvironmental archives. Facilities such as Deepstore have not been considered as it does not meet criteria that demonstrate accessibility, and it does not have experts on hand. A large archive facility such as Deepstore could offer much in terms of short-term cost effectiveness and available storage capacity, but it clearly will not compete against options such as Flag Fen and Fort Cumberland.

Flag Fen

During a scheme of ditch and dyke cleaning on the south-eastern outskirts of Peterborough, Cambridgeshire, in 1982, large timbers preserved in the waterlogged peats of the former wetland were revealed (Malim *et al*. 2015; Pryor 2010). The discovery led to over two decades of excavation revealing a 1km long Bronze Age and Iron Age timber alignment replete with ritually deposited artefacts and ecofacts (Pryor 1991). The anoxic environment created by the waterlogged peats and organic clays allowed for excellent preservation of the remains on a scale not usually encountered (Taylor 2001; Malim *et al.* 2015). In 1987, the 28-acre site was opened to the public for a three-month trial period which owing to its success became a near permanently open visitor attraction (Pryor 1989). A significant percentage of the acquired land has been incorporated into an archaeology park with exhibits and attractions whilst land to the northwest has not been developed and remains vacant (S Wilson 2019 personal communication 8 February). The occupied part of the park hosts a steady stream of the paying public for guided and unguided tours, workshops, and school visits co-ordinated with learning objectives and national syllabus.

Since Flag Fen opened to the public in 1987, it has been staffed and managed by a variety of archaeologists, volunteers, and professional managers. Staffing has been informed by the ownership of the park, which has changed over the years from a mostly English Heritage funded entity to a local council owned attraction (Pryor 1989; DigVentures 2012). This has resulted in the intermittent presence of professional archaeologists being on site and ability to easily commit to archaeological excavation or on-site conservation (S Wilson 2019 personal communication 8 February). In the 21st century, Flag Fen has been used for the storage and of timber remains from the Holme Timber Circle, King's Dyke and Must Farm and Flag Fen itself. Timbers have been stored in the Hudson Barn, located near the visitor centre and have been monitored by professional archaeologists who variously work for the Fenland Trust and Cambridge University Unit (M Bamforth 2022 – former Flag Fen Conservation Manager personal communication 07 February).

Compared to the early days of the site as a visitor attraction, the role of archaeologists at the park have focused on excavation and conservation and less on public engagement and the delivery of educational content (S Wilson 2019 personal communication 8 February). Today, Flag Fen has a dedicated education officer that designs content for school groups and workshops. The content includes prehistoric archaeology but also includes themes surrounding ancient and modern ecology.

There are areas of the park that are vacant and have the space to support a storage facility. Due to significance of the sub surface archaeology, any building work which disturbs archaeological deposits of a scheduled ancient monument would be unacceptable (https://historicengland.org.uk/images-books/publications/scheduled-monuments-guide-for-owners-and-occupiers/). A solution could be sought in the use of portable modular container units, structures that have no little impact on sub-surface archaeology, although the effects of compression would need to be determined (Dekker et al. 2007). The last decade has seen the use of container units being considered as a solution as disparate as providing capacity in prisons to house inmates (Grant 2013), re-housing people in disaster hit areas (Zhang *et al*. 2014), temporary storage of pharmaceuticals in the cold chain (WHO 2020) and the storage of seeds in tropical environments (Trail 2019). Chilled stackable portable units are inexpensive, would require little to no planning permission, and have low running costs. The Scheduled Ancient Monument status of the site will likely add certain complications regarding developments. Container units may lead to sediment compression and if stacked, could impact the visual setting.

Having a facility for storing palaeoenvironmental archives at Flag Fen would provide opportunities for public access and frequent occurrences of engagement. The site welcomes patrons who visit and enjoy and learn about later prehistoric archaeology and local ecology. Both archaeology and ecology are articulated using a variety of techniques including immersive experiences such as the preservation hall, traditional museum display, tours and practical workshops that include basket making and plant and flower identification (S Wilson 2019 personal communication 8 February). Archived palaeoenvironmental remains could routinely be included in tours to demonstrate evidence-based examples of preserved remains and explain the role that these items have in the interpretation of ancient environments. The existing museum space in the old visitor centre could be furnished with at least one high powered and one low powered microscope that could facilitate the examination of samples. Dedicated palaeoenvironmental archaeology workshops that handle and use archived samples could be established and included in tours of the park, providing recourse to observe and situate them in their ecological context.

An area in which Flag Fen suffers in its suitability to provide optimal conditions for nationalised storage, is its ability to provide specialist archaeological staff or specialist equipment already on site that could deal with the conservation needs of palaeoenvironmental items. Ideally, there would need to be the presence of an archaeologist with experience of environmental archaeology and conservation who would attend the facility at least once a week to check the facility and handle any researcher requests for access. Other duties would include dispatching samples to regional museums for display and to provide access for local researchers.

Fort Cumberland

Fort Cumberland is located on the south coast in Eastney, Portsmouth. Fort Cumberland is a decommissioned artillery fort which was built in the 18th century to strengthen the defensive capacity of England's south coast (Saunders 1966). The 1747 fort was demolished and built over by the current version, with building lasting from 1782 to 1812. Since its completion in 1812, the fort has received many phases of renovation, rearmament, and reorganisation (Flintham 2011). Fort Cumberland has been the site of Historic England's and English Heritage's laboratory focus since 1998, when the Ancient Monument Laboratory was moved from Fortress House, London (National Archives 2005) and many of the specialist staff and heads of department were relocated. Consequently, the fort possesses a roster of leading specialists and the equipment required to analyse, conserve and curate archaeological palaeoenvironmental remains (Fairnell *et.al.* 2020; Historic England 2011; Historic England 2018b).

Fort Cumberland now accommodates part of the Historic England Investigative Science Team. This includes specialisms and services such as material science specialists, geophysicists, archaeological conservation scientists, and environmental archaeologists. The environmental archaeology team comprises seven team members that specialise in and offer advice for a wide range of archaeological palaeoenvironmental remains. In addition to the in-house skills, the team are equipped with microscopes and reference collections. The zooarchaeological collection contains over 3,470 specimens and owing to the ongoing preparation of recently deceased specimens, continues to grow. This collection is actively monitored and is often degreased and cleaned. The reference collection is used by the in-house specialists and is accessed by external visitors wanting to take measurements, photographs, and record the material. Specimens from the collection were also dispatched to museums for display and research by researchers in academic institutions (Fairnell *et al.* 2019).

Other relevant scientific services based at Fort Cumberland include archaeological conservation facilities. The specialist archaeological conservators work on a range of archaeological materials including waterlogged artefacts and palaeoenvironmental remains. Services offered by the archaeological conservationists include the vacuum freeze drying of waterlogged remains. A casemate – vaulted rooms that were used during the military occupation of the fort for multiple purposes including the storage of provisions and the accommodation of service personnel – have been fitted with tanks that can be used for the impregnation of wood with polyethylene glycol prior to freeze drying. Having the specialist skills, facilities, and capacity to conserve palaeoenvironmental remains positions Fort Cumberland as a strong contender for a national storage facility.

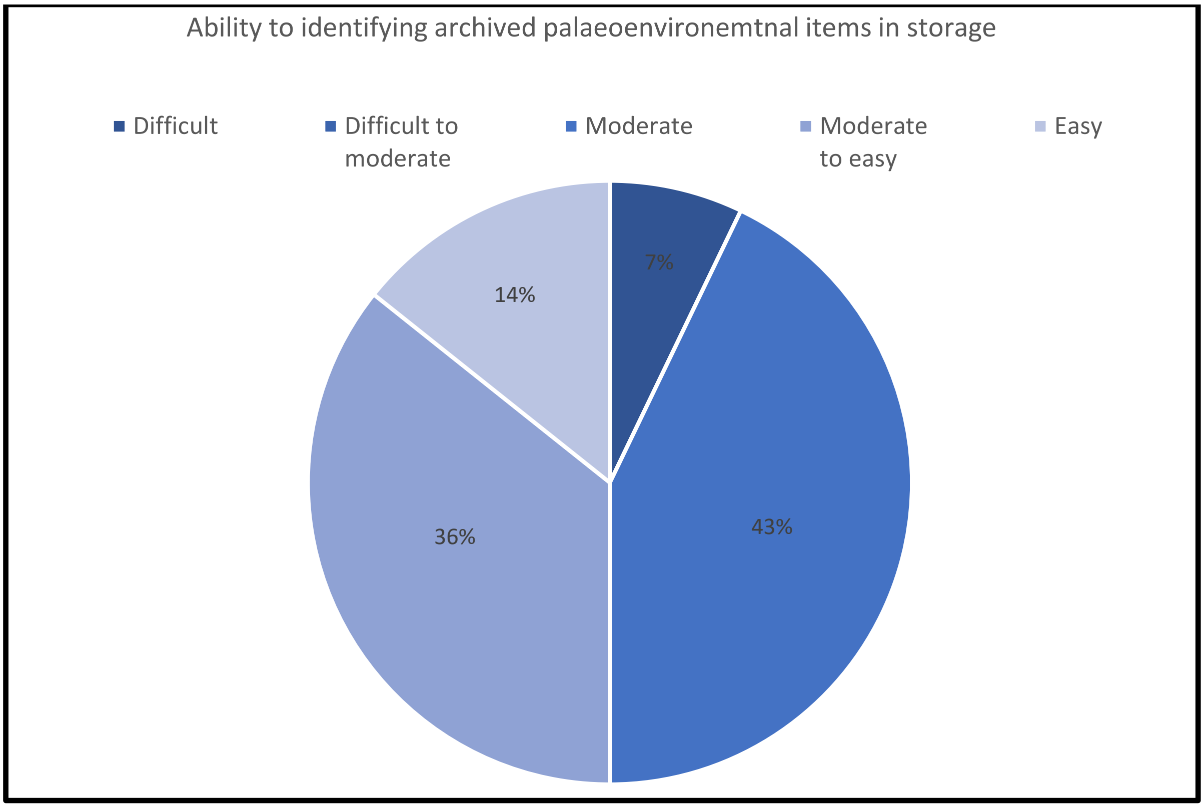
An additional service catered for at Fort Cumberland that further makes it conducive for the development of a national repository of palaeoenvironmental archives, is the archaeological archive specialists who are based on site. Standards for archiving are devised and managed by the team at Fort Cumberland who also provide up to date archiving advice for all members of the archaeological community. Having an innovative team with knowledge and expertise regarding archiving practice will ensure that palaeoenvironmental collections are curated to high standards.

An area in which Fort Cumberland is less suitable for the needs of a national storage is its limited public access, and its location on the south coast, arguably making it less suitable than a more geographically centrally located store. Researchers that require to access Historic England expertise, facilities or equipment and reference collection can visit by appointment. Similarly, to museums, researchers from academic institutions and commercial organisations can make appointments to visit the fort sporadically to consult reference collections, receive consultation and use equipment. This would allow researchers to access the archives and collections but in comparison to Flag Fen, which offers year-round opportunities for lifelong learning and daily school visits, does not demonstrate the same degree of public access and articulation through pre-existing educational packages. The value that having non-specialist access to specialist archives is explored further in Chapter Eight.

Another area where Fort Cumberland may struggle to provide the necessary attributes is in establishing available space for the development of the required controlled environments to store the full range of palaeoenvironmental remains. The two immediate solutions could be provided through the installation of chilled portable containers or by the remodelling of existing ancillary building, although given the status of scheduled ancient monument makes Fort Cumberland an unrealistic candidate. Ancillary buildings would require significant alteration to allow them to provide sealed and stable environments suitable for storage at different temperatures and free of temperature and humidity fluctuations. This could be achieved through two routes, installing self-contained controlled temperature units or by adapting the existing buildings to better manage palaeoenvironmental archives. Solar panels could be installed to generate renewable and inexpensive electricity required to power equipment such as dehumidifiers, cold stores. The scheduled ancient monument designation and listed status of Fort Cumberland may prevent the fabric of some of the buildings from being altered and consequently prevent ancillary buildings from being used.

Appraising Archaeological Palaeoenvironmental Archives - An Assessment of the Archaeological Palaeoenvironmental Archives at the Southwest Heritage Trust Archive Facility, Taunton, Somerset

The previous section identifies some solutions to the challenges associated with the storage of palaeoenvironmental remains. The solutions offered, such as developing a new dedicated repository for the curation of palaeoenvironmental archives, is an optimal solution but suffers from being expensive and, if ratified, would take years to bring to fruition. An option that would have less costs and could be achieved in a shorter time frame is an archive appraisal. Archive appraisals can harmonize archive quality, help to devise conservation plans, and enhance the quality of catalogues and accessible digital data. An archive appraisal is defined as a value-led review of items curated in a museum or repository. An archive appraisals methodology is proposed (detailed in appendix II), which is similar to that currently employed by the Dutch cultural heritage agency – *Assessing Museum Collections: Collection Valuation in Six Steps,* which was informed by the results of the Delta Plan Project for Cultural Heritage in the Netherlands and revealed how useful audits can be in exposing what resources exist with museums stores and highlight what items may require attention to support their ongoing conservation (Rijksdienst voor het Cultureel Erfgoed, 2014). The Delta Plan audit was the outcome of the 1991 court of Audit which concluded that two thirds of archaeological archive storage conditions were inappropriate and archaeological material was being dealt with in an inconsistent fashion and required improvement (Bruin 2004). The audits that were conducted as part of the court of audit and the Delta Plan were far more general in scope than the *Assessing Museum Collections: Collection Valuation in Six Steps*. The audits were not as reliant on the value and question-led approach but were operated as scoping exercises to coarsely determine if anything could be deselected and identify if any items were at risk from decay (Talley Jr 1999). This section of the chapter applies a similar model to the Delta Plan audit and commits to a scoping scheme that can inform a formal method of appraisal. To achieve this, an archive audit of the Southwest Heritage Trust Archive Facility, Taunton, Somerset was conducted to develop a prescriptive system of appraisal for archaeological palaeoenvironmental archives. The following archive audit aims to understand how searchable and findable palaeoenvironmental items are in archaeological archive repositories and determine how factors such as research potential, physical condition and conservation plans can be appraised. Collection management systems are used to locate items in storage but many of these are either not up to date or not easy to navigate. The museum partners were asked to grade how navigable their collections management software is on a five-point scale from easy to difficult (graph 4).



Graph 4. The 14 museum partners were asked about their ability to be able to locate specific items within their store. They were provided with five options ranging from easy to difficult.

Of the museum partners, only 14% of the respondents regard their digital catalogue allowing for archived remains to be easily located. Other challenges include backlogs in adding archived remains to catalogues. Using the museum responses as an indicator of museum's ability to commit to updating catalogues, three of the 14 stated that they do not have a backlog, with the remaining 11 responding that they have a backlog that ranges between a month's worth of accepted archive to update and up to 20 years' worth of archaeological archives. These results indicate that using a museum's catalogue to determine what exists in store may be unreliable and requires a physical search through the archived remains to genuinely appreciate what exists within the store and what potential and value archaeological palaeoenvironmental archives have.

To conduct the audit, the Somerset Heritage Centre, Taunton, Somerset was chosen given the rich history of research that has focused on waterlogged sediments in the region. The curator was able to facilitate the audit and the team that were based in the Somerset Historic Environment Record (HER), which is in the same building as the archive repository, were also able to participate. A broad approach to the audit was taken to determine what challenges can slow down or prevent formal archive appraisals that set out to define conservation plans, condition audits and update research agendas. This general approach conflicts with the more established methods of archive and museum collection appraisals that involve value-led staged methods that use specifically designed research questions to interrogate a repository's content and ascertains how well individual items can satisfy the questions, but these methods prove to be unsuitable for archaeological palaeoenvironmental archives in England. This audit was undertaken using an excel spreadsheet that records all available data encountered during the physical audit and will act as a preliminary project that can inform a methodology for formal palaeoenvironmental appraisal. A recommended methodology for formal archives appraisal has been informed by the outcomes of the Somerset audit.

The South West Heritage Trust Archive Facility, Taunton, Somerset

The archaeological palaeoenvironmental archives examined as part of this survey are owned by Somerset County Council/Somerset Archaeological and Natural History Society (SANHS) and Glastonbury Antiquarian Society, managed by the South West Heritage Trust, and curated in the Somerset Heritage Centre, Taunton, Somerset. The initial consultation visit occurred on the 2nd of October 2018 and was followed by a repeat visit part way through the retrieval stage on the 19th of December 2018. The Review was conducted from the 5th to the 13th of March 2019. The South West Heritage Trust archives were selected for this case study due to the curatorial team's ability to provide access to the entire archaeological palaeoenvironmental collection. Such access was made possible because of a combination of their own location audit - which occurred over the winter of 2018 and the spring of 2019 – with support from the curatorial team. Additionally, the Somerset Historic Environment Record (HER) being in the same building as the archived remains was also advantageous, because corresponding site reports and publications were easily accessible. An additional convenience of the organisational proximity was that the dialogue between HER and curatorial staff was much more fluid and assisted with better navigation of the archives and the corresponding reports and publications.

Contacting the museum as early as possible is recommended as access can take up to three months to organise. The Somerset Heritage centre is typical of many other archive repositories in that staff workload is high and it can take extended periods for researchers to achieve access to archived remains. Once access was achieved, the curator provided a tour of the store and provided a space with which to closely examine a selection of archives. After meeting on several visits, the curator allowed me unsupervised access to the palaeoenvironmental archive. The rationale for the decision is outlined below.

> *Because I had met you several times before, I was relatively happy to leave you alone in the store for periods of time (having decided that you were trustworthy or at least more*

interested in mud/grain/charcoal than anything shiny!). However, I would not have been prepared to leave someone I had not met before alone in the stores as it is too much of a security risk. I would have found it difficult to stay in the store with you for the whole period of your visit as there were certain tasks that I could not do from the stores. Other museum curators are also likely to be concerned about security.

The curatorial team offered to retrieve the palaeoenvironmental components of archaeological archives and store them in a separate part of the heritage centre's store to allow them to be audited. Except for large mammal and bird remains, all archived palaeoenvironmental remains are regarded as being relevant to the project. To ensure that this concept was sufficiently expressed to the curatorial team, a list of relevant materials for selection was provided. The list included pollen, diatoms, charred plant remains, charcoal, wood, soil samples and molluscs. Beyond the scope of the list, the curatorial team operated under a 'if unsure retrieve it' policy. The 'unsure' items were checked during occasional visits to help with the retrieval. No errors in curatorial decision making were identified.

Every archaeological archive that includes a palaeoenvironmental component was collected from the county of Somerset (excluding North Somerset unitary authority). North Somerset was not included in the study due to time constraints.

The archaeological palaeoenvironmental archives retrieved from the store include *c*.760 samples from *c*. 90 archaeological investigations. A great amount of variation in quantities of remains existed between site archives, with some of the boxes containing little material such as Bradley Hill, compared to the Meare Lake Villages which produced high quantities of biological material. In total, the repository contains *c*.1900 archaeological archives, indicating that approximately 4.74% of sites in the Somerset archaeological collection contain palaeoenvironmental remains.

Results of the audit of archaeological palaeoenvironmental archives

Archive retrieval began on the 15th of December 2018. This ambitious plan - which I am grateful to the South West Heritage Trust curatorial team in bringing to fruition – involved retrieving all archives which contain palaeoenvironmental remains and depositing them in a separate part of the store. Fortuitously, the curatorial team were conducting a location audit across the entire archaeological collection during the winter of 2018 and the spring of 2019. The Trust secured a small amount of funding to allow for a small team of additional staff to undertake the audit. The audit involved a detailed review of the catalogue against physical remains in archive boxes and re-locating certain boxes to freshly organised locations. During the location audit the team removed all boxes which contained any archaeological palaeoenvironmental remains and deposited them in a separate area within the store. A quote from the curator regarding location audits methodology is included below.

> *We searched through the store box by box and pulled out the relevant material and then used the collections database to find the accession number, site name, civil parish, and date of fieldwork if this was not clear from the box. I also found the HER number on the collections database and then searched on the HER to identify relevant information/reports.*

The location audit was assisted by the knowledge of the current curator, Amal Khreisheh and the previous curator, Steve Minnitt, which proved invaluable in identifying legacy archives that contained palaeoenvironmental remains, especially excavations such as the Meare and Glastonbury Lake Villages. Their knowledge of the store's content proved especially valuable, given that the collections management systems struggled to locate the palaeoenvironmental components. A quote regarding the collections database from the current curator is included below.

> *"None of the archaeological archives had up-to-date storage locations so it was impossible to use the collections database to locate things. Also, most archaeological archives only have a global record on our collections database, or a global record and individual records for just the small finds. This meant that palaeoenvironmental material did not show up in a collections database search, so, the only way to locate the material was to go through the store box by box. Older archives do not seem to be labelled with their contents so you actually have to look in each box to find out what was inside."* (A Khreisheh 2018 personal communication 2 October)

Once retrieved from the rest of the archives, it was revealed that *c.*714 samples from 81 sites contained palaeoenvironmental remains. The extracted palaeoenvironmental components required approximately 4m³ of space which was identified in the main store. A rough equation to calculate necessary space could be calculated by dividing the number of samples by the storage capacity. In this instance there were approximately 760 samples, and when divided by the 4m³, it suggests that 1m³ is required for every 178 samples. This model is obviously approximate as it can depend on the size of the samples but may serve in providing future appraisals with a quantification regarding space requirements for a full assessment. The rough quantification of 25 samples for every $1m^3$ can be offered as an approximate indication of space requirement. The space required per metre could be reduced if items were transferred into correct packaging.

Regarding time management, the retrieval stage took approximately 16 person days. The factors that influence the time required to conduct the archive retrieval include the completeness of the cataloguing system and the curator's familiarity with the store. In the example of archives managed by the South West Heritage Trust, the collections management system was not capable in locating the palaeoenvironmental components of archives and the location audit was therefore essential in locating all relevant archived remains. Unless a curator has complete confidence in their catalogue and the store's contents, future appraisals should consider a box-by-box location audit to retrieve all the desired items.

Retrieving Contextual Data

Once the archives were accumulated, the physical assessment could begin. The physical assessment commenced in mid-March 2019. The results of the assessment were entered onto the paper pro-forma. On reflection, this process could be streamlined by entering the data straight into the database using a tablet using picklists in excel. This would make the process of data collection and databasing much simpler and would not require data entry tasks to be repeated. On the first day of the appraisal, however, it was noted that the wireless internet did not work in all areas of the store. If the assessment forms were expected to be filled out on an online server such as Google Docs, intermittent internet signal may prohibit this. It is recommended that using an excel/word version stored on an electronic device will avoid such issues from preventing progress.

The assessment involved a detailed inspection of each archive box, followed by the recording of details on each bag or accompanying paper record within the archive box. In addition to the project name and site code, the year of excavation and phase of work, context and sample number were identified. Surprisingly, the assessment revealed that of the 81 sites, 45% did not have data that could *readily* link the individual items to specific contexts. This high figure could be the result of the legacy of excavations that focused on waterlogged sediments in the first half of the 20th century. Formal methods of recording such as the single context system of recording that is ubiquitous in Britain today, were not employed for excavations prior to the 1970s with excavators relying on textual descriptions (Carver 2012). For example, unprocessed soil samples from the 1936 Meare Lake Village East Field No. 3 excavations do not have context and sample numbers, having descriptions such as ‘mound 15C Clay floor continuous with 15B’. This information proved sufficient to cross reference with the excavation report and, with some confidence, re-contextualise the sample. It is therefore vital that as much detail as can be found with the physical remains is recorded at this stage to allow for the item to be traced to its context. If information is being gathered to update or strengthen a collection’s management software or determine how archived remains can complement a research strategy, it is particularly important that any additional information regarding a description of the context that can be gleaned from accompanying information should also be added. Such data may prove vital in provenancing samples.

Assessment to devise a Conservation Plan

The assessment revealed multiple indicators that can be used to develop a conservation plan specific to the Somerset Heritage Centre. The assessment revealed that no wet legacy archives were present in the accumulated archives. This reduces the need to install the necessary facilities required to store and curate existing waterlogged remains. The Somerset Heritage Centre’s collection policy states that it will not collect wet archives (South West Heritage Trust 2017) and if this policy is maintained, there will be no need to install facilities. Should the museum service wish to change its policy and accept waterlogged remains, they would need to source the correct equipment to maintain the correct environment.

The assessment concluded that of the dry palaeoenvironmental archives, *c.*314 of the *c.*714 (44%) samples do not contain charred plant remains. For the non-botanical remains such as shell and soil samples, the controlled environments within the store are between 18°C and 24°C and 40% and 60% RH.

A minor, but potentially significant beneficial addition to the museum’s conservation capacity, is a fridge-freezer. As demonstrated by practices in natural history collecting, genetic and isotopic information has been shown to degrade in when not stored at chilled or frozen temperatures. If genetic and isotopic materials in dry archaeological palaeoenvironmental archives are demonstrated as being at risk of decay if they are not stored at sub-zero conditions, there is a substantial risk that, should an assemblage be analysed and returned to an environment that hastens decay, its future reanalysis will return different values. Additional research into the survival of palaeoenvironmental remains is necessary to determine if genetic and isotopic materials in archaeological palaeoenvironmental remains behave similarly to recently collected specimen (Burrell 2015). Should future research conclude that internal features in palaeoenvironmental materials are susceptible to decay unless chilled or frozen, fridges and freezers may be required to store samples from an assemblage that have been sub-sampled for isotopic or genetic research or have been subjected to a non-destructive analysis. This will ensure that degradation caused by incorrect storage does not hamper future attempts to re-test or reanalyse the materials.

Regarding the containers and packaging, the Somerset audit revealed a great deal of variability. For example, the charred plant remains, shell and wood charcoal recovered from Cannards Grave (Museum Accession Number TTNCM 6/2017), Shepton Mallet (Museum Accession Number TTNCM: 31/2000) and Brean Down (Museum Accession Number TTNCM 123/1997), are maintained in glass and plastic and can be regarded as of acceptable condition, whereas the wood charcoal collected from Cannington Cemetery (Museum Accession Number TTNCM 134/1994), is stored in paper bags and requires critical attention. The variability present in the quality of storage containers in the Somerset store requires attention to bring them up to an acceptable standard.

A conservation assessment would require a detailed itemised inventory of each item to understand space requirements and what the controlled environment requirements are likely to be. In addition to the itemised inventory of archived remains, the containers and their quality should also be recorded. To take a detailed inventory of each sample to determine the quality and suitability of each container, it is estimated that a collection of archives this large would take between eight to ten days.

Assessment to identify missing materials items

Each of the archive boxes were examined to identify if items were missing. The assessment revealed that ten of the 81 sites (12%) of the site archives did not contain the palaeoenvironmental component that is listed in the report. The sites that have missing samples are listed below:

Bowden Reservoir Pipeline (Museum Accession Numbers TTNCM 182/1992 and TTNCM 183/1992

Cannington Court, Cannington (Museum Accession Numbers TTNCM 29/2012)

Great Yard Illchester (HER PRN: 28943)

Heritage Court, Glastonbury (Museum Accession Numbers TTNCM 104/201)

Longforth Farm, Wellington (Museum Accession Numbers TTNCM 90/2012)

M5 Junction 24 (Museum Accession Numbers TTNCM 10/2011)

Nerrols Farm, Cheddon (Museum Accession Numbers TTNCM 37/1999 TTNCM 86/1993)

Northover Cemetery (TTNCM 80/1988)

RNAS Yeovilton (Museum Accession Numbers TTNCM 67/2016 TTNCM 89/2012 TTNCM 161/2000)

Shepton Mallet (Museum Accession Numbers TTNCM 31/2000)

In two of these cases, the flots were present but the processed remains listed have not been deposited. The remains were not kept with the main flot. There is no record of these samples being lent to an individual or an institution, which strongly indicates that they were not deposited with the rest of the archive and were likely retained by the specialist. As expressed in the Historic England Environmental Archaeology guidance, there are legitimate occasions where a specialist may wish to retain certain samples, but this should only occur when the owner, project manager, and museum curator have been informed and agree on this. Where possible, efforts to try and reunite these samples with the rest of the archive should be made. Individual museums can make appeals to the specialists that they know have retained samples, or, alternatively, there could be a national amnesty through organisations such as the AEA.

Assessment to Determine Research Potential

One objective of the assessment was to determine if and how the Somerset Heritage Centre archaeological archives could contribute towards discrete research questions and larger regional or national research strategies. An appraisal with a similar remit is the York Museums Trust (YMT) *Old Collections, New Questions: Researching the Roman Collections of the Yorkshire Museum*, which successfully used a staged approach to determine the research potential of the Trust's Roman collections (Tilley 2018). In the *Old Collections, New Questions* example, a collections audit was required to ensure that ADLIB, the collections management system, was sufficiently up to date. The questions used to determine research value derived from a wide range of research projects conducted over a 50-year period. *Old Collections, New Questions* identified 20 new projects that the material can contribute towards. Palaeoenvironmental remains were not considered in this project.

To determine if the archived palaeoenvironmental remains could contribute towards research questions, two questions from the Southwest regional research framework have been selected (Grove & Croft 2012). Once the assessment of the archives was complete and all information from the catalogue and the paperwork and information on the bags that accompanied the physical remains was harvested, it was possible to consult the reports and publications to extract taxonomic and dating information. Due to the sometimes-fragmentary nature of the available contextual data, it is recommended that the documentary search is completed after the physical assessment, as this will reveal a realistic view of what exists in the archives and what level of information is available. The search through the site reports and publications to collect geospatial information, interpretative data and taxonomic data required visits to the local HER and libraries to collect and copy relevant site reports and publications. Finding the corresponding reports was streamlined using the accompanying HER number which can be used in the HER to identify the accompanying paper archive. The search through the HER to find and copy the relevant reports took approximately 3 days. The HER team were incredibly supportive and assisted with navigating the library.

With regards to the quality of data, there was a clear link between when the fieldwork was conducted, with older sites either demonstrating incomplete supporting evidence or being difficult to navigate when compared to records from more recent field investigations. Items from some of the older sites took more effort to securely provenance to the correct context. The excavations in Lamyatt Beacon, for example, were conducted in 1958-1960 and produced seven bags of wood charcoal each of which contain a sample or context number, but these numbers do not correspond to any numbers in the report. Sites through the 1970s and 1980s such as 5-8 Fore Street, Taunton and Blackmoor Swallet respectively were found to suffer from a similar failing in inconsistent reporting and contextual detail. Once the data had been recovered from the original reports and each item was provided with contextual and geospatial data, two questions from the South West Archaeological Research Framework (SWARF 2022) were selected to determine if the archived remains could offer useful contributions to answer them.

> Question one – *21b – "Better understanding is needed of how the process of agricultural intensification can be detected on archaeological sites. Better use of the evidence should be made by integrating environmental and artefactual evidence to test theory, coupled with comprehensive dating programmes. For example, better understanding of the development of field systems and increase in arable between c.2000 and 1500 BC remains important."* (SWARF 2022 - Question 21b https://researchframeworks.org/swarf/a-research-agenda-for-archaeology-in-south-west-england/#section-98)

This research theme could be addressed by the Wick Lane, Norton Fitzwarren, assemblage. The Norton Fitzwarren assemblage was recovered during the 2006 excavations that were conducted by Cotswold Archaeology (Alexander and Adam 2011). The excavation revealed a ditch containing emmer/spelt grain and wheat grain that remains undated and two Collared Urns which date to

1870-1600 BC and a host of charred plant remains including *Galium* spp. (Cleavers), spelt wheat, wheat grain, cultivated oats, indeterminate cereals, hazelnuts, corn cockle seeds and small seeded grass (Alexander and Adam 2012). Materials from the undated ditch could be dated to determine if the feature is Bronze Age and then establish if it relates to the establishment of field boundaries in the Bronze Age. Additionally, the spelt could be re-examined on account of the early date. Spelt from Monkton Road, Thanet, Kent dates to 1890-1690 BC and is considered one of the earliest examples of spelt in England and the examination of the Wick Lane example could contribute towards an understanding of agricultural intensification (Archaeology South-East, 2007).

> Question two – *27a - Despite this being a priority for archaeobotany for many years, when, where and how the change from cultivation of hulled to free-threshing wheats took place is still not understood. This major change which will have affected husbandry and crop-processing practices occurred sometime in the centuries covering the late/post-Roman–Early Medieval periods. Efforts must be made to target suitable assemblages.* (SWARF 2022 - Question 27a https://researchframeworks.org/swarf/a-research-agenda-for-archaeology-in-south-west-england/#section-98)

Free threshing wheat was identified in site archives from late Roman and early medieval contexts at the Ilchester to Barrington Pipeline (excavated 2006), Northover cemetery, Ilchester (excavated 2008) and Great Yard, Ilchester (excavated 1995). The Ilchester to Barrington Pipeline archive also contains hulled barley which dates to AD 500-640 (Brett *et al.* 2009). Ilchester makes for a well-defined study area as it is well researched and the Roman and early medieval occupation is well understood (Richardson 2002). The wheat seeds from these three sites could be incorporated in a multi-proxy analysis that include crop stable isotope analysis, functional weed ecology and quantitative archaeobotanical analysis (Hamerow *et al.* 2020). This would require additional work that would involve a survey of the modern plant ecology in the Ilchester environs and stable isotope analysis of the archived seeds to determine $\delta 13C$ and $\delta 15N$ values. The results could contribute towards an understanding of the reasons that supported the adoption of the cultivation of free threshing wheats.

Regrettably, two of these sites, Great Yard, Ilchester and Northover cemetery, Ilchester are two of the archives that are missing, presumably retained by the specialist. This demonstrates that in the example of the Somerset Heritage Centre, there are missing palaeoenvironmental archives that have potential to contribute to regional research. If scaled up to other museums, specialist retaining archives could represent a significant challenge.

Assessment to Improve Catalogue Quality

As stated by the curator at the Somerset Heritage Centre, the collections catalogue does not provide sufficient detail that can locate archived palaeoenvironmental items within the store. Deficiencies in both analogue and digital data in reports and catalogues can prevent researchers from gaining access to archaeological palaeoenvironmental archives (Lodwick 2019a; Stewart et al. 2013; Lejeune 2007; Jarman *et al.* 2019). The absence of available data can suppress the use and reuse of the archived palaeoenvironmental resource and deter researchers from doing archive-based research (Childs and Benden 2018; Swain 2003). The current catalogue contains universal conceptual values, such as contextual domains, that do not relate to the needs of individual assemblages (Huggett 2018; Cooper and Green 2016). Idiosyncratic domains focused towards palaeoenvironmental remains and the needs of specialists such as type of material, morphological information, scientific dating data, quantification of items in an assemblage, associated geospatial data, and taxonomic information, could be used to promote materials to users and enhance occurrences of use for display and reuse in novel research. In addition to the domains required to locate and analyse associated digital data, there are also national and international standards of digital data handling such as FAIR (Findability, Accessibility, Interoperability and Reusability) principles and Historic England's HIAS (Heritage Information Access Strategy) that need to be considered (Wilkinson *et al.* 2016: Historic England 2021).

Whilst conducting the assessment, it became apparent early in the process that well-defined domains need to be formulated to appropriately focus the audit. Furthermore, details cannot be identified from the items themselves, and reports and publications would need to be consulted to provide details regarding interpretations, taxonomic information, and co-ordinates. This topic was revealed as being complex and difficult to audit without much greater consideration. Therefore, Chapter Six is dedicated to understanding how cataloguing and the digital representations of archived remains can be improved.

Physical Condition audit

The Somerset audit revealed that there are two basic tiers of condition audit that can be conducted: the non-specialist review and the specialist review. The non-specialist review requires an examination of general evidence of condition such as cracking, evidence of mould, post accession collapse or drying out, and evidence of pest activity. These conspicuous factors can be observed using published guides and reports that highlight the effects of damage and degradation.

Specialist reviews require omit more detailed attributes that may be less noticeable to an untrained eye. For example, an audit that can assess the condition of charred cereal remains for stable isotope analysis would require an examination of cross sections of oat and rye to determine factors related to the temperatures that the seeds were exposed to during charring (Vaiglova *et al.* 2022). In this example, the external features cannot provide enough details. Contrary to this is analysis of charred plant remains for morphometric analysis, which require complete external features required for precise measurements (Portillo *et al.* 2020).

These examples simultaneously demonstrate the importance of having aims that are well defined in advance of the assessment and that the anatomical factors required to determine suitability for analysis are intricate and require the input of specialist knowledge and the necessary equipment required to conduct the analysis such as a high-powered microscope. Consequently, specialists would be best placed to conduct condition audits but if funding or staff availability prevent the full-time participation of a specialist, they should at very least be heavily involved in a consulting role. The condition audit also highlights the importance of specialists to include the physical condition of remains in assessment and analysis reports. This will ensure that this information is available upon deposition with the museum.

Chapter Summary

As highlighted in Chapter Three, storage capacity and consistency amongst standards is a challenge, resulting in undeposited palaeoenvironmental archives that are not being effectively managed, and deposited archives being stored in variable conditions. The options of either a regional system, similar to those in the Netherlands, and a national centre similar to an ESB have been explored as potential solutions to the challenges experienced across England. There is also the option of bringing museums into standardised parity by undertaking archive audits.

As highlighted in Chapters Two and Five, specialised centres that houses palaeoenvironmental remains, would ensure that undeposited materials can be made available for public science outreach and research in perpetuity. As indicated by the survey, museum curators would not mind palaeoenvironmental components leaving the region and being stored elsewhere. The Dutch case study demonstrated that having fewer, larger repositories would prove beneficial for the curation of palaeoenvironmental remains, given that more focused control could be offered to the remains and reduces the risk to a region becoming underfunded and not being able to provide the necessary tools and facilities. Although a likely expensive option, a single archaeological archive repository may be the best option for archaeological palaeoenvironmental remains. In the examples of Flag Fen and Fort Cumberland as potential national centres examined, numerous pros and cons emerged. Having the skilled staff and specialist tools and facilities on site is important, but so too is the location of the site. Furthermore, the two examples – selected due to them having skills and staff – are both scheduled ancient monuments, and present complications relating to developments of environmentally controlled stores. Finally, and perhaps most notably, are the challenges associated with the identifying funding to develop a specialist facility as well as the revenue streams to ensure maintenance.

A more cost-effective measure could be the auditing of the palaeoenvironmental components of archaeological archives. Audits could bring a museum's collection of archives up to standards that would ensure continuing conservation of the archived palaeoenvironmental resource. Using a methodology approved by organisations including Historic England and the Society for Museum Archaeology, will allow for repeatable audits that can bring archives into a standardised parity.

With regards to the curation of waterlogged palaeoenvironmental materials, there are clearly no prescriptive outcome that determine whether remains should be maintained in their wet state or dried. The decisions that support whether items should be maintained or dried comes down to factors such as rarity, individual potential for enduring research, how the materials satisfy research aims, and, crucially, the local repository's ability to accept wet archives. This former point is ostensibly preventing the option of conserving waterlogged in a wet state. A specialised central repository a section dedicated to wet archives that has built-in expertise and facilities could allow for the collection and long-term storage of waterlogged remains.

Chapter Six – Access, Discoverability, and Interoperability of Archaeological Palaeoenvironmental Archives.

Introduction

The value of an archaeological archive depends on user awareness of its existence and how readily it can be accessed and used. Researchers have reported challenges accessing specialised archives and collections (Dooley *et al.* 2013). These challenges loom large for researchers requiring access to palaeoenvironmental remains (Jarman *et al.* 2019; Lodwick 2016). Deficiencies can characterise these challenges in both analogue and digital data in reports, specialist databases and museums resources, all of which are recognised venues expected to indicate the location and quantities of archived remains and supporting rationales for long-term storage (Lodwick 2019a; Stewart *et al.* 2013; Lejeune 2007; Jarman *et al.* 2019). The absence of sufficient data can stifle opportunities to use and reuse the archived palaeoenvironmental resource, potentially dissuading researchers from committing to archive-based research (Childs and Benden 2018; Swain 2003).

Furthermore, unlike practices in natural history museums, the necessity to include links to fossil remains as a measure to ensure repeatability and re-testability is absent (Meineke *et al.* 2018). To determine which of the available options could be most effective to store, share, and link data, this chapter (Chapter Six) assesses the various tools, platforms, and institutional practices to ascertain which could be supplemented to include comprehensive datasets and encourage open access sharing. By means of establishing the most effective methods that can best serve researchers, the following aims will be pursued:

- Examine the current platforms and tools and determine how/if they can be augmented to provide enhanced data storage and sharing capacity levels.
- Determine if access to archived palaeoenvironmental archives and interoperability between archives can be improved.
- Establish how digitised archaeological palaeoenvironmental archive data can be made more widely available for transdisciplinary engagement.
- Discover appropriate methods that can encourage use and reuse.
- Find suitable methods of storing and sharing data consistent with the Historic England Heritage Information Access Strategy (HIAS).
- Identify ways of encouraging and facilitating researchers, including those at undergraduate, Masters, PhD level and post-doctoral levels, as appropriate to consider ways of using existing archives rather than if new research requires new samples.

Regrettably, insufficient data has created challenges for archive-led research in general, but archaeological palaeoenvironmental remains have inherent challenges and opportunities. Opportunities, for example, lie in the developments in data sharing and semantic web technologies and their ability to artificially situate biological items back into the feedback-driven ecosystem through the use of diversely recorded data and proxies (Bowman *et al.* 2015; Ware *et al.* 2019). These opportunities are being exploited in adjacent sciences that use natural history biological data and bio-collections that can be cross-referenced using digital tools, which allow for interdisciplinary working and open access reuse of data (LeFebvre *et al.* 2019; Huggett 2017). Additionally, methods of sharing and interrogating multiple datasets are being propelled by FAIR (Findability, Accessibility, Interoperability and Reusability) principles (Wilkinson *et al.* 2016) that have revitalised natural history and biodiversity science collections by linking museums, herbaria, and laboratory bio-collection data (Webster 2017; Soltis and Soltis 2016; Nelson and Ellis 2018; Lendemer *et al.* 2020)

To glean how these challenges and opportunities can be augmented or improved to benefit researcher experience and encourage reuse, this chapter takes the opportunity to review how palaeoenvironmental archives are made accessible and interoperable. The platforms, organisations and institutes assessed will include HERs, the ADS and OASIS and resources hosted by museums such as CIDOC CRM and online catalogues/databases. The assessment will firstly consider the appropriateness of the available resources through criteria that meet FAIR principles, secondly enable the use and reuse, and thirdly meet the Historic England Heritage Information Access Strategy (Wilkinson *et al.* 2016; Carlisle and Lee 2016; Huggett 2018). These will be compared to natural history museum practices to highlight which institutions and tools can best serve researchers and effectively enable use and reuse of the archived palaeoenvironmental resource. Noticeably absent from these platforms and finding aids are regional and research specific research frameworks. These have been given dedicated focus in the following chapter.

Use and Reuse

To determine the effectiveness of the tools and digital platforms that provide data relating to stored palaeoenvironmental remains, a range of available technologies, philosophical principles and the institutions that facilitate the storage and sharing of data will be analysed through a lens of how sharing facilities enable use and reuse (Bauer-Clapp and Kirakosian 2017). Use and reuse is a commonly referenced purpose of developing digital methods of data banking and dissemination (McManamon 2018). Remarkably, what constitutes and differentiates use and reuse of data has rarely been scrutinised (Faniel *et al.* 2018). Huggett (2018) provides a rare example that defines the use of data as the utilisation of collected data to be analysed in a way that the author or collector understood its long-term use to be at the point of collection. In the context of archived remains, use, as defined by Huggett, could represent an accession number. Accession and box numbers are signifiers that remain constant in their form and purpose irrespective of technological change and can be used in the way intended for decades. Reuse is the secondary use of the data, which was not intended by the collector/author (Huggett 2018). Secondary use could entail using different technology to process the digitised data or using the physical remains in analyses beyond the scope of the intended project. This chapter adopts Huggett's definition of use and reuse throughout.

Users

Data storage and sharing services are expected to serve the domain of environmental archaeology and will naturally attract users from within that domain (Beck and Neylon 2012). Environmental archaeologists should, therefore, primarily be treated as the most common users. Although environmental archaeologists are expected to be the most frequent users of archaeological palaeoenvironmental data, it seems sensible to consider a more inclusive use that extends beyond the domain, given the contemporary prevailing philosophy regarding sharing data leans towards open access (Taylor 2016). Furthermore, palaeoenvironmental archives are directly relevant to researchers in biology concerned with the history of plant and animal communities etc. Therefore, the term 'researcher', used throughout this chapter, is applied in the broadest term and relates to any person who may wish to engage with archived physical remains for the comprehensive purposes of 'research'.

Chapter Six also explores how an archive-led data-sharing resource can broaden the users and include researchers and scientists from outside of the domain of archaeology (Amand *et al.* 2020). For example, sharing and interoperability could be achieved by semantic web technologies, currently regarded as being at their peak in what they can achieve (Patel and Jain 2019). These technologies, combined with shifting attitudes toward sharing data using principles such as FAIR, cast data sharing in a new light, making it more feasible than ever to involve researchers from outside the domain (Wilkinson *et al.* 2016).

Storage and Sharing of Digital Data

To promote and facilitate the use and reuse of archaeological and heritage data, digital tools and platforms are essential, especially considering that much data is digitally born in today's archaeological practice (Taylor *et al.* 2018; Dell'Unto *et al.* 2017; Katsianis 2021). Over the last 30 years, digital tools such as relational databases and semantic web technologies have been used to store, organise, and share data (Cooper and Green 2016; Kadar 2007). The institutions that use these tools and platforms to make heritage and archaeological data publicly available online museum resources include Historic Environment Records (HERs), Archaeology Data Service (ADS), universities, and interest groups that have developed dedicated environmental archaeology databases. To deal with the 'datafication' of archaeology and heritage domains, tools such as CRMs and advanced relational databases have been developed to analyse large amounts of data that were previously made difficult or impossible to perform (Huggett 2020). Although these systems have proved proficient at creating an ecosystem of data that appropriately details the excavation and post-excavation process, their efficiency in enabling access and reuse of archived remains has rarely been considered (Lukas *et al.* 2018; McManamon 2018).

Over the last 30 years, the tools and venues for data handling in archaeology have become many and varied (Huvila and Huggett 2018; Faniel *et al.* 2018). By way of bringing the tools, strands of data and data producers together, the Heritage Information Access Strategy (HIAS) was initiated in 2013 to formally recognise partnerships across the heritage sector and improve public access to data created by Local Authorities, HERs, Historic England, contractors, and volunteer groups (Carlisle and Lee 2016). HIAS is a Historic England-led initiative that aims to bring cost-effective solutions to historic environment digital data handling (May 2015). The HIAS has eight principles that provide greater coherency and accessibility to digital heritage data. The findings from Chapter Six will be assessed against the HIAS principles to establish which tools, methods, and institutes best suit further development to serve archived palaeoenvironmental remains (https://historicengland.org.uk/research/support-and-collaboration/heritage-information-access-strategy/).

- Principle 1: Local Authority HERs should be the first point of call for and primary trusted source of investigative research data and knowledge.
- Principle 2: Historic England should be the first point of call for and primary trusted source of national datasets, such as the National Heritage List for England and the national marine heritage dataset.
- Principle 3: Historic England, together with its partners, should continue to champion the development, maintenance, and implementation of standards for the creation, management, sharing, reuse and storage of digital historic environment data.

- Principle 4: Investigative research data or knowledge should be readily uploaded, validated and accessed online.
- Principle 5: A national overview should continue to be delivered online through the Heritage Gateway.
- Principle 6: Such data or knowledge should not be at risk of loss, fragmentation, inundation (in data), or system obsolescence.
- Principle 7: Historic England should, on behalf of the nation, ensure that a security copy of all such data exists in accordance with Principles 3 and 6.
- Principle 8: Digital data should be supported by material archives in safe repositories accessible to the public.

The principles outlined in HIAS support the domain of archaeology and provide principles that can introduce quality assurance and harmonise database schema (Carlisle and Lee 2016). The harmonising of database schema is important, given that archaeological archives housed in museums and contractor stores represent large and diverse assemblages and datasets, and have been managed and devised in various ways that are sometimes arbitrary. For example, archives in museums have been gathered according to collecting area boundary, a museum's ability to collect archives due to available space and staffing, and internal collecting policies (Bustard 2000). This arbitrary collection process can result in synthetic analyses being obfuscated by assemblages separated by spatially and culturally artificial influences that have little bearing on past occupation or formation processes. These limitations begin to demonstrate a need for archives to be made more accessible, meet a shared vision of operational standards, and be sufficiently interoperable to perform cross-platform research and encourage reuse (Perry 2016). This drive for accessibility can benefit the analysis of remains, as an open and accessible database of archived remains would extend beyond the arbitrary borders of the unitary authority and allow for extra-regional research. The collection of principles in the HIAS is regarded as timely and appropriate guidance to ensure that any new tools or platforms devised to serve archaeological palaeoenvironmental remains meet nationally approved standards.

Semantic Web and relational databases

Today, relational databases and semantic web technologies are the primary means of storing and disseminating digital data. Relational databases in cultural heritage domains were first experimented with in the 1980s, and semantic web technologies were adopted in the 1990s as the internet became ubiquitous through home computing and Web 2.0 (Burners-Lee *et al.* 2001). Because both the relational databases and semantic Web are repeatedly referenced throughout this chapter, clarification of these concepts is provided here.

Relational databases

Relational databases organise digital data and metadata into tables that can be operated using programming languages that can undertake queries across multiple tables, allowing large datasets to be searchable (Codd 1970). The ability to reference multiple tables provides greater capacity for data handling, making relational databases, in many ways, superior to flat databases, which are constructed from a single table (Thomer and Wickett 2020). Each relational database has fixed objects significant to the subject domain and the intended inquiries. These objects are designed to record significant analytical outcomes appropriately and provide sufficient fields to use, reuse and recycle data (Watt and Eng 2014; Kung 2013). Within the cultural heritage domains of archaeology and museum archaeology, objects can include a universal conceptual value, such as contextual data alongside higher-tier idiosyncratic data that relates to the needs of individual assemblages (Huggett 2018; Cooper and Green 2016). Put simply, a database is organised and designed following its planned use. Idiosyncratic concepts could be as diverse as scientific dating information, morphological information, geospatial data, and archive location.

The capacity to hold large amounts of data in a searchable format appropriately position relational databases for archaeological and museum management, given that they both generate large and diverse datasets (Kadar 2007). Consequently, relational databases have been utilised across the cultural heritage and museum sectors since the 1980s (Ryan 1992). These include museums (for example, see the British Museum (Griffiths 2010), commercial archaeology practices and university departments (for example, see the Integrated Archaeological Database (Stead 1988)).

The mathematical theory and means by which tables are linked have barely changed since the heritage sector adopted relational databases, but how databases are shared within the sector and are engaged with by specialists and non-specialists has become more sophisticated (Cleve *et al.* 2015). Consequently, the dissemination of data relating to archived remains and engagement with physical stored archives is facilitated by digital means and, depending on the domain, has been supported by practice-theory innovation (Fagan 1995; Huggett 2020). However, the application of practice and theory-led approaches in the construction of platforms of available data differ across the cultural heritage sector, and the way relational databases are utilised varies in their attempts to achieve desired outcomes. This chapter examines how platforms that use relational databases in museums and archaeological practice have met the central aims of storing and communicating archaeological palaeoenvironmental archive data for researchers and identifying if relational databases are an appropriate tool for future use.

Semantic Web

The idea of the semantic Web - technologies that recognise the semantics of web-based information - is almost as old as the World Wide Web (Bernstein *et al.* 2016). Semantic Web technologies allow machines to make sense of internet content and make those results readable and understandable to humans (Richards 2006). Semantic web pages can be constructed using off-the-shelf software, which allows for text and hyperlinks to be machine-readable and identify data and information that accord to rules that enable automated analysis (Richards 2015). Over the last 20 years, the semantic Web has become its dedicated field of computer research and continues to be developed to create an increasingly valuable and elegant method of cross-referencing web-based data. The areas of the semantic web that are typically being investigated include the following (Bernstein *et al.* 2016):

- Defining languages and standards
- Describing and querying the semantics of resources on the Web.
- Developing tractable and efficient ways to reason with these representations and to query them efficiently.
- Understanding patterns in describing knowledge.
- Defining ontologies that describe Web data to allow greater interoperability.

These areas of investigation are essential to ensure the development of a fully searchable web that can serve researchers from all domains, including cultural heritage and archaeology. In addition, very comparable avenues of research can be identified in the continuing development of the CIDOC CRM and other affiliate CRMs, that similarly use semantic technologies to search between datasets. CIDOC CRM will be discussed in further detail later in this chapter.

Systems of Storing and Sharing Archived Archaeological Palaeoenvironmental Data

The next section of the chapter examines the current modes of storing and sharing data related directly to archived archaeological remains and determines if they are suitable to be expanded and repurposed or if a new system is necessary. The methods of storing and/or disseminating data examined includes.

- Historic Environment Records (HERs)
- Archaeological Data Service (ADS)/ Online AccesS to the Index of archaeological investigationS (OASIS)
- Online museum resources
- Environmental Archaeology databases
- Conceptual Relational Models (CRMs)
- FAIR Practices in natural history museums

Historic Environment Record

Upon completing a phase of archaeological fieldwork, one outcome of an archaeological project is the deposition of the archive, comprising both documentary records and material remains, with a publicly accessible curatorial repository (Pearson 2020; Brown 2021 personal communication 9 July). Alongside the process of archive deposition, the results of archaeological investigations require updating in the local Historic Environmental Records (HER) (Cooper and Green 2016). HERs operate as repositories of final reports and digital data and facilitate public access to the archaeological record (https://www.algao.org.uk/localgov/hersmr). Nationally, there are 85 regional HERs in England, most of which are funded by local authorities and are often managed by joint services (https://historicengland.org.uk/advice/technical-advice/information-management/hers/).

HERs (formerly Sites and Monuments Records - SMRs) were initially intended to act as publicly available catalogues for the results of research that focused on terrestrial archaeological sites and historic monuments (Gilman 2004). In 2003, following the English Heritage' Power of Place' (Clark 2019) review, the remit was expanded to include historic landscape data, historic building information and seascapes (Darvill 2009; Illsley 2019; Gilman 2004). The expectation of today's HER is to serve as an entry to the archive (Newman 2010). Once a scheme of fieldwork is completed and the documentation has been deposited, access to the material is provided to researchers who can make appointments to visit the physical reports or are hosted online via the Archaeological Data

Service (ADS) library (Newman 2010; Illsley 2019; Moore and Richards 2015; https://historicengland.org.uk/advice/technical-advice/information-management/hers/).

Within the heritage sector, HERs/SMRs were early adopters of digital technologies to provide capacity for data warehousing. These early examples can be characterised as small relational databases developed to manage the contents of HERs and have developed to include more sophisticated storage systems capable of complex searchability and data extraction (Illsley 2019). In addition to providing the primary repository for recent excavation data, HERs have been investing in their ability to provide digital access and are digitising their analogue reports into Optical Character Recognition PDFs (Allen *et al.* 2018; Richards 2015). The investment in digitising the backlog allows for disseminating reports and excavation data, providing uninhibited access unencumbered by opening hours and improving information flow (Allen *et al.* 2018).

As part of Historic England's Heritage Information Access Strategy, HERs are incorporating data from the National Record of the Historic Environment (NRHE) (Flower and Lush 2017). The NRHE is a resource that contains more than half a million digital records related to England's historic environment. The National Archaeological and Buildings Records database was compiled in the 1980s and represented the earliest example of a digital database within English archaeological practice (https://nrhe-to-her.esdm.co.uk/). Also included in the NRHE is the Excavation Index, a digital index that contains details of archaeological excavations and related fieldwork (Evans 2015). Today, the NRHE contains digital records, including a description of the site of investigation, a location, subject type, the period it relates to and a unique NRHE site number (https://archaeologydataservice.ac.uk/archives/view/398/).

Efforts to develop HERs into comprehensive centres of archaeological knowledge-making are apparent from multiple angles, including the HIAS and the migration of the NRHE, but there are still challenges in using HERs to find data relating to what and where remains are archived. To identify and extract information regarding archived palaeoenvironmental remains, the data that HERs contain demonstrate several issues. These can be characterised as inconsistent inclusion of specialist reports included as appendices (Lodwick 2019), a failure to include details that state which remains have been archived, their respective quantities (Stewart *et al.* 2013), and any rationale for their selection for archive and any recognition of their condition upon deposition. These issues were encountered during a search through grey literature reports, publications, and stored data which was conducted at Somerset HER, Taunton, as part of this doctoral research (outlined below). The search was undertaken to find details relating to archived palaeoenvironmental remains curated in the museum store to determine what research and display potential the archived remains possess. Knowing what remains are held provides opportunities to examine how thorough the archived reports in HERs are in detailing what has been deposited and why.

Somerset HER Search

As part of the archive audit undertaken at the Somerset Heritage Centre, Taunton, Somerset, which is detailed in Chapter Five, the comprehensive list of palaeoenvironmental remains created as part of the audit was used to examine the accuracy of information listed in reports held in the HER. This bottom-up approach ensured that the inventory of remains was consistent with what was in the store and not influenced by a potentially incomplete catalogue or inventory. Most of the archive boxes were found to have an accompanying HER number on the boxes themselves, which was used to identify accompanying reports. The final list comprised: site code, HER number, a description of the material, and, where available, context and sample numbers. The list was taken to the local HER to collect and copy relevant site reports and relevant publications.

At the HER, the details searched for included: taxonomic information, a quantification of what palaeoenvironmental remains have been archived, some form of rationale in some form of selection policy or strategy, and a full specialist report. The search results demonstrate that reports published over the last twenty years were found to contain more details than older excavations, which did not demonstrate such complete and easily navigable supporting evidence compared to more recent field investigations. For example, the excavations in Lamyatt Beacon conducted in 1958-1960 produced seven bags of charcoal deposited in the local museum. Each bag contains a sample or context number, but these numbers do not correspond to any numbers in the report. Sites through the 1970s and 1980s, such as 5-8 Fore Street, Taunton and Blackmoor Swallet sink hole in the Mendips, Somerset, respectively, were found to suffer from a similar failing in inconsistent inclusion of details.

The data held in HERs and stored and disseminated through the ADS demonstrate great variability in their quality and consistency regarding specialist reports and information regarding what has been archived and why. A fundamental challenge is identifying ways disparate data from inconsistent reporting can be harmonised and made searchable and available for use and reuse.

Archaeology Data Service and OASIS

The Archaeology Data Service (ADS) was established in 1996. The ADS originally intended to catalogue and preserve digital data created through the archaeological process (Richards 1997). Since its inception, the landscape of digital archiving has evolved, and even greater importance is placed on the need for a digital repository, and the ADS has Core Trust Seal certification, and today they curate and preserve data and provide access. The ADS now plays a vital role in British archaeology and is internationally recognised as a leader in digital archaeology's theory, method, and practice (Moore and Richards 2015). Indeed, a review in 2013 revealed that commercial archaeology organisations rely on the ADS Library of Unpublished Fieldwork Reports to draft desk-based assessments and produce written investigation schemes (Beagrie and Houghton 2013). The report demonstrated that the utility of the ADS is being realised by the archaeological community and has become a trusted resource used by most members of the community (Evans 2015). As ADS usership has increased, some investigators have recognised the value of the resources and exploited the power of the ADS to make enhanced levels of data available and usable. Projects such as Star Carr (https://archaeologydataservice.ac.uk/archives/view/postglacial_2013/downloads.cfm) and The Silchester Project (https://archaeologydataservice.ac.uk/archives/view/silchester_ahrc_2007/) have used the ADS to deposit large amounts of data that surpass the minimum basic requirements and enabling greater opportunities for data reuse. The resulting data is available via downloadable spreadsheets of specialist and excavation data, videos, photographs, photogrammetric models, specialist reports and publications. In the instances of these projects, the data can be found on pages in the ADS ARCHIVES (https://archaeologydataservice.ac.uk/archive/).

As a means to store and disseminate data, the ADS is partitioned into three distinct areas: i) Archsearch - a resource that contains monument and event records, ii) ARCHIVES - a data repository, and iii) LIBRARY - a library that contains grey literature reports, published monographs and journal articles that have been deposited by commercial archaeology organisations, academic-led excavations, volunteer-led fieldwork (https://archaeologydataservice.ac.uk/search.xhtml). The most common depositors of data are commercial organisations (Richards 2002). Data is submitted through the Online AccesS to the Index of archaeological investigationS (OASIS), which was developed to record the outcomes of archaeological field work by the group responsible for conducting the work (Hardman, 2009).

Online AccesS to the Index of archaeological investigationS (OASIS)

OASIS is a web-based form that allows cultural heritage practitioners and archaeologists to update regional HERs and national organisations with details regarding their investigations, to develop an online index of 'grey literature' reports (https://oasis.ac.uk/). The service acts as a tool to gather information about the work that a contractor, crowd-sourced, volunteer or academic enterprise has conducted and enables reports to be made publicly available via the ADS.

OASIS essentially began as a way of automating compliance in development-led archaeological practice and improving information flow between contractors, the academic community and local government (Wright and Richards 2018; Kilbride *et al.* 2003). In 2001, the index of grey literature report was added to the ADS ArchSearch catalogue (Kilbride *et al.* 2003). OASIS now offers an index of the ever-growing number of grey literature reports generated by developer-led, crowd-funded and volunteer outreach (Richards and Hardman 2008). To update OASIS, users engage with a digital 'event record' form that, once completed, updates the system with details of the work they have conducted because of the field investigation. Reports uploaded to the OASIS facility are available via the ADS Grey Literature Library (Moore and Richard 2015).

The OASIS list splits the collected archive data into three categories: physical, paper, and digital (https://archaeologydataservice.ac.uk/blog/oasis/?p=383). Each category possesses an archive identifier, archive contents, archive media, archive location, and notes. All this information is inputted by the party that is committed to the investigatory work, most likely a commercial archaeology organisation (Richards 2002). The uploading of information in the OASIS form is the responsibility of the organisation conducting the investigation. This relies on a combination of factors, including the organisation's values, the attitude that the project team have towards compliance and the capacity of a HER to enforce the completion of the form (Richards 2017).

A key aim of OASIS was to improve connectivity and workflow between all stakeholders involved, and whilst this aim has been partially met, the workflow of the OASIS system has benefited some members of the archaeological community more than others, and experienced challenges such as backlogs in final HER sign off (https://oasis.ac.uk/country/england/index.xhtml?country=england). For example, the workflow could lead to delays between Level 1 users – groups conducting the investigation – uploading a completed report once a project is completed and validated by Level 2 users – HER and government organisations. A number of factors cause delays, including a lack of resources that can validate the forms or there is no provision for a HER, leading to some HERs opting out of the review process. These obstacles have been extensively reviewed, and new measures to resolve these have been implemented as part of the OASIS V upgrade (see below).

Regarding ADS/OASIS, a challenge emerges. The searchability for archived remains within the reports and archives. There are issues regarding the search options on OASIS, as the search only operates using geographical and monument fields rather than bibliographic sources or event classification, making searches awkward and unreliable (Evans 2015). Inconsistent inclusion of details that relate to what has been archived, why it is has been archived and where it has been archived, can make detailed searches complicated and unreliable.

OASIS V

After five years of sector-wide review, OASIS is undergoing a significant update to its functionality and is compliant with the Heritage Information Access Strategy (HIAS) in its efforts to improve open access of heritage data (Richards 2017). The version now being beta tested is the fourth update of OASIS, but the project team have decided to call this new version OASIS V (https://archaeologydataservice.ac.uk/blog/oasis/?p=716). Updated functionality will address key challenges such as HERs having the staffing and time to review reports by keeping the OASIS record open throughout the project, enabling records to be continually updated with new data such as archive accessioning information or specialist reports.

Furthermore, OASIS V recognises that the system needs to facilitate greater workflow and communication between Level 1 users (community group, contractor, academic organisation) and Level 2 users (HERs and government organisations). This will involve metadata and reports being held for review by the HER prior to final acceptance of the report and allow for communication between the levels. Another crucial addition to OASIS V is Level 3 users – museums and archives. Adding Level 3 users allows museums and archive repositories to use the OASIS form to communicate guidance regarding what archives are accepted, deposition standards and collecting areas. In addition, museums can attach pro-forma and downloadable documents through their account. Including Level 3 users will allow museums to see what materials are destined for their institute and allow them to better plan for deposition (https://archaeologydataservice.ac.uk/blog/oasis/?p=742).

To assist with the drive to make the new version of OASIS open, accessible and able to provide data in a reusable way, OASIS V will promote FAIR (Findable, Accessible, Interoperable and Reusable) principles (https://archaeologydataservice.ac.uk/about/adsFAIR.xhtml; Wilkinson *et al.* 2016). FAIR principles and sub-principles are equipped with prescriptive measures that ensure a data service meets the requirement to make for effective data stewardship, rather than simply acting as a repository for data (Wilkinson *et al.* 2016).

OASIS + Modules

To better provide users with the opportunity to store and disseminate their data to a specialist audience, allow for greater interoperability, and report investigative work to national and regional heritage bodies, the OASIS upgrade will include OASIS + modules. The modules will be supported on the ADS website, with data entry being handled by OASIS. Examples of OASIS + include the Burial Space Research Database (Pillatt *et al.* 2020). The Burial Space Research Database was developed as an outcome of the Discovering England's Burial Spaces project, a Historic England-funded project that developed the tools and standards for recording burial spaces such as cemeteries and churchyards. The Burial Space Research Database encourages a range of users, including community and volunteer groups and contractors, to update their results in a methodologically sound way that can then be used and reused by other groups. To maintain consistency and integrity, a minimum set of standards have been agreed upon for accession (Pillatt *et al.* 2020).

OASIS + modules are relational and use a schema designed to suit the needs of the specialist community, with metadata options and concepts developed to record concepts pertinent to that domain. In the example provided by the Burial Space Research Database, the following concepts were recognised as being significant:

- Site name
- The group or individual undertaking the survey.
- Site locations
- The religious denomination of each burial space.
- OSGB grid references of plots.
- Dates of the surveys undertaken.

These concepts for data collection are no doubt appropriate to the needs of the domain, but what happens if these concepts become dated or superfluous in the future? It is, therefore, vital that the intended recipients of the databases are well understood. A well-formed understanding of what the recipients require can ensure that the conceptual fields of relational databases do not become redundant. These fundamental challenges are being addressed by providing enhanced functionality that adds cross-platform linkages to other databases such as the National Biodiversity Network Atlas and Church Heritage Record (Pillatt *et al.* 2020). The ability to link surveys or individual plots to other databases strengthens the case for developing a relatively simple database, given its capacity to have an extended reach to other venues of data collection and analysis. Linkages to other platforms provide users with greater opportunities for use, reuse and interoperability, and the concepts and data can be expanded in perpetuity.

The developments in OASIS V are resolving many of the issues that have been observed over the last decade (https://archaeologydataservice.ac.uk/blog/oasis/?p=742). Extending OASIS to include Level 3 users will hopefully allow for greater communication between users and improve archive quality and usability. The OASIS + modules present opportunities for specialist domains to focus on their needs and collect, store, and disseminate data appropriate to their needs, rather than collecting a minimal amount of data and a link to bibliographic content (Pillatt *et al.* 2020). With the OASIS + modules providing so many benefits, a dedicated module should be considered for storing and disseminating data relating to archived archaeological palaeoenvironmental remains.

OASIS V presents exciting new developments that enable greater interaction with collecting institutions. The addition of this facility begins to bridge the gap between museum and contractor and can hopefully offer productive channels of communication. Other benefits of the upgrade include the OASIS + modules and digital venues that can be tailored to suit the needs of each domain and sub-domain. Sub-domains such as the Burial Space Research Database realise the value in OASIS + modules. It therefore begs the question of whether a dedicated module would suit the needs for archaeological palaeoenvironmental archiving. A dedicated module could act as the 'missing' link within the archaeology database ecosystem and provide comprehensive links to physical remains. Similarly to the Burial Space Research Database, the ability to facilitate cross-platform interoperability would provide links to digital data repositories such as biodiversity aggregators, a function that would suit a palaeoenvironmental database. In this capacity, the module could link archive data to recorded morphometric and taxonomic data in a coherent searchable venue and provide data deriving from specialist observation of the physical remains and enable reusability and re-testability. By providing links between digital data and physical remains, an archaeological palaeoenvironmental archive module would also contribute to the Heritage Information Access Strategy, especially Principle 8: Digital data should be supported by material archives in safe repositories accessible to the public.

To implement such a service, an archaeological palaeoenvironmental archive module would require buy-in from the environmental archaeology community, commercial vendors, and local authority archaeologists, who would enforce the OASIS form being completed (https://famearchaeology.co.uk/a-new-oasis/). Once buy-in has been achieved, such a system would no doubt provide many benefits to current archaeological palaeoenvironmental archiving, but for existing legacy archives, these benefits could not be realised (Frieman and Janz 2018). A museum's full catalogues of palaeoenvironmental archives would be the optimal way to encourage the use and reuse of archived remains. An OASIS module could encourage greater use and reuse compared to archives on ADS as the results would be uniform and more likely to be linked to the physical remains themselves and effectively signpost to their location. Backfilling the system with stored archives could be achieved using a CRM (details on pages 176) but would have cost and time implications. Determining the actual cost of a module would require some form of negotiation and business case building, but to provide a guide, the Burial Space Research Database module cost was £74,000. (https://digitalcreativity.ac.uk/news/discovering-englands-burial-spaces-project-wins-funding). Historic England would need to cover the cost of an archaeological palaeoenvironmental archive OASIS + module.

Museums Online

So far, Chapter Six has focused on how digital data can be organised; the following section examines how data management changes when physical objects relate to data. Today, most European museums have an online presence, with websites and online content playing an important role in a museum's capacity to engage and communicate with the museum community and prospective patrons (Dunmore 2006). Since the 1990s, many museums and cultural heritage institutions have prioritised providing access to their collections, exhibitions, and supported learning via their dedicated websites (Poulovassilis *et al*. 2020).

The practice of maintaining catalogues and inventories is a practice as old as museums themselves (Poulot 2013). Catalogues and supporting documentation such as acquisition registers and inventory files that manage a museum's acquisitions, loans, and contents have always been a vital part of museum management (Wentz 1989). These tools and documents have existed in different formats, including card indexes (Turner 2016). Individual museum catalogues share certain similarities but exhibit many differences, such as terminologies and the language used to describe objects (Wentz 1989). The variability in a catalogue may hinder the searchability and trans-institutional interoperability of museum collections and archaeological archives. In the 1980s, these challenges were addressed by the availability of increasingly affordable computing and the developments in relational databasing (Thomer and Wickett 2020). The benefits of digitisation include combining multiple tables in one database, essentially facilitating faster updates and improving the speed of inquiry and information retrieval (Abell-Seddon 1988). For clarity, the differences between a database and a catalogue are elucidated. A catalogue is a browsable entity created by museum staff and specialists drawing links between certain objects and themes, while a database is searchable and enables users to find their information and make their links (Gil-Fuentetaja and Economou 2019). Museum databases and catalogues provide curators and museum workers with information to quantify and describe what items are held by the institution (Griffiths 2010).

Developments in the semantic Web and its potential for sharing data, coincided with advancements in new museology and the fostering of constructivist approaches, whereby museum visitors engage in interpretation and the development of development of knowledge (Hellin-Hobbs 2010; Poulovassilis *et al.* 2020). The implementation of constructivism at a time when online resources were being developed resulted in a discussion within the domain of museology that focused on how museum resources are created and engaged online (Binyue and Shigeki (2011). Constructivism places pedagogy and learning at the centre of its philosophy, and exponents of the approach consider how digitised, and non-digitised data could be presented to the public (Hein 1998; Belanus and Fernandez 2014). Within the constructivist model, how online data is selected and made available as online resources have been divided into two approaches, the direct intervention approach, user freedom and institutional intervention (Gil-Fuentetaja and Economou 2019; Hein 1998). Institutional intervention involves the specialists and staff within the institution making judgements on what content is useful to the intended users. Essentially, the heritage sector and museums must decide if they are more interested in funding projects to assist small groups of experts or to engage with non-expert collections more efficiently. This realist vision of the theory of knowledge is more closely aligned with the output of a catalogue which would offer highlights of the collection and not include search tools (Gil-Fuentetaja and Economou 2019). Contrary to the realist vision, the user freedom approach provides users with all available data unfiltered by the institution. User freedom would allow for searching tools, details of the full collection, downloadable databases, and online exhibitions (Gil-Fuentetaja and Economou 2019).

Where a museum falls on the spectrum between user freedom and institutional intervention will vary between institutions and will further differ according to the institutional values and educational aims. Once decisions have been made regarding what content is relevant and how this can be technically achieved, those decisions can shape the future of their capacity to share information. As Gil-Fuentetaja and Economou (2019 pp 313) have observed, the "philosophy of communication of digital contents differs among museums and, even when not immediately obvious, has a lasting influence on their technological implementation schemes". This demonstrates that regardless of how well designed an online resource might seem, once in operation, augmenting and updating digital databases can be complex. Such complaints are very much linked to the architectural facets of relational databases.

Although museums will share certain commonalities in their learning agendas, such as the national learning curriculum, individual museums will have their aims in what they wish to communicate (Foreman-Peck and Travers 2013; Hooper-Greenhill *et al.* 2004). This has understandably led to the wide variability of both content and operational facilities. The variability in online resources has been examined by Lejeune (2007), who found that online databases and catalogues can range from containing object names and numbers and a short description through to interpretive information and suggested further reading. Variation was also observed between the available search tools. These ranged from single keyword searches to more complex advanced searches dealing with multiple terms (*ibid*).

Is there, then, any potential for online museum resources being updated to disseminate information relating to palaeoenvironmental archives that they have in their care? Such an undertaking could prove complex - online museum resources are largely intended for educational purposes and cannot be relied on for critical use and reuse to locate and interrogate details concerning archived archaeological palaeoenvironmental remains. Furthermore, the variability of online resources, as a consequence of them suiting their learning agendas and resulting architectural idiosyncrasies, does not lend such services to the needs of many archaeologists who require enough data to be used and reused (Huggett 2018).

If a museum wished to include additional information that could allow specialists to find the relevant data, online museum catalogues constructed from relational databases could experience challenges in them being updated. Therefore, some level of intervention is necessary to create something that can present a manageable portal that is inviting and easy to manage. Of course, it could be argued that this information could be found by a researcher in the project archives, but this could be time-consuming or prove to be a fruitless exercise, as has been experienced by many researchers so far.

Collections Management Systems

Collections management tools are databases used within museums to manage their holdings. The systems used vary from institution to institution, but one of the most used systems is MODES (Roskams with Whyman 2007). Other options include developing bespoke systems that use SPECTRUM. Guidelines issued by SPECTRUM, the UK collection management system, offer guidance for the museum sector, allowing them to construct their cataloguing policy (SPECTRUM 3.2 2009), suggesting that:

> *"Create a record for each object or group of objects and make these records accessible by object number. Other retrieval options will be provided by indexing* […]*. Allow for the addition of information as it becomes available.*
>
> *Catalogue information must include, at the very least:*
>
> - *The object number or entry number;*
> - *The object name;*
> - *The number of items or parts described in this record;*
> - *A brief physical description;*
> - *A reference to acquisition method, date and source information;*
> - *A reference to location information;*
> - *A reference to available images."* (Patsatzi and MacKenna 2007 pp.102)

Typically, the details held in the collection management system are not shared with researchers. This can be achieved if a researcher contacts a museum with a request, relevant returns of a search can be exported into a Microsoft Excel spreadsheet and shared with a researcher, but it is implausible that a full catalogue would be exported and shared.

Although digital museum resources offer little in terms of their ability to store and disseminate data for use and reuse, valuable lessons can be learned. When designing web content and deciding what to web-publish, museums had a theoretical consideration regarding what they wanted from their institute to disseminate. A new platform for storing and sharing data in environmental archaeology could take inspiration from museums to develop a high-quality database. A new database expected to store and promote details relating to archived remains must include theoretical principles that are consensus driven before construction begins to ensure the true long-term goal and values can be realised.

Online Environmental Archaeology Databases

In 1997, Eiteljorg stated that the purpose of an archaeological database is twofold, to provide a trusted venue for data warehousing and for extraction to facilitate research, placing relational databases as an appropriate tool to store and disseminate data (Eiteljorg 1997). To serve these two basic aims, archaeological relational databases have, for the most part, been designed in a top-down way that considers what data is relevant at the point of analysis and can be considered significant in the future (Kadar 2002).

Up until the 21st century, the design of archaeological databases has generally occurred independent of theoretical grounding, especially when compared to museum practices. There have been occasional attempts to introduce supporting theoretical elements to digital data storage and dissemination in archaeology, many of which have centred around the ADS. Except for the ADS, attempts to question archaeological data through a theoretical lens were relatively few and far between. The reasons for the dearth of theory have never been explored or adequately determined, but the prevalence of post-processual archaeological theory at the time (Johnson 2019) may be a reason for a data-heavy topic free of interpretative value being overlooked.

In a relatively rare instance of theoretical grounding being given to databasing, Schlader (2002) confronts the reality that most archaeologists have appreciated little or no value in the approach given to databases since their burgeoning use in the 1980s. Wrestling with this fact, Schlader (*ibid*) forwards three theories that can support archaeology databasing. The first is a functionalist/Marxist theory that views digital data as having no value beyond what it describes. The inference is that data can be treated as culturally valueless items that need to be arranged in a way that allows them to be recalled when required. The second theory is a more cognitive approach, similar to the idealist vision of constructivism, where a future is envisioned where all data is made available to all people. The third align to a realist vision, whereby specialists and experts select what information is made available. The application of these theories can result in a range of outcomes. For example, viewing data as something relatively valueless and subjective could result in a reduced emphasis on the value of archives for future research and encourage researchers to look to new excavations to address the research questions. Alternatively, environmental archaeology, a topic that has perpetually struggled to promote itself to a non-specialist audience, could find data about environmental archives being focused on specialists with no consideration for use outside of the discipline.

In the twenty years after Schlader's publication, there has been an increasing consideration of how archaeological digital data can be approached in theory-practice-based perspectives that consider esoteric matters and exceed the purely functional value of digitised data (Richards 2006b; Power *et* *al.* 2017). A catalyst for a much wider discussion of digital data - in all scientific domains - was the advent of the much publicised 'Age of Big Data' (Lohr 2012). Big Data, the concept by which "Information assets characterised by such a High Volume, Velocity and Variety to require specific Technology and Analytical Methods for its transformation into Value" (De Mauro *et al.* 2015), has inspired discussion that extends into the theoretical consideration and includes the works of Latour (Latour 2012) and Derrida (Derrida 1995) into how databases are theoretically, or not theoretically, constructed (Bowker 2014). The dialectic surrounding Big Data was further provoked by Anderson's polemic statement that the new age of Big Data came to an apparent end of theory (Anderson 2008). Anderson's assertion that large amounts of data will usher in the end of a need for theory was met with a great of discourse across many scientific domains (Mazzocchi 2015). Thematically, despite these discussions - within the domain of archaeology - the functionalist approaches have in some sense remained in place, and the more cognitive approaches have not been developed, instead preferring discussions surrounding the tools that are used and ways that data is organised. What has been neglected are the discussions surrounding esoteric themes such as openness, transparency and how we can understand data to find silences within datasets (Huggett 2020).

Environmental Archaeology

Within this history of archaeological database development and use, where does archaeological palaeoenvironmental archiving fit? Within the environmental archaeology literature, evidence of theory-led reasoning supporting the development of databases is scant. In earlier examples of archaeological palaeoenvironmental databasing such as the Archaeobotanical Computer Database (ABCD) (a compilation of data relating to archaeobotanical remains recovered from archaeological deposits what was developed in 1996) rather than including lines of enquiry that transcend the immediate value of the data and take into consideration topics - such as transparency, database scalability and modelling and the nature of reuse - priorities have focused on the compilation of recorded data (Cui *et al.* 2014; Tomlinson and Hall 1996). Unlike practices in natural history museums, the necessity to include links to fossil remains as a measure to ensure repeatability and re-testability is absent (Meineke *et al.* 2018). The attitude towards linking the physical location is evident in the 1993 publication regarding the development of the ABCD;

> *"There are several categories of information that are often not included, for example, the reference collections and publications used to identify the materials, the location of the archive and final location of the fossil materials themselves…*

Some reports do mention where the archaeological archive is stored but, as this author has occasionally found, this archive may never have been deposited where it is said to be!" (Tomlinson 1993 pp5)

At the time, the decision not to include the links to the material evidence seemed rather innocuous. The ABCD is not available as a relational database but has been published in Internet Archaeology in text form (Tomlinson and Hall 1996). Regrettably, little consideration was taken to appreciate how a database can be scaled and receive additional concepts in the future.

Subsequent to the publication of the ABCD, one of the most significant developments in environmental archaeology databasing was ArboDat (Kreuz and Schäfer 2002; Lodwick 2019). The ArboDat database was created by Angela Kreuz at the Kommission für Archäologische Landesforschung (Kreuz and Schäfer 2002). Arbodat is a relational database supported by Microsoft Access. Individual specialists possess a copy of the database and share data within the community, and it is therefore not open access (Lodwick 2019. The database was designed to investigate historical and biological questions and not be impaired by political borders, effectively building a "supranational data exchange" (Kreuz and Schäfer 2002). As a system that can interrogate archaeological palaeoenvironmental data across wide geographic areas, ArboDat is proving particularly deft and has been accepted by organisations such as Historic England as the in-house system to collate and analyse large archaeobotanical datasets. A vital aspect of ArboDat is that it provides standardised terms for preservation, standardised taxa names, dating and feature types. Without this standardisation, specialists would not be able to exchange data easily (Lodwick 2019). These are minimum standards that can maintain database integrity, but ArboDat lacks concepts regarding archiving, the location of the physical remains, and any rationale supporting why items were selected for archive.

ArboDat has taken certain leaps forward compared to the ABCD. The aim of creating a system that can extend beyond political borders is an admirable addition that can answer questions across a broader geographic scale. Its format – a relational database managed by individual specialists is less static than the Web published text of the ABCD. However, when designing ArboDat, it appears that the decision-making processes were similar to those of the ABCD in terms of neglecting the location of the physical remains. Furthermore, the fact that data within ArboDat is not automatically open access and available to the public, severely limits opportunities for using and reusing archived physical remains.

ArboDat has been used in the recent Plymouth/Birmingham/Historic England Biodiversity project (de Vareilles and Woodbridge 2020). The project uses long-term ecological records to understand trends and patterns over wide geographical regions and millennial time scales (Woodbridge *et al.* 2021). Critical to the project is the subfossil evidence – the pollen, insects, and plant remains, and how they have been used to understand biodiversity change (de Vareilles and Woodbridge 2020; Woodbridge *et al.* 2021). ArboDat was identified as a suitable platform to store and make accessible data relating to millennia of biodiversity (de Vareilles and Woodbridge 2020). However, as highlighted, ArboDat does not insist on including the location of archived remains as minimal compliance. This is problematic given that biodiversity science has collections and archives at the heart of it, rather than the recorded data.

Environmental Archaeology databases in the age of Big Data

In the 21st century, there have been attempts to develop environmental archaeology databases that have more holistic aims and learn from the lessons from the big data revolution (Pearson 2020). At the same time, there has been a burgeoning interest in integrating archaeological data with biodiversity data using digital sharing platforms to examine human-environment relationships (LeFebvre *et al.* 2019). This interest is occurring concomitantly with developments in digital archaeology and examinations of practices surrounding data reuse (Lodwick 2019, Huggett 2017, Kintigh and Altschul 2010). However, these more broad-minded considerations that include how data is accessed and reused are born from necessity as traditional modes of creating, sharing, and synthesising data have proved inadequate against a backdrop of progressive developments in other sciences (Lodwick 2019, Wilkinson 2016, Dallas 2015, Altschul *et al.* 2017, Huvila and Huggett 2018).

An example of a progressive database is the Strategic Environmental Archaeology Database (SEAD) developed by Buckland in Umeå, Sweden. It was established in 2008, and set out to develop a database that was designed to encourage engagement through an accessible GIS format (Buckland 2011a). The creators of SEAD acknowledge that environmental archaeology and environmental science data is too large to be approached without a large-scale database system, and a well-organised system can allow for knowledge creation and transparent working (Buckland 2012). Database concepts and objects include bibliography, taxonomy, bibliography, contacts, images, and metadata, but the platform does not include information relating to the location of archived remains. This failure to include the archive location appears to have persisted across the developments of environmental archaeology databases. Not including a link to the physical archive location removes the recourse to retest, a cornerstone of the scientific process (Cleman 2014).

SEAD links to other databases, such as BugsCEP, which allows for referencing insect remains with modern proxies (Buckland 2011b). An additional benefit is its ability to allow for multiproxy analysis of multiple cross-platform datasets on the system, therefore not requiring the use of other programmes or software (Buckland 2011b).

The developers of SEAD are addressing the questions and topics such as transparency, open access, and how to encourage learning and reuse, topics that have until recently seldom been considered in archaeological data management and especially in environmental archaeological data management. The consideration of concepts as vital as transparency is a welcome addition to the environmental archaeology data ecosystem, but can a data handling service achieve transparency without acknowledging the location of the fossil evidence and a stated route to access the remains for research and re-evaluation/re-testing? In short, databasing in archaeology, especially environmental archaeology, has at times suffered from taking a data-heavy and theory-light approach. Unfortunately, this deficiency in archaeology is relatively common, as observed by Hugget in 2020.

> *We need to be more cognizant of the possibilities and risks associated with digital data and methodologies and the consequences that may flow, appreciating that they are not simple, straightforward, or capable of being set aside in the enthusiastic pursuit of data-driven solutions.* (Huggett 2020 p515).

How, then, is it possible to solve the challenges inherent in most databases that experience missing archive data whilst simultaneously providing open access and encouraging the use and reuse of the archived palaeoenvironmental resource? Regrettably, the architecture of relational databases means that they cannot easily have additional concepts added. If, however, the administrators of databases such as ArboDat or SEAD chose to overcome technical difficulties and add dedicated archiving concepts, it could, in theory, begin to facilitate the storage and dissemination of newly created and uploaded data. However, there are further challenges in updating and backfilling existing database entries with relevant archive data, most notably the time taken to undertake this operation and the consequential cost implications. A further issue is a risk of duplicating the task of backfilling data in instances where the same data from the same site appears across multiple databases, for example, a database that deals with insect remains, and another that deals with plant remains. The final matter is that individual specialists update the currently used environmental databases rather than the contractor, making monitoring compliance and suitability to the HIAS more complicated.

In terms of encouraging the use and reuse of data, the new generation of environmental archaeology databases such as SEAD offers exciting means to share data across other semantic web-based platforms. This level of functionality can enhance interoperability using internationally accepted data aggregators, making accessing and reusing data more manageable and providing opportunities to make collections greater than the sum of their parts. As environmental archaeology databases with sharing capabilities are embraced, potentially unforeseen challenges may be encountered. Crucially, data aggregating tools such as Zoobank, GBIF, Genbank will not accept accessions without a link to the institution that holds the specimen and a link to the physical remains themselves. This topic will likely grow in importance as genetic research within archaeology grows in significance as a new generation of methods is embraced. As the field of archaeogenetics develops, the need for access to archived material will also increase, making the topic of palaeoenvironmental archiving an important topic in the future.

The museum holding the samples must also be registered with the aggregator service. Moving towards this level of functionality could prove highly problematic for a domain that has only intermittently provided archive location information within databases.

Conceptual Relational Models

Developments within environmental archaeology databasing have used conventional forms, most notably the relational model. Within the museum sector, developments have been extending beyond traditional forms of data management, such as Conceptual Relational Models (CRM). CRMs can be used as a tool to extract information and provide missing links between museum databases. This tool could be used to link multiple databases creating an opportunity to share data from a variety of existing sources. This has exciting ramifications for archived palaeoenvironmental remains and the linkages that could potentially be made between archives and archaeological databases.

In the early 1990s, the International Council of Museums (ICOM) recognised that museums and libraries were being encouraged by a raft of stakeholders as diverse as the public and politicians to use the burgeoning potential of the internet to disseminate information relating to their contents (Gill and Miller 2002; Doerr 2009). Consequently, a wealth of material was created using a localised database schema, each containing domain-specific concepts (Gill 2004). Each of these databases was developed with their own ontology, which can be large and idiosyncratic, meaning that data between the ontologies could not be interrogated across each descriptive schema (Doerr and Iorizzo

2008). Without a consistent ontology that extends across libraries, museums and archives, the Semantic Web applications are ineffective and unable to allow for interoperability and cross-domain discovery (Gill 2004; May 2017). To confront this sizable challenge, the Committee of the International Council of Museums (ICOM) began work on the International Committee for Documentation (CIDOC) Conceptual Relational Model (CRM) in 1996 (Doerr 2003). The CRM was designed to provide mediation between localised schema and distinct databases to allow for a global tool that can interrogate all cultural heritage data (Crofts and Doerr 1999).

The CIDOC CRM is a knowledge organisation system (KOS) which handles gazetteers, taxonomies, ontologies, thesauri and classification systems that can be human and machine read (Guarino 1998). Using Semantic Web principles, the CIDOC CRM seeks to provide semantic interoperability by introducing a standardised core ontology that is relevant to cultural heritage practitioners (Doerr 2003, Richards 2006a). The ontology is semantically rich – meaning all information is correctly formatted and contextually diverse – and can provide data harmonisation through contextual relationships rather than typical object fields in relational databases (Oldman *et al.* 2016). Structurally, a formal ontology contains classes, subclasses, properties and individuals (object and datatype) and in the case of the CIDOC CRM has a hierarchy of 86 classes/entities and 137 properties which have been devised bottom up by understanding what concepts are significant to cultural heritage (Gergatsoulis 2010; Pasha and Sattar 2012). Therefore, the descriptive schema utilised by museums and archives will bear sufficient overlap of elemental concepts through the classes and entities (Gill 2004). These include diverse concepts that include people, events, places, and objects, and although diverse, all share universal interrelationships allowing them to be cross referenceable (Doerr 2003*;* Gill 2004). Consequently, the CRM ontology is regarded as being event-based rather than data-driven (Cripps *et al.* 2004).

To improve the utility of the CIDOC CRM and semantic interoperability, there have also been calls for shared terminology systems and thesauri used across museums, libraries, and archives (Doerr 2003). Using controlled vocabularies can allow complex KOS to organise concepts through semantic relationships. If controlled through agreed thesauri, domain vocabularies can provide easier interaction and searches across different schema (Tudhope *et al.* 2008). Consistency of terminology in combination with semantic interoperability, such as the CRM can begin to build comprehensive interrogable models. The introduction of defined vocabulary expected to be used by practitioners that interact with the CRM would, in all likelihood, require a degree of training. The costs involved in identifying training require consideration.

Extended versions of the CRM and CIDOC CRM and archaeological practice

Multiple CRM extensions have been developed that are domain specific. Today, specific extensions relating to archaeology have augmented the CRMsci. CRMsci is "*a formal ontology intended to be used as a global schema for integrating metadata about scientific observation, measurements and processed data in descriptive and empirical sciences such as biodiversity, geology, geography, archaeology, cultural heritage conservation and others in research IT environments and research data libraries*" (https://cidoc-crm.org/crmsci/home-1). A research group have used CRMsci and extended the CIDOC-CRM ontology to include datasets specific to the domain of archaeology (Cripps *et al.* 2004; Faniel *et al.* 2010). The outcome was the CRM-EH, an extended CRM that included 125 extension subclasses and four extension sub-properties (Binding *et al.* 2010). Critically, the CRM-EH was developed to use the event-based methodology and "*is based on the archaeological notion of a context, modelled as a place, from which a series of archaeological events have removed the constituent context stuff. It includes entities to describe stratigraphic relationships and phasing information, finds recording and environmental sampling*" (Binding et al. 2008 pp 3). The terminology the CRM-HE used to ensure consistency was the FISH thesauri, an agreed vocabulary of terms used within cultural heritage management and archaeology (http://www.heritage-standards.org.uk/fish-vocabularies/). The FISH thesauri are linked to the Simple Knowledge Organisation System (SKOS), a recognised standard that supports the organisation of classification schemes and thesauri (Binding *et al.* 2008; Binding 2010). The CRMarchaeo has supplanted the CRM-HE. CRMarchaeo is an internationally approved standard that can allow for the plethora of excavation methods and standards that exist across the globe (Doerr *et al.* 2020). CRMarchaeo has not been completed yet, and the graph database query portal is not yet available for use.

Other innovations in the blending of archaeology and CRMs include collaborative work with the University of South Wales and subsequent development of the Semantic Technologies for Archaeological Resources (STAR) and Semantic Technologies Enhancing Links and Linked data for Archaeological Resources (STELLAR) projects using CRM ontology to enable web-based tools to allow searches across multiple sources (Richards 2017). STAR was designed to enable semantic interoperability between multiple databases that handle grey literature reports using a cultural heritage ontology (Harrison *et al.* 2017; Binding *et al.* 2008). STELLAR uses the STAR standards of grey literature extraction by articulating excavation data in terms of the CRM ontology, that can provide these representations as linked data (Tudhope et al. 2011). What this means is that STELLAR can extract key concepts and datasets from OASIS reports and deposit them in a store without using the full ontological model using only common archaeological concepts. When sufficient archive-related data has been included, this sophisticated method could be augmented to extract archive data from OASIS reports (Tudhope *et al.* 2011).

In conclusion, the developers of the CRM standard and those who have taken on the mantle to produce domain-specific CRMs are attempting to realise the equally ambitious vision of Burners-Lee's concept of the Semantic Web (Berners-Lee *et al.* 2001). The efforts that have gone into the creation of CRM-EH/CRMarchaeo deals with excavation data have painstakingly identified subclasses and concept-driven glue that brought archaeological practice directly under the umbrella of the CRM family. How, then, could a CRM benefit archaeological palaeoenvironmental archiving and can CRMs provide semantic interoperability between the disparate data sources and, crucially, do archaeological palaeoenvironmental remains require a devoted CRM? Designing and delivering a dedicated CRM would likely require multiple academic partners, prove labour intensive, and would no doubt prove prohibitively expensive. Beyond matters relating to the financial cost, the challenges that face the disparate nature of palaeoenvironmental data do not require event-based semantic interoperability, and such a facility would be too extravagant for the needs of palaeoenvironmental archives. Data relating to archived remains that extend beyond the FAIR principles are either identifiable in linked bibliographies or on emerging databases that handle archaeological palaeoenvironmental data.

Although the development of a dedicated CRM for archived palaeoenvironmental data is too elaborate for its needs, there are positive aspects that can be taken from the CRM and the archaeological extensions. For example, STAR and STELLAR have successfully extracted data from the OASIS index and museum data satisfactorily (Tudhope *et al.* 2008; Tudhope *et al.* 2011a; Tudhope *et al.* (2011b). The data from the selected sources could potentially provide information about archived palaeoenvironmental remains that could be used to populate a relevant database. If a new relational database was developed, CRM or STAR could be used to, at least partially, automate the data collection process, saving a great deal of time in manual data input. An obvious, but major stumbling block related to the CRMs, is that it can clearly only extract information that has been digitised, and critically, is consistent. During the search through documents in the South-West Heritage HER (further detailed in Chapter Five), and a search through the digitised versions of these reports would not be able to provide consistent domains that could be searched. Where absences exist in published and collated data, physical archive searches would need to be performed and the data would need to be backfilled manually.

Additional benefits of CRMs and STAR include the adherence to structured terminology and the inclusion of pick lists. Future databases developed to deal with data relating to archived remains could be completed using FISH thesauri and picklists with appropriate terms to ensure cross-referenceability and can enable quick and simple entry.

CRMs could be a useful tool for collating digital data across multiple collections and can backfill information in a way that cannot be achieved with a relational database. There are, however, currently no dedicated ontologies for archived palaeoenvironmental remains. With the absence of dedicated ontology, alternative options in natural history are examined in the following part of the thesis. Data sharing in natural history has been the focus of recent innovations, and given the shared ecological focus of archived palaeoenvironmental remains, aspects of natural history museums and herbaria are examined for potential insight.

Natural history museums and FAIR principles

Natural history museum collecting and archiving archaeological palaeoenvironmental remains share many methodological and practice-based similarities (Evans and O'Connor 1999; Walls *et al.* 2014). Furthermore, whilst archaeological palaeoenvironmental remains may not have been collected for strictly archaeological purposes, many will have been collected for geological or biological reasons but still demonstrate future archaeological potential. Whilst museums collect plant and animal specimens from historical contexts or live trappings, archaeologists recover plant and animal remains from archaeological contexts, and challenges in preserving biological materials in perpetuity share similarities (Hope *et al.* 2018; Amand 2020; Bedford 1999; Brown 2011). Despite these similarities, natural history museums have advanced their techniques in preserving and promoting biological remains, given their remit for taxonomic, phytogenic, and genetic research and their long legacy of collecting and preserving biological materials (McGhie 2019). Recent advances in disseminating and sharing biological collections have advanced biodiversity science which often relies on museums and is inspiring a project revisiting old collections (McGhie 2019; Schindel and Cook 2018; Lendemer *et al.* 2020). Therefore, natural history practices and developments in biodiversity science data sharing innovations are examined to identify potential best practice methods in storing and disseminating data relating to their biological holdings and determine if archaeological data could be used similarly.

There are many similarities between biodiversity science and environmental archaeology. Environmental archaeology can be summarised as the study of the ecological relationships of past human communities and the interaction between people and the environment through time, whereas biodiversity science examines human activities and ecosystem function, linking the social, economic, and environmental domains of sustainability (Evans and O'Connor 1999; Niesenbaum 2019, Walls *et al.* 2014). Further evidence of the similarities can be found in the cross-over of research topics which mutually include research topics such as species invasions (Borroto-Paez and Mancina 2017), climate change (Fernandez *et al.* 2015) and disease ecology (Jolles and O. Ezenwa 2015). A key difference, however, exists between archaeology and biodiversity science, the value placed on collections. In most biosciences, collections are regarded as a cornerstone of research, as succinctly expressed by Bakkes and Urban.

> *"The combination of taxonomy and biological collections underpins the foundations of biology in general, for, without either of the two, biology would not exist as a research discipline."* (Bakkes and Urban 2014. Page 8)

Further evidence for the vital role collections play in biodiversity science is apparent if we look to the United States, where significant financial investments for initiatives secured through government agencies such as the National Science Foundation (NSF) are utilised to digitise and disseminate biological collection data (Monfils *et al.* 2017, Beaman and McCartney 2020, Hedrick *et al*. 2020). These investments have strengthened and built strategic relationships, identified gaps in collection data, and promoted discovery (Webster 2017, Lendemer *et al.* 2020). These advances have been achieved by reimagining the capabilities of biological collections by transforming individual repositories of isolated specimens and assemblages into cohesive interconnected research tools in their own right, capable of geospatial and temporal monitoring of biodiversity, infectious diseases, habitat loss and pollution events (Page *et al.* 2015, Soltis 2017, DiEuliis *et al.* 2016, Funk 2018). Using linked collections and digital web-based tools, it is possible to integrate information held on an institute's relational database, link to other platforms and cross-reference these with environmental data, observation data, ecological data, geographic data, and satellite data (LeFebve 2019). Initiatives that standardise the methods and tools that can share and interrogate data to engender learning and knowledge creation are extended to how researchers can investigate biodiversity.

The Extended Specimen Network

The most successful of the recent initiatives is the Extended Specimen Network (ESN). It was first posited to exploit enhanced data from single avian specimens by linking the physical specimens with data such as images, behaviour, species interaction, and geographic range via links provided by data aggregating services (Webster 2017, Lendemer *et al.* 2020). Subsequently, the ESN has been adopted by the Biodiversity Collections Network (BCoN) and has been extended to non-avian specimens enabling the study of how organisms grow, diversify, and interact with one another and crucially examine how environmental change and human activities may affect those organisms. The updated holistic aim is to:

> *"link physical specimens to the data derived from them, such as gene sequences, images, behaviour, and species interactions, we can better define and understand the traits that comprise an organism. Such information has direct benefits to society and quality of human life, including how zoonotic diseases are transmitted and controlled, how crops can be more effectively and efficiently grown in changing climates, and how we can sustain and use biological resources in our ocean"* From BCoN (Biodiversity Collections Network 2019).

In practice, the ESN maintains the physical specimen central to the network and, critically, does not purely rely on recorded data (Lendemer *et al.* 2020). Instead, the specimens are linked to extended attributes such as genetic or isotopic data, phenotype information and environmental data available as field notes, videos, genetic code, audio recordings, or CT scans (Ellwood 2020). Open access data aggregation services provide links to the extended media (LeFebvre *et al.* 2019, Biodiversity Collections Network 2019). Data aggregator services can archive and share a variety of data, including new nomenclature (Zoobank), entire genomes (Genbank), morphometric data (Morphbank), biodiversity data (GBIF) and stable isotope data (Isobank) (McGhie 2019; Schindel and Cook 2018; Monfils et al. 2017; Pauli *et al*. 2015; Benson *et al.* 1997; Robertson *et al.* 2014). Using open access data aggregators provides the added advantage of placing archived specimens into FAIR (Findability, Accessibility, Interoperability, and Reusability) guiding principles, allowing for the discoverability of remains to specialists and non-specialists alike (Wilkinson *et al.* 2016; Boeckhout *et al.* 2018).

The ESN is used by natural historians and biodiversity scientists and is beginning to add long-term vision and enhanced networks to bio-collections by creating comprehensive links between individual specimens and collections via digital data aggregators while maintaining the specimens themselves central to the digital ecosystem (Guralnick and Constable 2010, McGhie 2019, Stills 2014). An initiative such as the ESN can enable greater opportunities for sharing of data and provides opportunities to find research gaps whilst enhancing the value of ecological specimens. Adopting ESN principles in the domain of archaeology could allow for cross-pollination with other disciplines, enabling environmental archaeology to broaden its capacity to participate in conversations regarding sustainability, biodiversity, and nature conservation. A key question, however, is *can* the ESN principles extend into archaeology and are the inclusion of such principles is necessary? On an international scale, the answer seems to be yes, with archaeology museums in Norway and Florida beginning to include their environmental archaeology collections and archives on international data aggregator services. In England, current protocols in digital archiving do not dictate that uploading information to data aggregators should be included, and it is currently unclear to what extent they are voluntarily used. Without knowing the quantity to which data aggregators are used, it is challenging to determine archaeology's readiness to have links to data aggregators as part of a database system should be a priority. To determine if external data aggregators are a priority, a study of archaeological and bioscience publications is offered to determine if data aggregators are used and if a new service needs to consider links.

An examination of the use of data aggregators in archaeological science

The following part of the chapter attempts to understand to what degree archaeological science uses data aggregators by comparing their frequency of use by examining articles published in archaeological and biological sciences. Articles covering ten years of publishing for the four journals were downloaded, and terms were searched by year of publication using Adobe Acrobat advanced search. The search terms were designed in such a way as to produce three distinct groups of information:

1) The first search determined the frequency of collection using the search terms 'museum' and 'collection'. These terms took into account samples or specimens housed in museums, herbariums, universities, online databanks, or could be privately owned.

2) Next, each occurrence of 'museum' or 'collection' was assessed to determine if the material was analysed as part of a new study or used as comprehensive reference material. To ensure consistency across all four journals, occurrences of reference collection were discounted, and only those samples and specimens used in new studies were counted.

3) A search determined the use of data aggregation and data bank services in the biosciences and archaeology. This was achieved by searching for occurrences of data aggregator use. Commonly used data aggregators such as **Genbank, Zoobank, Vertnet, Gbif, Massbank,** and **BOLD** were selected. A differentiation was made between aggregators used

to access archived samples and those used to deposit data into the archive. UK-based data sharing services such as **ABCD, ArboDat, ADS**, and **OASIS** were additionally searched to determine with what frequency databases and data sharing services are referenced in archaeological articles. These terms were entered into adobe search, and each article was analysed for occurrences of the term.

Additional data handing measures included filtering non-research-focused papers to make the scoring more reliable and accurate. Therefore, the following category of articles was considered superfluous and removed from the potential dataset from all four journals. These included publisher notes, introductions to special editions and conference and symposium reviews. *The Journal of Archaeological Science* was subjected to additional filtering to remove non-environmental topics such as geo-archaeology, ceramic petrography, materials analysis, and developments in scientific dating techniques.

Limitations in the search

British spellings of words were maintained throughout the study for consistency. The spelling of foreign institutions such as museums was not included, but similarities in spellings existed, such as the French spelling *Musée*, or the Spanish spelling *Museo*; it still provided a positive result due to the similarities. However, the Hungarian spelling of museum, which is *muzeum*, and the Romanian, which is *muzeu,* for example, do not share enough similarities to be identified and would not be included.

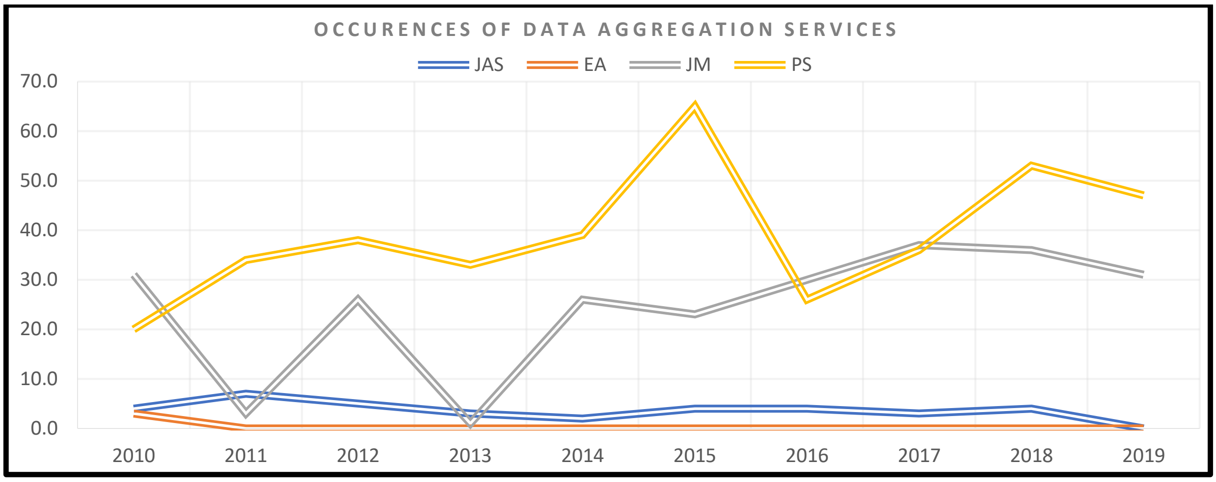
Results

In total, 3750 journal articles from four journals published between 2010 and 2019 were analysed for responses to the selected search words. Therefore, the total number of journal articles published each year is supplied in table 11.

Journal title	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
JAS	66	57	73	69	77	67	35	24	37	21	526
EA	12	13	12	18	22	29	34	29	32	30	231
JM	143	128	138	132	109	126	147	161	131	130	1345

PS	110	136	156	115	150	196	179	149	207	250	1648
											3750

Table 11. Filtered journal articles published each year from 2010 up to and including 2019. Journal of Archaeological Science (JAS), Environmental Archaeology (EA), Journal of Mammalogy (JM), Plant Science (PS).



Graph 5. The total occurrence of data aggregator use over 10 years (2010-2019) across four journals. The percentage of positive occurrences is expressed along the Y axis as annual occurrences of data aggregator use. Journal of Archaeological Science (JAS), Environmental Archaeology (EA), Journal of Mammalogy (JM), Plant Science (PS).

Over ten years, the occurrence of data aggregators in published articles across the four journals demonstrates that data aggregators are used to deposit and retrieve information with much greater frequency by the non-archaeological biological sciences. In total, the journal Plant Science uses data aggregators in 23.7% of the journals, and 18.1% of articles in the Journal of Mammalogy used aggregators. However, when occurrences are amalgamated, the two archaeology journals use data aggregators with less frequency, the Journal of Archaeological Science uses aggregators in 4.84% of the articles, and Environmental Archaeology demonstrates data aggregator use in only 1.3% of the articles (graph 5).

The reasons that support data aggregator services playing a more significant role in biological sciences are unclear but may lie in the philosophy that underpins natural history collections, that the type specimens on which original identification and description were based should be accessible and available for re-testing and experimental repeats. This fundamental principle has likely developed within practices into the age of Big Data and still places the specimen central to the enquiry. Alternatively, the reasons for greater reliance on data aggregators could be more administrative and could relate to whether a museum has registered with the data aggregator service. For example, natural history museums are signing up for services such as GBIF, a commonly used tool in this domain, but it is much less recognised in archaeological circles.

Chapter Summary

Existing relational databases that could be modified to offer information relating to the archived palaeoenvironmental remains include those specific to the domain of environmental archaeology and online museum resources. Including detailed data pertaining to archived remains in an online museum context would be incongruous and inappropriate amongst content aimed at a general audience. Environmental archaeology databases would be an appropriate venue for information relating to the physical remains. Linking the physical remains to the existing attribute data would achieve greater transparency and bring archaeological practices in line with biological science. This potential solution would result allow for retesting, validating and further developing experiments and contribute to the aims of the Heritage Information Access Strategy. Whilst being an attractive option as a solution, it is mired in debilitating challenges. Adding new domains to existing relational databases is complex and, if achieved, would require backfilling with data to leverage the most significant potential value. The process could involve the double handling of data by inputting archive data from the same excavation across multiple platforms.

The updated version of OASIS, OASIS V is embracing the opportunity to bridge the gap between a museum, contractor and HER by providing open access to the form and making it viewable to all parties. It is expected that better archives can be created by making the process more transparent and inviting museums into the process (Pillatt *et al.* 2020). Another development of OASIS V is the addition of the OASIS + modules. These provide open access platforms to facilitate the storing and sharing of data specific to a specialist domain. As a tool that can satisfy the challenges inherent in storing and communicating data relating to physical archived palaeoenvironmental remains, a dedicated module is arguably the most elegant solution. The module could include a simple range of concepts filled in by the group or organisation conducting the fieldwork as part of the OASIS process. To leverage the greatest value out of the module, existing archives and legacy archive data would need to be added to the database. This could partially be achieved using a CRM, extracting the necessary data from OASIS grey literature reports and museum databases. Likely, there would still be a shortfall in data, especially from pre-1990s excavations reports that are inconsistent in information relating to archiving practices. Where data cannot be identified, it would require a bottom-up approach that requires a museum audit to retrieve the information and input it manually.

An additional benefit of a dedicated OASIS + module is its ability to offer cross-platform linkages. This facility would allow for existing environmental archaeology databases to provide links to the site or individual sample and reference the location of the fossil evidence, rather than relying on taking published sources at face value and providing opportunities for repeatability. Having the option to include data aggregators can allow the data to be shared alongside biodiversity data. The survey of published sources demonstrated that the use of data aggregators in archaeological practice is low compared to biological sciences, but a reason for the relatively low uptake could be linked to the fact that providing links to the physical remains, a prerequisite of using many aggregators, has been absent. Links between environmental archaeology databases, a dedicated OASIS module and international databanks would open opportunities for interoperability and sharing, especially in biodiversity.

Chapter Seven – The Creation of Archaeological Palaeoenvironmental Archives

Introduction

An aim of the doctoral research is to confront the archaeological archiving challenges specific to archaeological palaeoenvironmental material in England (see Chapters One and Two). Of the myriad challenges that currently confront archaeological archiving, an array of these can be satisfied by the introduction of critical forms of archive creation, such as those advocated by the Perrin *et al.* (2014) in A *Standard and Guide to Best Practice in Archaeological Archiving in Europe* and in the CIfA/Historic England Toolkit for Selecting Archaeological Archives (referred to as the Selection Toolkit throughout) (CIfA/Historic England 2019). Repeatable and monitorable archive creation methods that extend across the life of an archaeological project can assist project stakeholders to determine relevant constituent parts of an archive and identify any conservation needs (CIfA/Historic England 2019, Perrin *et al.* 2014). By operating a well-conceived selection strategy with stakeholders' opinions and up-to-date standards and guidance, it should be possible to make judgements to enable the filtering of redundant information to create relevant archives that can increase the potential for use (CIfA/Historic England 2019). Additionally, selection strategies can simultaneously promote cross-sector collaboration and address critical challenges confronting archaeological archiving (Boyle *et al.* 2016, Smith and Tindall 2012).

The Challenges Confronting Archaeological Archives

Archive Creation, Selection and Retention Reports and Publications

In addition to national/international agencies and chartered institutes that have drafted multiple standards and guidance, stakeholder groups have also conducted exploratory surveys and reports to understand archiving practices and identify how their community and cross-sector collaboration can improve the archiving process. Three groups that have been motivated to improve archiving practices are museums and repositories, local government archaeologists and specialist interest groups, all of which have produced reports that examine how improvements to selection and retention can positively affect their working practices and improve reference material for research. A selection of these reports and outcomes produced by stakeholder groups are examined to determine what conclusions can be applied to archaeological palaeoenvironmental archiving.

Museums

Museums in England produce their own standards for archaeological archiving. These archiving standards documents are undeniably helpful guides and provide practitioners with requirements specific to that institution's capacity and facilities. However, they are often varied in the quality and insight they offer (for examples, see Birmingham Museums' *Archaeological Archive Standards* Lewis *et al.* (2019) and Northamptonshire Archaeological Resource Centre's *Archaeological Archives Standard* (Donnelly-Symes 2020). The variable standards are a consequence of limited access to specialist skills and knowledge, a resource that has become increasingly difficult to source with museum specialist staff shortages due to recurrent budget cuts (Mendoza 2017). The pressures that factors such as skills shortages and budget cuts contribute to problems of archive creation have been examined by the Historic England/Society for Museum Collecting Reports and are briefly examined below.

The Historic England funded Society for Museum Archaeology reports produced by Edwards (2013) and Boyle *et al.* (2016, 2017, 2018) examined museums' collecting capacity in England and quantified the attrition to services and skills because of budget and staff cuts. Albeit briefly, these reports examined tasks linked to collection practices, such as selection and retention. Interestingly, the Edwards (2013) report observed that the absence of specialist knowledge in museums demonstrates how collaboration is necessary to improve selection and retention and determine what is relevant for future deposition.

> *Selection and retention need to be considered both in relation to existing museum collections, and to archives for future deposition. In relation to existing collections levels of expertise are relevant. Museums with no archaeological expertise in house would need expert advice and assistance. There could potentially be a role for period and artefact special interest groups, but funding would need to be obtained. In relation to the creation of archives for future deposition, this is an area where collaboration between all parties is required, to ensure agreement between museums, archaeological contractors and planning archaeologists on what is appropriate* (Edwards 2013 pp. 46).

The Edwards comment highlights the unpredictable levels of expertise in museums and emphasises a reliance on specialists and specialist interest groups for input regarding selection, ensuring that they are asked to provide recommendations for retention and discard.

Local Government Archaeologists

The views and opinions of local government archaeologists regarding archive procedures are examined in *Planning for Archives: Opportunities and Omissions* report (Donnelly-Symes 2019). The report was motivated by the outcomes of the Mendoza Review (2017) and the Howell and Redesdale (2014) report into Local Government Archaeology. A survey conducted as part of the *Planning for Archives* report (Donnelly-Symes 2019) revealed that 65% of Association of Local government Archaeological Officers (ALGAO) England members would expect Written Schemes of Investigation (WSI) to reference archive creation information such as selection strategies. This number could be considered as being rather low, if we consider that the use of the Selection Strategy Toolkit is a requirement of being a CIfA Registered Organisation. Involvement at the WSI stage is a salient suggestion, but unfortunately, the report identified that the project design stage engagement with archiving is rare, with only 18% of survey respondents revealing that selection was being considered at the project design. Whilst the *Planning for Archives* report (Donnelly-Symes 2019) also revealed that the ALGAO England members surveyed believed that archaeological archiving is a topic that requires further guidance, it should be noted that at the time of publication, the Selection Toolkit was not published.

Specialist Interest Groups and the Archive Selection Process

Individually, a specialist's involvement primarily offers advice on what to retain for long-term storage and can also work with other stakeholders to offer expert advice regarding specific remains, with their interpretation and input extending to public outreach or museum display (CIfA/Historic England 2019). Collectively, specialists within archaeology have collaborated and included archiving and selection guidance in best practice guides including ceramics (Barclay *et al.* 2016) and faunal remains (Baker and Worley 2019) The level of archiving and selection advice offered by best practice documents varies between the groups. This variation is briefly examined using Historic England best practice guides that focus on environmental archaeology and archaeological ceramics (pages 189- and 190 respectively).

Environmental Archaeology

Historic England has produced multiple best practice guides within the umbrella of environmental archaeology. Within these guides, there is a variation in the amounts of space dedicated to considerations regarding archiving. For example, the archaeological faunal remains guides clearly outline that archive consideration should begin at the project design stage and continue throughout the project (Baker and Worley 2019). The guide also contains case-studies that reuse archived data, presenting the benefits of well-managed archives.

Comparatively, the Historic England *Environmental Archaeology: A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-Excavation (second edition)* (2011) does not detail selection or aims for archive creation. The only indication of archive creation is as follows.

> *"Decisions on what to include for archiving should be made in consultation with the specialist, the project manager and the archive repository".*

The absence of selection advice in the Historic England environmental archaeology guidelines is perhaps to be expected, given the wide range of information the document is meant to promote.

Archaeological Ceramics

In the example of archaeological ceramics, multiple period-specific groups have collaborated to produce best practice guides that include selection advice that covers the best practice for treatment and transfer, but interestingly, also promoted the development of curated pottery type series (Orton 2004, Historic England 2015a). Explicit guidance in documents such as *Archaeological and Historic Pottery Production Sites: Guidelines for Best Practice* (Historic England 2015a) recommends that "samples of new or unrepresented types should be offered to local, regional and national ceramic type series and reference collections" (Historic England 2015a).

Constructing regional and national reference collections and type series introduce multi-period consensus-driven aims that provide achievable goals, while concurrently promoting archiving values across the ceramic specialist network, is significant as it introduces aims that transcend project-specific needs. The introduction of a holistic archiving aim that surpasses the needs of a specific project is thought provoking. Are there overarching aims for archaeological palaeoenvironmental archiving that could improve archive selection? Is there, for example, a need to develop archives that represent a multi-temporal georeferenced biodiverse record in England? The potential need for holistic aims in archaeological palaeoenvironmental archiving is explored in greater detail later in this chapter and the in the discussion and conclusion.

Palaeoenvironmentally specific objectives

Using the Selection Toolkit benefits as a basis, a chapter objective has been designed to investigate how the selection of archaeological palaeoenvironmental materials for archive selection is approached. The Selection Toolkit is regarded as the preferred source to develop chapter objectives as it has been compiled using some of the most prominent published selection guides, including *A standard and guide to best practice for archaeological archiving in Europe* (Perrin *et al.* 2014), *Archaeological Archives: A guide to best practice in creation, compilation, transfer and curation* (Brown 2011), *Selection, Retention and Dispersal of Archaeological Collections* (SMA 1993), and is methodologically and theoretically up to date. The objective focuses on how the palaeoenvironmental components of an archaeological archive are created, engaged with, and establishing the efficacy of communication and collaboration between stakeholders respectively. Specifically, the objective has been developed using the following Selection Toolkit benefits (CIfA/Historic England 2019 pp. 1-2).

- Establish the relevance and potential of the material assemblages in the archaeological archive, and therefore increase the opportunities for promotion of, and engagement with, the Archaeological Archive.
- Enable a better understanding of, and preparation for, the preservation requirements of the Working Project Archive.
- Help ensure that all relevant procedures and guidance have been considered and followed at all stages of a project.

Methodology

The chapter objective is further explored through survey data collected as part of this doctoral research and has been used to examine the opinions and practices in the archiving of palaeoenvironmental, remains. The survey data is complemented by three case studies and an exploration of comparative aims in order to provide a combination of qualitative data and quantitative data. Survey data is supplemented by three case studies, they are as follows.

Part one - seeks to examine specialist/archivist involvement in archive selection. The survey data is supplemented by case study one.

Case-study one: The 2004-2014 excavations and supplementary research conducted at Star Carr, Yorkshire, as part of the POSTGLACIAL - This project was selected due to the abundance of biological remains recovered during the project and the decisions made in creating the archive.

Part two - investigates when in the project cycle, specialists consider selection. Part two is supplemented by case study two.

Case Study 2: Greatham South Flood Alleviation Scheme, Stockton on Tees - Archaeological Excavation. The Greatham case study was selected because of its missed opportunities for access and display due to failings in the selection and archiving strategies.

Part three - Examines the guidance and standards used by specialists. Part three is supplemented by case study three.

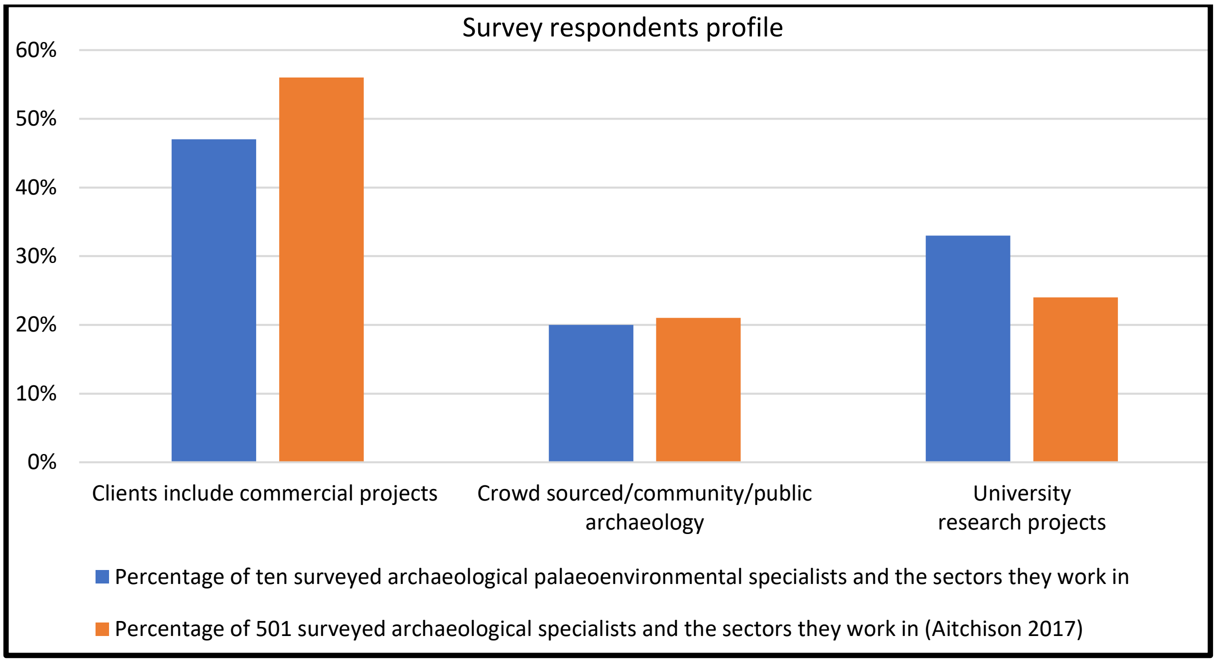
Case study 3: The East Midland Historic Environment Research Framework - this has been selected as a case study to determine if research frameworks could be used as a platform to guide how the palaeoenvironmental component of archaeological archives are compiled.

Survey Methodology

Survey data was gathered via an online Google Forms survey. The ten-question survey was distributed to a combination of specialists. The specialists focused on palaeoenvironmental remains including charcoal, plant macrofossils, pollen, shell remains. In addition to specialists archive managers from the most prominent market providers of archaeology and heritage services, including AOC, Headland Archaeology, Oxford Archaeology, Pre-construct Archaeology, Wessex Archaeology, York Archaeological Trust were asked to contribute. To encourage participation, anonymity in the survey was offered as an option. Of the 18 independent and contracted specialists, academics and archive managers, ten responded.

Profile of Survey Participants' Client Base

A combination of in-house specialists that focus on archaeobotany, wood and charcoal, who work for heritage/archaeology consultancies, independent specialists and archive managers were requested to participate in the survey. The survey participants were encouraged to choose, as many of the supplied options as necessary to represent their client base. The results of the survey are demonstrated as being broadly representative of wider professional activity, as demonstrated by the 2017 Aitchison survey of archaeological specialists. This is demonstrated in graph 6.



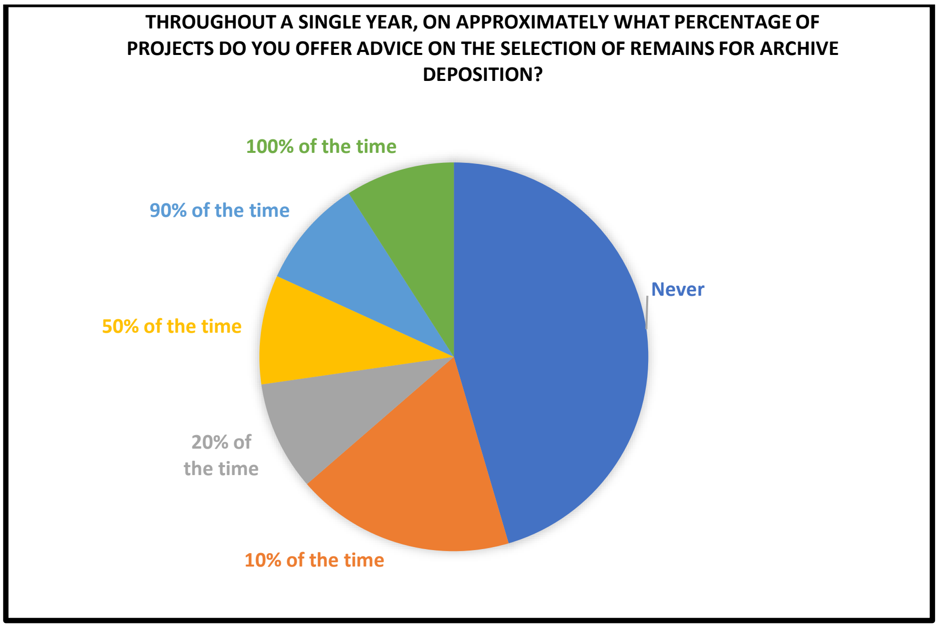
Graph 6. Graph 6 details the results from the ten specialists the profiled as part of the of survey and is compared to the composition of specialists and their professions across the wider profession as detailed in Aitchison *et al.* 2017.

Part One - Specialist/Archivist involvement in Archive Selection

To better understand how strategies and policies are adhered to in palaeoenvironmental archive creation, the frequency with which selection is considered, and the timing of such practices in the project cycle, is examined with survey data and case study examples.

Throughout a single year, on approximately what percentage of projects do you engage with the selection of palaeoenvironmental remains for the final archive?

Ideally, some form of a methodologically sound and repeatable archive selection process should occur on each archaeological project (CIfA/Historic England 2019). The process requires multi-stakeholder participation. Across the stakeholders, specialists are vital in the selection of palaeoenvironmental data. Their insight ideally positions them to offer valuable advice regarding future research and communicative value regarding the respective assemblages they have been contracted to analyse.



Graph 7. This graph demonstrates the annual rates of specialist and archive managers engagement with archive selection practices. Coloured labels indicate % of projects.

The frequency with which specialists and archaeological archive managers participate in the selection process has been determined by asking the respondents to quantify occurrences of engagement with the selection of remains. Respondents were given the option of answering in 10% increments ranging from 0% to 100% (Graph 7). 46% of respondents replied that they never (or <10%) provide guidance on what should be deposited over a year. The remaining respondents replied that engagement with the selection process ranges between 10% and 100% of the time.

This survey data offers an insight into the frequency that specialists and archive managers consult on archive selection. Participation in the archive selection process is overall low, but there are encouraging signs from some of the participants that suggest selection is considered with more regularity, up to 100% of the time. To glean insight into how the survey participants who regularly provide selection advice operate, case study data is included.

Case Study – Greatham South Flood Alleviation Scheme, Stockton on Tees. Archaeological Excavation

The survey provides quantitative data regarding the frequency that selection is engaged with by specialists. The survey examines an example from one of the survey participants to understand more about the selection process and how the palaeoenvironmental component of an archaeological archive is created and observe potential areas of best practice or improvement. This case study takes a closer examination of that selection strategy to determine if/how it meets the expected standards.

Archaeological works undertaken by the University of Durham were conducted in advance of embankment construction as part of a flood alleviation scheme at Greatham South, Stockton on Tees. The flood defence scheme was a £16m development that provides 48ha of natural freshwater habitat that protects seal species and birds (https://environment-analyst.com/uk/72004/16m-teesside-flood-scheme-delivers-48ha-of-new-habitats). A vital aim of the project stakeholders, who included the RSPB, Natural England, and Environment Agency, was to provide the public with opportunities to experience freshwater habitats that have been destroyed and displaced by the 19th and 20th century industrialisation in the North-East of England. The RSPB manages the newly developed habitat at the Saltholme Visitor Centre, located 2km south of Greatham (https://community.rspb.org.uk/placestovisit/saltholme/b/saltholme-blog/posts/interpretation-for-greatham-creek). The visitor centre facilitates public outreach and interpretation and hosts members of the public and visiting school groups for tours.

The archaeological works included i) targeted excavations, ii) strip, map and record and iii) archaeological monitoring. The project's most intensive aspects included the excavation of two salterns and recording a section across the old sea wall. The fieldwork was conducted throughout 2017, and the report and final archive were prepared in 2018 (Archaeological Services Durham University, 2018).

Throughout the archaeological fieldwork, palaeoenvironmental remains including pollen and foraminifera from column samples and waterlogged seeds, humified organic material, beetles, buds, and wood were recovered from bulk sampling a wide variety of features and deposits. The array of environmental evidence and the contractor's inclusion of selection advice lends the Greatham scheme to be included as an appropriate case study.

The results of plant macrofossil and pollen analysis indicate a wetland environment in the Middle Neolithic that can be characterised as an alder carr environment with constituents of oak, willow, and birch. Evidence from plant remains and foraminifera indicated that the alder carr environment persisted into the Bronze Age when fluctuating sea-level levels encouraged saltmarsh, tidal creeks, and mudflats. These results from the Greatham excavation did not reveal information that was previously unknown, but it does provide further physical evidence to the region's past environment and biodiversity.

The Greatham Selection policy

The final report offers an Archive/OASIS paragraph in the Project Background section. The report states that:

> The archive is currently held by Durham University and will be transferred to Durham HER and museum service in due course. The flots, charcoal and pollen preparations will be retained by the University of Durham.

The selection policy does not include quantitative data that reveal what material has been retained from the working project archive. Also absent is any information regarding whether waterlogged remains have been retained and what measures have been taken to store waterlogged samples. Rather, it seems that this palaeoenvironmental archive policy is used consistently by the contractor in all their reports.

Beyond the selection policy's quantitative element, there does not appear to be broader stakeholder interest in how the palaeoenvironmental remains could have been used to provide educational or display value. The prehistoric environmental proxies and their data could have been used at the Saltburn RSPB visitor centre as a medium to articulate five thousand years of environmental change and provide context to the aims of freshwater habitat creation. Could, for example, the plant macrofossils have been loaned to the RSPB and included in display or part of a school visit, adding to evidence-based learning experiences that can convey the environmental history of the Greatham wetland.

Overall, the Greatham project provides an example of a policy on selection but does not meet the recommendations of a selection strategy as advocated by Perrin *et al.* (2014) and CIfA (2019). For example, Perrin *et al.* states that “practitioners who were working with similar stakeholders in the future could benefit from identifying the potential of the archaeological works and the resulting archive potential at an early stage of the project and included archive aims as part of a cohesive end to end selection strategy rather than a standard policy” (Perrin *et al.* 2014 pp 25). As part of the Greatham project, there has not been a decision on what to keep, rather everything has been retained as part of a standard strategy. The Greatham example fails to achieve stages set out in the CIfA Selection Strategy toolkit, by not taking into account the aims and objectives of the project or any published frameworks or guidance documents (CIfA/Historic England 2019).

Part Two - When in the project cycle, do selection considerations take place?

The stages at which archive selection strategies are implemented play an essential role in successfully developing a final archive that reflects the aims of the project (detailed on pages 197-198) (Perrin *et al.* 2014, CIfA/Historic England 2019). This is particularly important for archaeological palaeoenvironmental remains. Their sometimes-complex storage needs require early consideration to determine the conservation needs of the remains (Milner *et al.* 2014). The unpredictable nature of archaeology means that archive selection needs to be monitored throughout the project to consider changing variables.

As highlighted by the ALGAO report (Donnelly-Symes 2019), local government archaeologists would like to see archive creation considerations occur at an early stage of the archaeological project. Perrin *et al.* (2014) and CIfA/Historic England (2019) state that archives should be considered throughout the entire archaeological process. Regarding the palaeoenvironmental component of archaeological archives, when considered alongside all the other remains that are recovered. it is unclear where this is considered.

The project stages are outlined below. Nomenclature follows CIfA (2019) and Perrin *et. al* (2014).

1 – PROJECT PLANNING (PROJECT DESIGN)

Task – Draft a selection strategy.

Personnel - Entire project team including the Project Manager, collections curator, local authority representatives, conservators, company archivists and named specialist.

Involves - Producing the selection strategy.

2 – DATA GATHERING (EXCAVATION/SAMPLING)

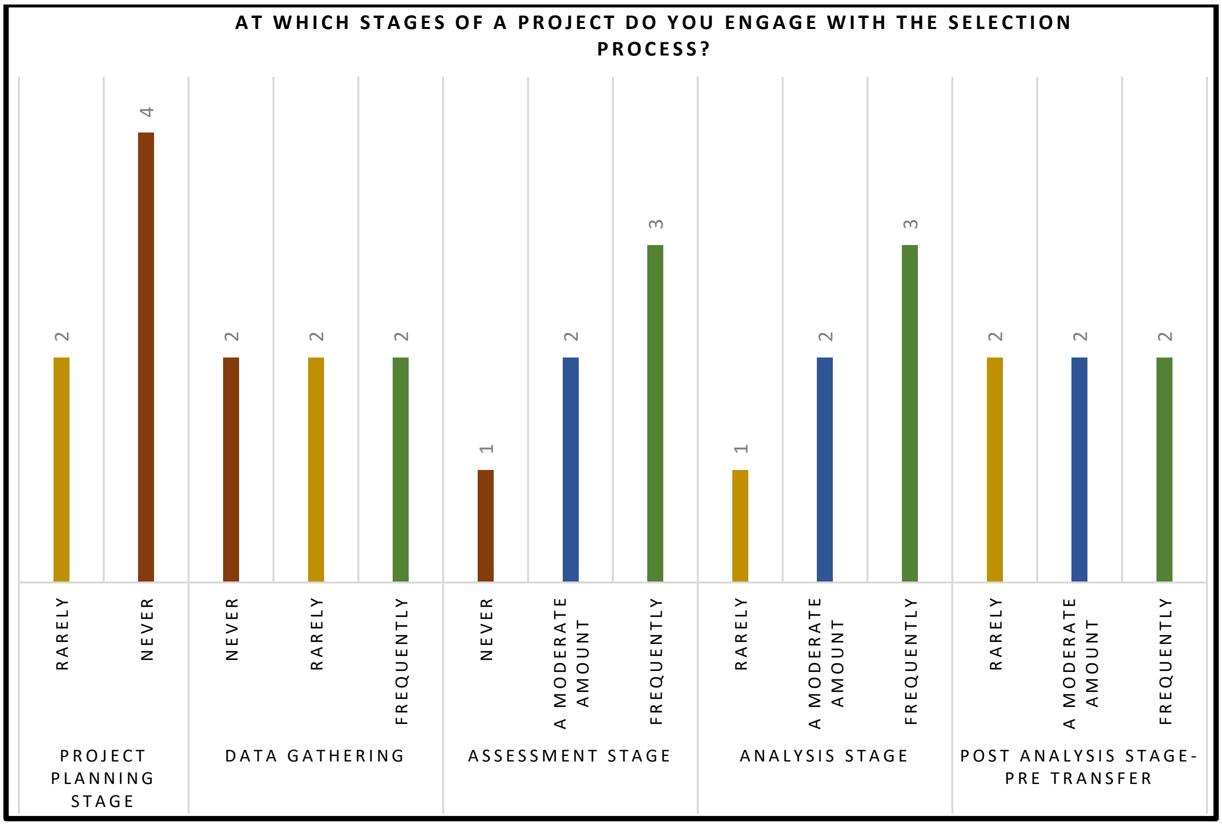
Task – Review and amend the implemented selection plan if necessary.

Personnel – Project Manager, Museum curator, local authority representatives, conservators, company archivists and named specialist, field staff,

Involves – Reviewing the implemented selection strategy and updating the strategy if circumstances dictate. Circumstances could include the recovery of unexpected remains. Operate de-selection where necessary.

Requires – Continued consultation with project aims and amendments to it.

3 – ASSESSMENT, ANALYSIS, REPORTING & ARCHIVE TRANSFER (EVALUATION-ANALYSIS-TRANSFER)
Task – Use gathered data to review and update the implemented selection plan.
Personnel – Project Manager, Museum curator, local authority representatives, conservators, company archivists and named specialist.
Involves – Reviewing implemented selection strategy and updating it using final gathered data. Deselection would also be carried out in this stage.
Requires – Continued consultation with project aims research frameworks.



Graph 8. This figure demonstrates stages in the project cycle do specialists and archive managers consider archive selection. The graph demonstrates that consideration regarding archive creation is most likely to occur at the analysis stage.

Published standards recommend that the selection strategies commence at the project planning stage and continue to be assessed and updated throughout the project's course (Perrin *et al.* 2014, CIfA/Historic England 2019). The six survey participants who responded that they offer selection advice were asked to provide more detail about the stages at which they engage with the selection process (graph 8).

The survey revealed that selection is only rarely considered at the project planning stage. The likelihood of selection consideration increases at the data-gathering stage and continues to increase up to the analysis stage – the stage of the process that is most likely to experience specialist involvement. During the post-analysis stage, there is a decrease in selection activities. The results of the survey indicate that selection does not occur throughout the life of a project.

Case Study Two - Star Carr POSTGLACIAL Project: A Case Study Examining the Development of an Archaeological Palaeoenvironmental Archive

Star Carr is an internationally significant site of Early Mesolithic occupation located in the Vale of Pickering, North Yorkshire (Conneller and Schadla-Hall 2003). The site is notable for the extensive area of occupation, the favourable preservation and diversity of palaeoenvironmental remains preserved within former lake sediments (Conneller *et al.* 2012; Gonzalez and Huddart 2002; Taylor *et al.* 2018). Discoveries in the early 2000s, including a large timber platform and the shallow footprint of a domestic dwelling, resulted in the site receiving scheduled status (list entry 1401425) (Taylor *et al.* 2017). Regrettably, Star Carr and the deposits around palaeo-lake Flixton are under threat by dewatering, resulting in the degradation of organic remains and microbial attack of the wooden artefacts (Boreham *et al.* 2011). The diminishing opportunities to retrieve organic remains place ever more significance on the value of the archived remains, which have become numerous and widely distributed across the region (Innes *et al.* 2011; Saul and Milner 2013).

The most recent excavations conducted at Star Carr - the European Research Council (ERC) funded POSTGLACIAL project - has been selected as a case study to examine a good practice example of archaeological palaeoenvironmental archive development. The case study examines the development of a palaeoenvironmental archive at a site experiencing sensitive conservation conditions. Of particular interest is the project's commitment to archive mapping – the process by which disseminated remains and documents from an archaeological investigation are located – and the active monitoring of conservation needs and archaeological archive selection throughout the archaeological process.

Discovery and early investigation

The site's archaeological potential was first recognised in the 1940s by amateur archaeologist John Moore (Mitchell 1955; Milner et al. 2018b). Moore's initial observations derived from freshly cleaned drainage ditches that revealed faunal remains and chipped stone alluding to the presence of Early Mesolithic occupation (Saul and Milner 2013). Emboldened by the discoveries, Moore excavated small areas around the former Lake Flixton, identifying apparent extensive areas of Mesolithic occupation (Moore 1954). The Moore excavation archive was deposited in the Rotunda Museum in Scarborough, North Yorkshire (Saul and Milner 2013). The deposited artefacts and ecofacts include barbed points, birch bark rolls, and chipped stone (Saul and Milner 2013).

Unfortunately, it is unclear if all the artefacts were deposited, and no supporting documentation appears to have been included with the archive.

Clark and the University of Cambridge

Sir Harry Godwin, who became acquainted with Moore through a shared research interest in the Vale of Pickering, informed Cambridge colleague Professor Graham Clark of Lake Flixton's waterlogged conditions and archaeological potential (Milner et al., 2018b). Clark was searching for site with well-preserved deposits to apply new approaches focusing on site economy and environment and became interested in the prospect of investigating Star Carr (Saul and Milner 2013; Milner et al. 2018b; Milner et al. 2013). The site was first excavated by Clark and a team from Cambridge in 1949 and was returned to over the two following years (Clarke 1949; 1950).

The excavation revealed the exceptional preservation of waterlogged remains, including an array of artefactual and environmental evidence, including faunal remains and antler, over 1000 worked fragments of flint, beads, birch pitch, birch bark, pendants, iron pyrites, pebbles, and wood (Saul and Milner 2013; Clarke 1949; High et al. 2016). Clark's 1954 monograph indicates that the final archive has been distributed to the following museums for long term storage (Clark 1954):

- The British Museum - stored in the Natural History Collection, the Department of British and Medieval Antiquaries at Bloomsbury and Frank's House.
- The Natural History Museum, London
- The Rotunda Museum – stored in the Scarborough Museum Trust at Woodend, Yorkshire.
- The University Museum of Archaeology and Ethnology at Cambridge.

In the years following the excavations, portions of the archive have been loaned to other museums, including Whitby Museum, Hull Museum, the Yorkshire Museum, and the National Museum of Ireland. The loans were for research and display purposes (Saul and Milner 2013).

Except for the birch bark rolls stored in the Woodend store in Scarborough, conservation was undertaken in the 1950s by impregnating the organic remains with plasticised polyvinyl (PVC) (Beekman 2020). The use of PVC as an impregnator was confirmed in a letter to the Assistant Curator of Whitby Museum (Saul and Milner 2013).

Vale of Pickering Research Trust

Subsequent fieldwork at Star Carr and other sites of interest around Lake Flixton resumed from the mid-1970s. The Vale of Pickering Research Trust conducted the fieldwork, and their work continued through the 1980s and 1990s (Milner et al., 2018b). Trenches excavated by the Trust were cited either at a distance from or adjacent to Clark's interventions with aims of identifying the spatial extents of the site, better defining the chronology of occupation and recognising the changes in local vegetation history (Cloutman & Smith 1988; Mellars & Dark 1998; Conneller et al. 2012). A 30m timber lakeside waterfront platform, pollen and plant microfossil evidence recovered from the freshly excavated trenches and test pits, in combination with deposits and cuttings adjacent to Clark's excavation, allowed for the development and reinterpretation of the environmental narrative that was largely uncontested since the 1950s (Milner et al. 2018c).

In addition to the insight into Mesolithic occupation and Early Holocene environment provided by the environmental data, a concerning amount of physical degradation of the ecofactual and palaeoenvironmental evidence was also detected (Rowley-Conwy 1998). Agricultural activity, most notably ploughing, appears to have damaged the site in the intervening years between Clark's excavations and the Vale of Pickering Research Trust's interventions (Milner *et al*. 2018c). The degradation of the remains and the soils and sediments at the site is alarming and demonstrates the significance of archiving palaeoenvironmental remains when intensive agriculture and dewatering threaten waterlogged resources.

The site archives from the Vale of Pickering Research Trust fieldwork were stored at the University of Cambridge, the University of York, and the University of Durham. Sediment cores and the flint were maintained at Cambridge, and the ecofacts and organic artefacts were retained at York University (Saul and Milner 2013). Regrettably, a selection of the organic remains stored at the University of Durham was lost, perhaps because of a malfunctioning fridge (Mellars and Dark 1998). The remaining artefacts held in Durham were dispatched to the University of York in 2010 (Mellars and Dark 1998; Saul and Milner 2013). Much of the archive was not conserved except for a selection of wood. A 2013 review of the archived remains from the Trust excavations, revealed that the remains are now in poor condition, and the material was found to have formed yellow crystals and developed a smell of sulphur (Saul and Milner 2013).

The 2003 to 2012 University of York fieldwork

Throughout the 2000s, researchers from the University of York have managed multiple research phases at Lake Flixton. Between 2003-2008, a team from the university committed to a scheme of field walking, auger survey and test pits to determine the spatial extent of the former lake and the palaeotopography of the Mesolithic landscape (Milner *et al*. 2018c). The field walking and auger survey was supplemented with ground-truthing and test pitting intended to characterise better and identify the physical extents of the dryland and wetland occupation and, crucially, assess the preservation of the Early Holocene contexts (Milner *et al.* 2018b). The investigations undertaken through the 2010s successfully revealed that occupied areas around Lake Flixton were larger than previously considered. The geochemical data demonstrated that many sediments and artefacts are decaying (Milner 2011; Boreham 2011). The concerning degree of decay and degradation at Star Carr was a key driver supporting the subsequent NERC research project with a central aim of determining the cost of future work and management of organic material and the timber platforms (Milner 2012a).

The 2010 NERC funded excavations revealed that advanced deterioration of the artefacts and the palaeoenvironmental remains was irreversible (Milner 2012a). The project concluded that opportunities to conduct fieldwork and address critical questions were becoming limited due to drying sediments and would benefit from an extensive scheme of fieldwork (Milner 2018a). This scheme of fieldwork may have represented a final opportunity to answer long-standing questions before critical degradation and inform the future long-term management of Star Carr (Milner 2012b). Funding for a programme of excavations that inform future management was secured through the European Research Council, and a project design was agreed upon with relevant stakeholders in 2011 (Milner 2012b). POSTGLACIAL was programmed for three seasons of excavation in the summers of 2013, 2014 and 2015 and two years of post-excavation analysis.

POSTGLACIAL

POSTGLACIAL provides a case study example of a project that considers archaeological palaeoenvironmental archives in a comprehensive manner, that includes an assessment of the value of pre-existing archives and how archives generated through the project can benefit future research and display. The context is particularly relevant given the degradation of internationally significant remains. As a case study that offers best practice examples in archaeological palaeoenvironmental archiving, the project will examine how the archive has been considered and developed throughout the project from the design stage through review and delivery.

The importance of palaeoenvironmental archiving at Star Carr is further highlighted by a history of taxonomic misidentification of wood from Clark's excavation, as observed by Bamforth (2017). Clark's excavations did not identify the wooden platform and consequently failed to realise the value of the wooden remains (Taylor et al. 2017; Bamforth 2017). Recognising past cases of misidentification and a limited appreciation of the future utility of remains demonstrates the significance of developing a comprehensive palaeoenvironmental archive.

Project Design

As a condition of the original English Heritage grant, the POSTGLACIAL project design complied with the Management of Research Projects in the Historic Environment (MoRPHE) (Historic England 2015b). The document includes sections detailing ownership, budget, standards and practices, management structure and named specialists and programme of works. The project design emphasises the importance of conservation and archiving and outlines the details of the archive mapping project and how its outcomes can benefit outreach, display, and research. Each of these sections below is highlighted in greater detail below.

Star Carr Archive Mapping Project **–** The English Heritage funded archive mapping project was prompted by the recognised challenges of site archives that have become distributed internationally and, on occasion, have apparently been misplaced (Saul and Milner 2018). The project team recognised that the inaccessible nature of archives from Clark, Moore and the Vale of Pickering Research Trust interventions were preventing opportunities for research and museum display.

The results of the archive mapping project were produced as a report and are also hosted by the Archaeology Data Service (ADS) as a database resource that provides archive location and history to the excavations (Milner et al., 2013). The ADS hosted database contains searchable fields for artefact code, accession number, museum, species, artefact type, artefact material and photographs of samples and artefacts (figure 5). Details regarding contextual and spatial data are not included in the database and must be sourced via the original reports.

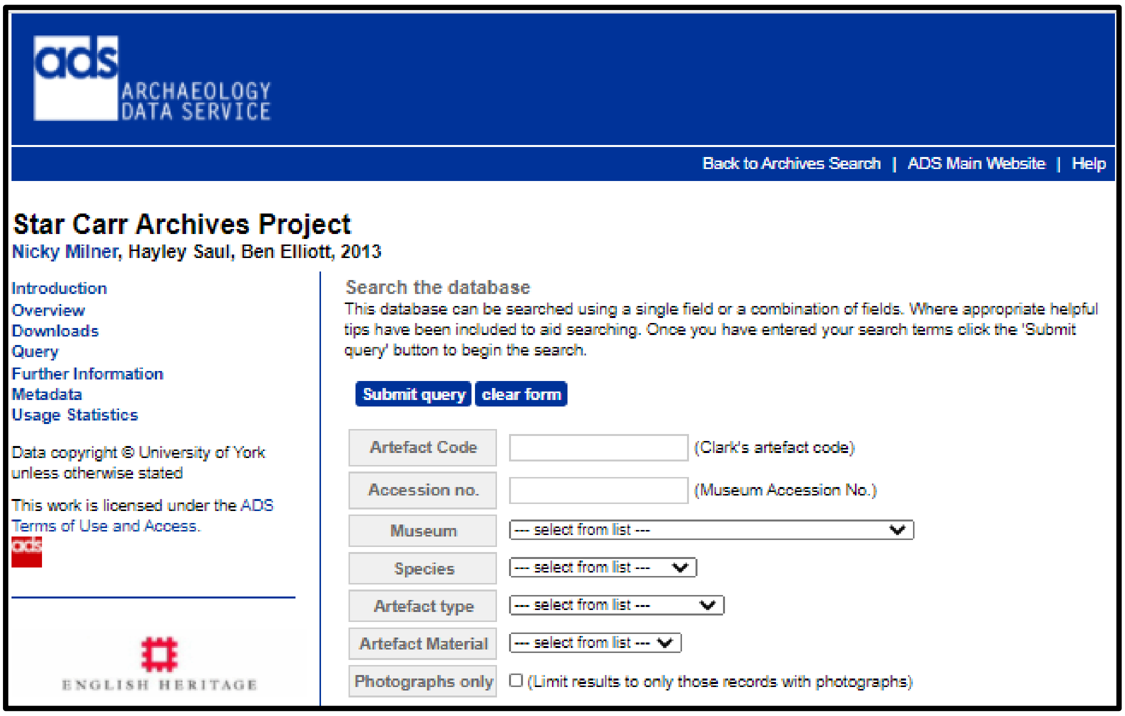


Figure 5. Figure one demonstrates the search option on the ADS hosted Star Carr archive mapping project. Data relating to artefact code, museum, species, artefact type, artefact material and photographs are accessible. Notably absent from the search options are spatial and contextual data.

Outreach and Display – At the project design stage, the POSTGLACIAL team discussed the potential for outreach and display at the Natural History Museum, London, the Cambridge Museum of Archaeology and Anthropology and the British Museum. Exhibitions would display archived materials in combination with more recently excavated remains. These exhibitions would document the history of investigation at the site and explore elements of daily life in the Early Mesolithic.

Ownership – From the outset of the project, the resolution of artefact ownership was recognised as being a potential challenge. When the project design was drafted, the landowners were not in total agreement that they would be willing to relinquish assemblages to the museums. This was recognised as being a topic that required revisiting periodically throughout the development of the project.

Archive Deposition – With agreements concerning archive ownership still requiring resolution, decisions regarding archive deposition were still to be finalised, but it was thought that the York Museum Trust would receive the archive. The York Museum Trust's collections policy at the time (Yorkshire Museum Trust 2015) stated that the organisation did not accept waterlogged remains, posing potential cost implications for the conservation of waterlogged remains. Conservation costs may prevent the deposition of the total palaeoenvironmental archive and require selection strategies that develops a system that recognises priorities. Criteria for prioritisation cannot *reliably* be determined at the project design stage due to the potential for degradation of remains and deposits, resulting in many assumptions and unknown factors. Put simply, excavation may reveal that many remains are too degraded and not worthy of retention or conservation.

Conservation needs – The highly acidic conditions of the deposits at Star Carr have become vulnerable to oxidation and increased acidification (Boreham et al. 2011; Milner, 2012; Taylor 2018). The acidic conditions developed largely as a result of lowered water tables, the development of aerobic conditions and the liberation of sulphuric acid by the decomposition of pyrite. The result being that by the time of the twenty first century excavations much of the bone was in very poor condition sometimes decalcified (Dark 2017a; Dark 2017b; Albert et al. 2016; Milner et al. 2011; Boreham et al. 2011). The threat posed by detrimental shifts in geochemistry was intensified by the diminishing water table, which is now below the wooden platform's horizon (Milner 2012). A combination of the deteriorating anoxic environment and geochemical factors was leading to the degradation of pollen and insects. The wood remains were observed as being particularly decayed and compressed. In 2010, some of the timber planks were found to have degraded entirely and could only be identified as imprints in the peat. Detailed examination of the surviving wood demonstrates that bacterial action has led to the decay of some of the wood (Milner 2012). Revisiting the conservation and archiving throughout the project was regarded as being crucial.

Management and timetabling – The project design defined the management structure and named each of the specialists contracted to analyse the excavated and sampled remains. Also included in the management structure was a named clerk of works, tasked with stakeholder liaison regarding archaeological archiving matters.

Budget – POSTGLACIAL secured a budget of 1,497,780 Euros from the European Research Council. Specific details regarding how the budget were to be allocated are scant, presumably due to the unpredictable nature of the *in-situ* preservation of remains. The budget for conservation and archiving needed to be revisited as the remains emerged and the conservation needs became apparent.

Standards and Principles – The principles and standards for archiving included UKIC 1990 Guidelines for the Preparation of Excavation Archives for Long Term Storage (Walker 1990), Management of Archaeological Projects (English Heritage 1991) and Management of Research Projects in the Historic Environment (Historic England 2015b). The final archive contained:

- a summary of the project
- a guide to the archive
- the project design
- the complete site archive, including all data, records and correspondence, produced during the programme of fieldwork;
- all artefactual and environmental material, appropriately indexed, conserved and packaged
- An electronic archive deposited with ADS, and OASIS record updated

Mid-Project Assessment

After completing the second year of excavation in 2014, and in advance of the 2015 excavation, a review of the conservation needs, and archive selection was conducted and re-costed accordingly (Milner et al. 2014). Ownership was agreed upon with the landowner, and York Museum Trust finally agreed to be the receiver of the archaeological archive.

Archive and Conservation Assessment

After two seasons of fieldwork were completed, sufficient results allowed for a conservation and archive selection strategy to be drafted by the specialists and stakeholders (Milner *et al.* 2014). The specialists concluded that the primary criterion for the retention should include remains that either did not require any conservation or were physically conducive to conservation techniques such as vacuum freeze drying. The secondary criterion required the remains to have the potential for research and display (Milner *et al.* 2014). Tests were undertaken to determine which of the wooden remains were preserved enough to be considered worthy of conservation. The test used a 10% sub-sample of the wood from the 2010 NERC project which was subjected to a condition assessment using techniques including: density assays, imaging of cell wall structure using Scanning Electron

Microscope (SEM) and maximum water content. The condition assessment revealed that cellulose had degraded between 24% and 70%, significantly reducing the strength of the wood. Iron and Sulphur contamination within the wood resulted in acidification due to reducing sulphur compounds oxidising (Milner *et al*. 2014).

Although the suite of tests revealed that the 2010 wood was, at least at a cellular level, in poor condition, the surface detail of woodworking evidence was rated between moderate to good on the Humber Wetland Project condition scoring criteria (Van de Noort 1995). Given the conflicting results between the surficial and cellular conditions of the wood, it was concluded that wood demonstrating alteration through human or animal agency and possessing observable evidence of woodworking technology should be retained. Specifically, these include deliberately altered items such as split timbers, trimmed ends, woodworking debris and any fragments that clearly showed woodworking evidence. Fragments of wood that did not fit these criteria were deselected. This selection strategy filtered the wood assemblage from 4516 recorded fragments to 66 items for conservation (Bamforth et al. 2018).

The delicate nature of the excavated wood led the specialists to determine that conservation of organic artefacts and samples should begin in 2014 to prevent post-excavation decay rather than waiting for the project to conclude (Milner *et al.* 2014). Conservation of the wood was achieved using a pre-treatment with chemical chelate to eradicate iron contamination (Milner *et al.* 2014). Polyethyleneglycol (PEG) wax was used to consolidate the wood, which was subsequently freeze-dried.

Contrary to the archaeological wood deselection policy, a decision was taken to select several unconserved faunal remains for long-term storage. Being dry and therefore accepted by the museum, the relevant stakeholders concluded that faunal and antler remains not subject to conservation techniques should be deposited, as their chemically un-treated status may prove beneficial for future techniques. The benefits for future research that chemically un-treated remains offer over conserved materials include the application of isotopic studies, ZooMS and radiocarbon dating. Due to having no option for storing wet archives, non-dried waterlogged remains could not be retained.

Post-Excavation Stage

By the point at which the 2015 field season concluded, conservation of the environmental samples and the organic artefacts was underway. Little negotiation was required as the archival selection process and stakeholder relationships were formed, and quantities and deadlines for deposition were primarily agreed upon and finalised.

Case study summary

The Star Carr POSTGLACIAL case study provides an example of a scheme that used an archive mapping project and assessments to realise better the long-term benefits of archiving palaeoenvironmental remains. The archive mapping project added a value that cannot be overstated. In general terms, it allows easier physical access to archaeological archives. However, as an aid for determining judgments regarding project-specific archiving, it can guide which conservation techniques have been successful in the past and may also indicate what would benefit from being archived. In similar examples in which a scheduled site is likely to include significant palaeoenvironmental remains, an archive mapping project which follows agreed protocols could be recommended by Historic England and provisioned for in the project budget.

The delicate nature of the wooden remains required tests at the assessment stage to determine the physical condition and judge if they were conducive to conservation. In combination with the archaeological technologies, the test results informed the decision-making process that guided the conservation techniques and archive timetabling. The decision making and assessment of the palaeoenvironmental archiving were largely successful, but the museum's collecting policy of not accepting waterlogged remains may prove detrimental. POSTGLACIAL represents what could be the final opportunity to retrieve remains from the Lake Flixton environs, and the regrettable absence of archived waterlogged wood and other plant materials and insects may prevent opportunities for future research.

Part Three - Guidance and standards used by specialists

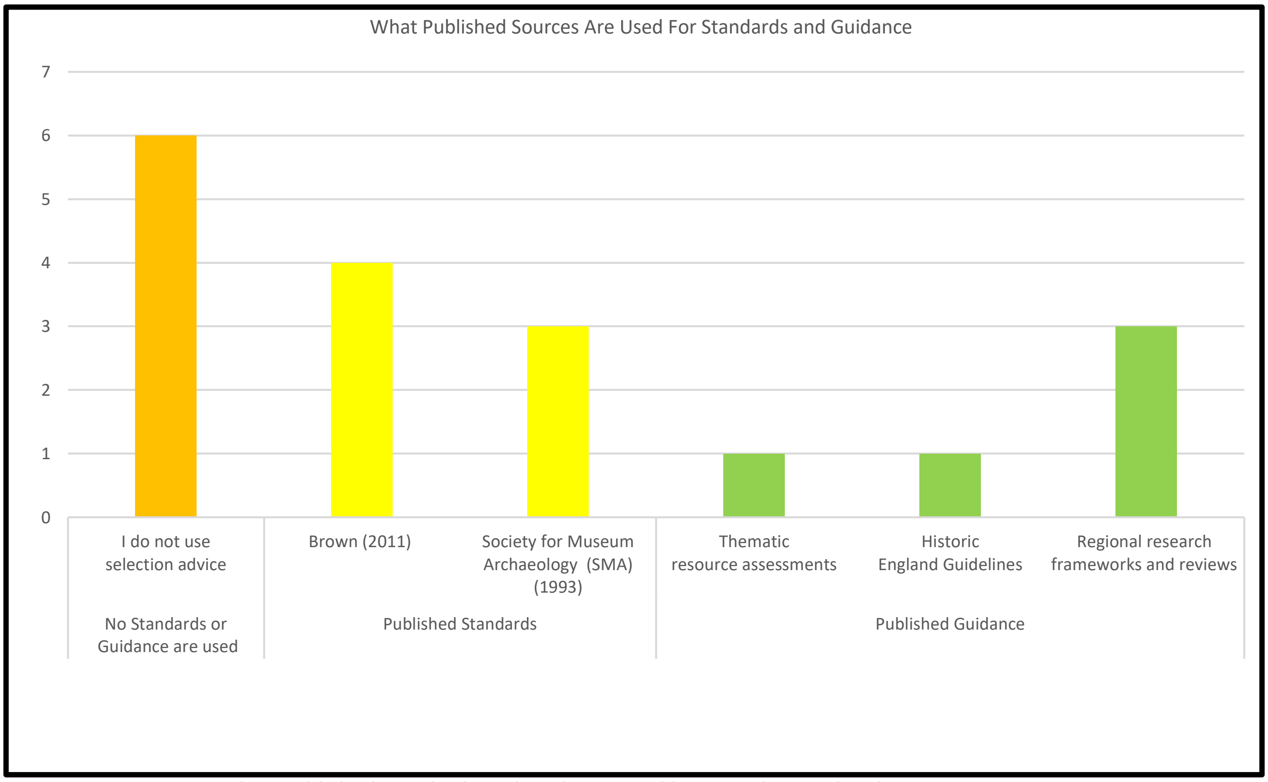
The key providers of standards – defined as the agreed measurable quality that should be achieved (Richards 2009) – are Brown (2011), Society for Museum Archaeology (SMA) (1993), and the Selection Toolkit (CIfA/Historic England 2019). The usefulness of published standards which extend to the selection process can be used as sources of information that can inform stakeholders of the value of all facets of the archaeological archive. Specialists who work with archaeological palaeoenvironmental remains have cited research frameworks as an essential resource in determining what should be maintained for long-term storage (see graph 9).

It is unclear what the frequency of use of guidance is and which of these resources are used by stakeholders regarding selecting and retaining archaeological palaeoenvironmental archives. Understanding which of these resources is used to make selection judgments may indicate where improvements can be made and how selection practices can be promoted.

The following section uses survey and case-study data to examine how guidance and standards are used in palaeoenvironmental archive creation. The examination of guidance is achieved by establishing *which* published standards and guidance are used, determine the efficacy of these resources for offering selection guidance, and finally determining how specialists would prefer guidance to operate in the future.

Published standards used in England are under regular review and agreed by recognised providers and arbiters of standards and good practice. They offer focused advice and are frequently non-specific regarding specialist materials and are not further investigated as part of this study.

What standards and guidelines exist for practitioners to assist in making meaningful selection judgments?



Graph 9. Published standards and guidance used by specialists and archive managers.

The survey revealed that 60% of the respondents claimed not to use published standards or guidance to make decisions regarding archive selection. The participants who use published guidance were encouraged to select as many of the supplied answers as necessary from a choice of options.

According to the survey, the most cited source for the guide for best practice for archiving is Brown (2011), with the second most cited source being the Society for Museum Archaeology's *Selection, Retention and Dispersal of Archaeological Collections* SMA (1993).

The survey revealed that of the published guidance - the Historic England best practice guides, thematic resource assessments, and regional research frameworks - regional research frameworks are the most commonly used form of guidance. It remains unclear how effective these are at providing practical information that can guide selection decisions. A study is provided that examines how effective regional research frameworks can offer advice on selection by determining if it is explicitly clear what palaeoenvironmental remains should be archived. Examples of research frameworks are further explored to determine their usability for offering guidance to encourage greater use.

Case study Three – The East Midland Historic Environment Research Framework

The environmental specialists and archive managers' survey indicates that research frameworks are the most frequently used selection guidance resources. The reported preference for research frameworks is consistent with standards promoted by CIfA (2019) and Perrin *et al.* (2014), both of which recommend that selection strategies are conceived using research frameworks combined with Local Authority guidance and Data Management Plans (Perrin et al. 2014, and CIfA/Historic England 2019). However, it is unclear if research frameworks' Research Objectives provide sufficient information to guide the selection of palaeoenvironmental data from the working project archive for inclusion in the final archive. Similar concerns have precedence in the Southport Report (2011) and the Pye-Tait consulting report (2014), highlighting that existing frameworks may not deliver ample guidance to specialist communities.

This case study takes a critical view of how specialists and archive managers can use a regional research framework and determine how, in practical terms, such resources could help judge the selection of remains for inclusion in the final archive. The case study also examines if more explicit selection guidance could be included in research frameworks to create better archives for future research potential.

Regional research frameworks are well-established methods of information dissemination (Olivier 1996). They have a wide readership and are an ideal platform to inform a wide range of historic environment practices (Belford 2020). Their sector-wide ubiquity appropriately positions them as a resource that can boost the adoption of selection strategies, a practice that appears to be rarely undertaken to a satisfactory standard (see section). Increasing participation in selection practices is necessary to create well collated, accessible, and usable archives (CIfA/Historic England 2019).

East Midland Historic Environment Research Framework

The current incarnation of the EMHERF culminated in a series of recommendations stemming from preceding versions of the agendas and strategies. Previous editions identified a need to create an online resource that can democratise historic environment decision making and respond to developing research foci without the looming obsolescence of a paper format (https://archaeologydataservice.ac.uk/researchframeworks/eastmidlands/wiki/).

The EMHERF includes Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Derbyshire, Rutland, and unity authorities of Nottingham, Leicester, and Derby. The project is managed by Trent and Peak Archaeology and is part of a national network of archaeological research frameworks for all regions of England (Pye-Tait 2014). Efforts by Historic England to create a mosaic of self-sustaining resources that any member of the community can update as part of a new generation of frameworks have been underway for the last few years (Miles 2015, Pye-Tait 2014). The EMHERF was designed with input from stakeholders across the historic environment community guided by an advisory panel and steering group comprising subject and period specialists (https://archaeologydataservice.ac.uk/researchframeworks/eastmidlands/wiki/). The Wiki format can allow any member of the public, or professional member of the historic environment community join, the framework and then use the portal to update references, observations, and newly published research. The online Wiki entries are evaluated by the steering group and specialist advisory panel reviewed, and then uploaded into the public domain.

An Assessment of the East Midland Historic Environment Research Framework for Guiding the Selection of Palaeoenvironmental Remains for Inclusion in the Final Archive.

This assessment aims to understand how an archive manager or environmental archaeology specialist could use a regional research framework to develop a selection strategy and create high-quality archives. The assessment interrogates two Research Objectives (7C and 5H), chosen due to their focus on environmental archaeology. The two research objectives are analysed using two criteria to determine what selection guidance can be gleaned. The effectiveness of the research objectives' ability to deliver selection guidance is measured against the objective's capability to guide the drafting of project design and data collection purposes. The comparison between archive selection/creation and project design/data collection will highlight selection guidance's relative efficacy. The two-point criteria are as follows:

A fundamental purpose of regional research frameworks is to provide data and content to enable users to construct problem-orientated question-led research (Museum of London, 2002). The question-led, hypothetico-deductive model is a foundation of archaeological practice (Darvill 2007, Hempel 1967). Research Objectives 5H and 7D are assessed to determine if there is sufficient information to construct a question-led approach for selection and, for comparison, field-led project design and data collection.

The East Midland Historic Environment Research Framework has a georeferenced environmental database, which is downloadable as an excel spreadsheet. This spreadsheet provides a valuable resource and demonstrates a strong regional interest in environmental archaeology. The spreadsheet will be included in the assessment to determine if the addition of a subject focused resource can prove helpful in developing selection guidance.

Research Objectives

Research frameworks are created through two key stages: i) the research assessment review, followed by ii) the development of the research framework. The research assessment review considers regional overviews and research agendas and draws out the essential questions whilst the framework introduces objectives and methods to interrogate the agenda.

The Research Agenda topics are interrogated by Research Objectives - subjects that reflect directions in relevant research (figure 6). Research Objectives are more adaptable and likely to change and be updated with greater frequency than agenda topics. This assessment has been achieved by choosing two Research Objectives for close examination. Research Objectives 5H and 7C are examined to provide insight into what levels of detail can be extracted to determine what should be selected from a working project archive and deposited for long-term storage.

For brevity, each of the Research Objectives has been trimmed to show only the sections relevant to the assessment.

7. HIGH MEDIEVAL (1066-1485): RESEARCH OBJECTIVES

Research Objectives / Updated Research Agenda	7.1 Urbanism				7.2 Rural settlement				7.3 Manors and manorial estates					7.4 Castles, military sites and country houses						7.5 Religion						7.6 Industry and trade				7.7 The agrarian landscape and food-producing economy					
	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	1	2	3	4	5	6
7A Undertake syntheses of urban and suburban excavation, survey and documentary data	●	●	●	●										●			●	●				●	●	●	●	●			●				●	●	
7B Enhance record of urban and suburban secular standing buildings and subterranean structures	●	●	●	●																									●						
7C Investigate provisioning of the medieval town	●	●		●																					●								●	●	
7D Investigate further the role of markets, fairs and ports and trading routes	●	●		●																						●		●						●	
7E Investigate the morphology of rural settlements					●	●	●	●															●												
7F Investigate development, structure and landholdings of manorial estate centres					●			●	●	●	●	●	●										●									●	●	●	
7G Investigate relationship between castles and great houses and their estates	●	●											●	●				●																	
7H Investigate location and character of medieval battlefields																			●																
7I Investigate development of the open-field system and woodland management					●	●				●													●							●	●	●			
7J Research the regional communications infrastructure		●		●																						●	●							●	

Fig 6. Figure shows the relationship between Updated Research and Agenda and Research Objectives (East Midland Historic Environment Research Framework: High Medieval Research Strategy - https://researchframeworks.org/emherf/research-strategy/high-medieval-strategic-objectives/)

Research Objective 5H - Investigate the Romano-British landscape context of rural settlements

In addition, appropriate environmental sampling strategies need to be encouraged to accumulate botanical and faunal data that will provide a secure foundation for studies of changing landscape context and site location strategies. East Midland Historic Environment Research Framework: Romano-British Research Strategy - https://researchframeworks.org/emherf/research-strategy/roman-matrix/

Assessment of Research Objectives 5H

Each period-specific section of the framework includes a sub-section that detail matters regarding environmental archaeology. The sub-sections were systematically searched through to identify a relevant Research Objective that contained references to environmental archaeology that can be further examined to understand the relationship to archiving. Research Objective 5H was regarded as fitting this criterion.

Research Objective 5H was devised using details from publications and frameworks including: Archaeology of the East Midlands (Lawton 2006), Strategic framework for Historic environment Activities and Programmes in English Heritage SHAPE (English Heritage, 2008), *Rural society in Roman Britain* Taylor (2007) and *EH National Heritage Science Strategy Report 2* (English Heritage 2009).

Identifying Research Questions

The information within the objective is wide-ranging, referring to 'appropriate' environmental sampling for the 'accumulation' of faunal and botanical data. These objectives provide little specificity and are consequently too vague to construct practical project design questions. For selection purposes, the general nature of the objective tacitly promotes the need to select – or accumulate – all palaeoenvironmental materials from the working project archive without any research questions or filtering. The objective is explored in greater detail using the linked frameworks such as SHAPE (English Heritage 2008) and Archaeology of the East Midlands (Cooper 2006) to determine if more obvious research questions or resources to construct questions can be identified.

A search through the relevant section of the Archaeology of the East Midlands (Cooper 2006) provides more explicit aims than those outlined in the East Midland Historic Environment Research Framework. For example, the dearth in the sampling of archaeological contexts encountered on rural Roman sites in Derbyshire is highlighted and recommends that such contexts should be sampled in the future as part of an integrated approach that considers artefactual and biological evidence**.** This information is sufficient to draft site-based project aims, highlighting a need to excavate and collect samples for biological evidence to understand more about rural settlements in the Romano-British landscape. Comparatively, there is no data in any associated frameworks that can allow for a question-led approach to indicate what data should be selected for long-term storage and how it could contribute to regional research. A practitioner using this Research Objective to determine archive selection would likely recommend selecting all palaeoenvironmental remains from Roman rural contexts with no filtering, consideration of quantities, taphonomic factors, biodiversity, or consideration of how this archive could contribute to existing archival knowledge.

Identifying what to select

There is no indication from the East Midland Historic Environment Research Framework Research Objective text clarifying what to select for long-term storage. Using the Archaeology of the East Midlands framework, it was possible to identify examples where specific data is encouraged for collection and analyses (Cooper 2006). One of the examples is included.

> *Analysis of weed floras and study of weed ecology may produce evidence of extensification of agriculture and may help to indicate the source of cereals.*

The downloadable environmental database (https://archaeologydataservice.ac.uk/researchframeworks/eastmidlands/wiki/Enviro) was consulted to search for an indication of how it could be used to see what has already been collected, what already is in store and therefore demonstrate how specific weed flora could contribute towards archival diversity. An inspection of the spreadsheet contains data that details the county, site, period, site type, evidence of waterlogging, coordinates, material class, scientific dates, notes, related publications, name of the specialist, and HER reference. Noticeably absent is any reference to if these remains were archived and, if so, where they currently reside.

Research Objective 7C – Investigate the provisioning of the medieval town by further detailed study of environmental data and human remains.

> *The increasing use of cess-pits in medieval towns means that there is extensive evidence for the diet of the population in medieval Leicester, Lincoln and other urban centres. At Causeway Lane in Leicester, for example, cess-pits and other contexts yielded remains of apple, blackberry, damson, grape, plum and pear, while vegetables included bean, leek and pea. Domestic animals and fowl were augmented by sea fish and oysters. The evidence of diet may be used to identify the various social groups of the town and their access to food, and, together with isotope analysis, may identify elements of the population born and brought up elsewhere. There are also many other aspects of economy, trade and craft that can be illuminated by the further study of this evidence, as has been suggested for Lincoln. For the medieval urban centres, environmental analyses may be supported by isotopic and other scientific studies of human remains obtained from cemeteries and by documentary research.*

Assessment of Research Objective 7C

By adopting a similar approach to the previous example, the framework's period-specific sections were searched to find palaeoenvironmental related guidance. Research Objective 7C fits this criterion and was assembled using details from supporting frameworks including: Archaeology of the East Midlands (Cooper 2006), SHAPE (2008), NHPP (2011), *English Heritage Thematic Research Strategy for the Urban Historic Environment* (2010), *English Heritage National Heritage Science Strategy Report 2* (2009), Stocker, (2003) *The archaeological agenda: An introduction to the Research Agenda Zone and entries* in Jones *et al.* (2011) and *The City By The Pool: Assessing the Archaeology of the City of Lincoln and Medieval Pottery Research Group* (2011).

Identifying Research Questions

Research Objective 7C provides insight into regional research priorities linked to the provisioning of medieval towns in the East Midlands. A search through the linked research frameworks and supporting literature revealed that this objective had been designed through a process of identifying gaps in published research (Cooper 2006; Stocker 2003). The objective provides explicit acknowledgements towards the data required to construct research questions – stated geographical locations, the types of the deposit that should be targeted for sampling, a focus on the specific data that should be analysed, and the proxies required for analysis contribute towards stated overarching themes. Collectively, there is enough information to construct research questions that would suit both a field-led project and an archive-based research project.

As stated earlier, the Research Objective is informed by gaps in published research. For selection and archive creation purposes, a framework user could draft a set of research questions that outlines what data should be selected to satisfy research objective aims, but these would not be satisfying any gaps in stored regional archives in the region. For example, is a profusion of oyster shell recovered from contemporary contexts within the environs of a proposed excavation that have already been archived? Are there specific taxa missing that could complement the existing archive and abundant taxa that do not require selection? Could an archive-led stable isotope project address aspect of this research objective and if so, what deficiencies in data could be addressed by informed data selection to complement such a project.

Identifying what to select.

If a user sought to determine what to target as part of excavation to understand more about medieval town provisioning, it would be clear how to achieve this using Research Objective 7C. Using this resource, a specialist or archive manager could use the information outlined in Research Objective 7C to develop a selection strategy to advocate which of the remains should be selected for long-term storage as they serve a currently recognised purpose in the research ecosystem.

Case study summary

Regional Research Frameworks have an ambitious remit, expected to provide details of prevailing research foci across the full spectrum of a region's historic environment. For palaeoenvironmental archive selection purposes, the framework and associated, linked frameworks/literature have revealed general guidance that does not contain sufficient information to design selection criteria and priorities for archive creation. If we expect to create more usable archives that can contribute to research questions now and, in the future, an approach that uses deductive, question-led reasoning may begin to address archive diversity and absences in the archive. More specific information could be provided by documents produced by museums such as palaeoenvironmental archive strategy documents or via palaeoenvironmental chapters in research charters. These could be similarly hyperlinked in the frameworks to the East Midland Historic Environment Research Framework example.

Chapter Eight. A Time and a Place for Nature? – Communicating Archaeological Palaeoenvironmental Archives in Museums and Public Science Engagement Events

Introduction

Archaeological archives present opportunities to articulate millennial-scale narratives of human experience and resilience through museums and other forms of science communication (Merriman and Swain 1999, Harrison *et al.* 2020; Shanks and Tilley 1987; Trow 2018; St Amand *et al.* 2020; Baird and McFayden 2014). Over the last 20 years, an increasing host of methods incorporating discursive modes of engagement, Information Communication Technologies (ICTs) and social media posting have supplemented traditional labelled object displays (UNESCO Institute for Information Technologies in Education 2011, Fedeli 2017; Jagodzinska 2017; McCall and Gray 2014). This chapter examines how palaeoenvironmental archives can complement the growing array of technologies and practices to invoke discussions regarding economically and environmentally related contemporary global challenges (the most prominent examples include the 17 United Nations sustainable development goals) within the purview of environmental archaeology (https://sdgs.un.org/goals). This research topic also contributes to 21st-century challenges in archaeology identified by CIfA as enhancing the means to promulgate archaeological research for public benefit (Wills 2018).

To determine how archived palaeoenvironmental remains are used in museum and public science engagement events, a combination of quantitative data, in the form of survey data retrieved from the museums, and qualitative methods, in the form of case study data, have been used. Of the three case studies, two examine archaeological archive use in museum exhibitions and a third complement archaeological archive use by providing an extra-disciplinary insight through natural history museum practice. When combined, the results reveal that best practices can be achieved by inviting specialist collaboration and applying mixed media alongside authentic evidence.

Archaeological Archives in Continuum: Renegotiating Archaeological Palaeoenvironmental Archives to Communicate Contemporary Global Challenges

Once selected, documentation, artefacts, and samples can be deposited in a repository for long-term storage (Brown 2011; Oniszczuk *et al.* 2021; Perrin *et al*. 2014). The process of selection requires key actors in the project – specialists, museum curator, project manager, local authorities, and archaeological conservators - to determine which elements of the Working Project Archive hold significance or value to make them worthy of transfer for long-term storage (CIfA 2019; Brown 2011; CIfA 2014; Perrin *et al*. 2014; SMA 1993). Although archive deposition often signals the end of a project, or phase of fieldwork, inclusion into the archival system ensures that the site, or locale of investigation, can endure as a discrete centre of knowledge production in, at least theoretically, perpetuity (Merriman and Swain 1999; Lucas 2010; Olivier 2011). As enduring reservoirs of knowledge, archaeological archives serve as opportunities to re-interpret and re-test excavation data (Baird and McFadyen 2014; Derrida 1995). Archaeological archives provide authentic evidence-based narratives of human resilience while simultaneously offering a testament to the scientific process, both of which can be leveraged for communication and education purposes (CIfA 2019; St Amand 2020; Pearson 2019).

The archaeological literature contains diverse examples of palaeoenvironmental evidence of human resilience, such as living through food shortages and climate change. (Vésteinsson *et al.* 2002; McGovern *et al.* 2007; Altchul *et al.* 2017; Guttmann-Bond 2010; Cebollos *et al.* 2015). Complementing the literature are archaeological palaeoenvironmental archives. These archives comprise biological remains such as pollen, insects, diatoms, fly pupae, wood, charcoal, and seeds that have been collected, analysed, and retained for future research and re-testing (Lodwick 2019). These archives can be revisited to construct narratives that can participate in educational activities and discussions regarding environmental and economic topics such as anthropogenically caused climate change, human-environment interactions, ancient economies, and foodways (Cameron *et al*. 2013; Van de Noort 2013; Vestergaard and Riede 2017).

Renegotiating Archaeological Palaeoenvironmental Archives

Whether through a didactic top-down approach or through more discursive methods - emerging scientific concepts and developments should be communicated to the public in an exchange between scientific sectors and society in a way that demonstrates mutually beneficial outcomes (Reeve and Woolard 2006). This society-science balance has proven to be critical. A failure to communicate the aims of science and make processes transparent can prove detrimental and, in the worst-case scenario, lead to a distrust in science and scientists (Forsberg *et al.* 2015; Goodwin and Heath 2016; Pohoryles and Tommasi 2017). We only need to consider examples such as the bovine spongiform encephalopathy (BSE) crisis, the publicly unsolicited introduction of GM crops in the UK and anti-vaccine movements to see how failing to include society in the discourse of scientific aims can be detrimental to the trust of science (Grove-White 2001, Science and Technology Committee 2000; Hornsey 2021).

Trust and openness in the scientific process are, therefore, essential. Amongst publicly available official reports and frameworks by NGOs and charities (IPCC- 2021; Secretariat of the Convention on Biological Diversity 2020; IETA 2019) are those that detail biodiversity loss, ecosystem collapse, anthropogenically caused global warming, food shortages, and enhanced species extinction rates. The results of these are variably promoted and challenged in media reports. For example, the climate crisis receives daily column inches from activists (Lamont 2020), policy critics (Monbiot 2022), and sceptics (Spiked Media 2021), creating a milieu of viewpoints that clash, contradict, and can lead to obfuscation and disinformation (Ross *et al.* 2016; Taylor *et al.* 2017; De Meyer *et al.* 2020; Treen *et al.* 2020). The contributions that archaeology can provide are noticeably absent from the reports and media statements. The discipline's ability to provide evidence-based narratives and articulate climate change and environmental degradation presents archaeology as an ideally positioned authority to add physical evidence of human-environment relations (Hebda 2007; Rockman and Hritz 2020). Museums and public science engagement specialists have an opportunity to use archaeological remains and case studies to articulate human-environment narratives and demonstrate real-world consequences alongside authentic evidence that provides empirical testimony (Immonen and Malinen 2021). The presented evidence can allow for a multivocality that can engage the issue in an informed space to allow the public to devise new questions informing cultural, political, and environmental futures (Hulme 2015; Hulme 2010). Additional benefits of using physical archaeological evidence in museums and public science events are that sharing results in public forums can influence public policy while simultaneously legitimising archaeology in the political discourse (Laws 2015).

How, then, can archaeological palaeoenvironmental archives be effectively used to contribute to the sharing of archaeological results and interrogate global challenges? Fortunately, the methods of communicating grand challenges openly and transparently have been thoroughly explored by museums and public science engagement specialists who have been instrumental in promoting the democratisation of science (Miles and Tout 1991; Bandelli and Konjin 2015). This has been achieved by taking multi-directional discursive approaches that effectively listen to public concerns. However, this dialogical position has taken several decades to mature, most notably from the 1980s where, despite the occasional appearance of terms such as 'inclusion,' 'audience', and 'participation,' institutional learning was undertaken through the so-called deficit model (Jagodzinska 2017, Chopyak 2002). The deficit model can be summarised as a unidirectional, top-down 'trust us we are experts' model that assumed that the public was at a deficit of knowledge, requiring the scientific community to supply this apparent shortfall (Rayner 2004; Stilgoe *et al.* 2014).

The deficit model was challenged in the 1990s, culminating in new museology's constructivist, society-focused objectives (Hooper-Greenhill 2000; Vergo 1997). New museology brought an enhanced institutional self-awareness that allowed for nuanced enquiries into the context, consequence, and purpose of museological practice (Macdonald and Silverstone 1990). These enquiries engendered a shift towards multidisciplinary working in museum interpretation and borrowed from fields including psychology, computer science, marketing, and pedagogy (Recupero *et al*. 2019). These innovative approaches have allowed museum professionals, science communicators and curators to apply detailed consideration to the display and interpretation of archaeological artefacts and sites (Skeates 2002). Environments and techniques adopted to communicate archaeological remains include traditional object displays, Information Communication Technologies (ICTs), and participatory practices.

Communicating Archaeological Palaeoenvironmental Archives

Historically, palaeoenvironmental archives have received little consideration regarding how they can be mobilised in an exhibition and on the public science stage. As demonstrated in the museum partner survey (see page 225), the reasons for this lie in a general unfamiliarity with environmental remains, perhaps due to a perception that they are more akin to natural history and limited in their ability to tell human stories, and the difficulties in displaying these items. Archived palaeoenvironmental remains often require microscopes to make them visible and require controlled environments to keep them appropriately conserved when displayed. Furthermore, how non-organic archaeological artefacts can be displayed and communicated has been far better explored. Artefacts – natural materials fashioned into an object through a social process (Pearce 2013) – are central to archaeological enquiry and have consequently received overwhelming attention and the application of theoretical approaches to interpret them and their creators and users (Dallas 2007). In many instances, archived palaeoenvironmental remains – such as pollen and diatoms - have not been made or fashioned through social processes (Pearce 2013). This can place organic remains beyond the reach of many forms of archaeological theoretical apparatus, such as the corpus of work conducted on object biographies (Ireland and Lydon 2016; Joy 2009). The absence of overt cultural capital inherent within palaeoenvironmental remains renders the communication of these remains difficult. Therefore, museums and science communicators require a range of tools and approaches to communicate the intrinsic values of palaeoenvironmental remains in addition to explaining scientific processes and concepts suitably engagingly.

Museums are variably used as venues for activities and agendas that incorporate entertainment, learning, education, and research (Hawkey 2004; Mujtaba *et al.* 2018; Bourdieu 1979; Bennett 1995; Hanquinet and Savage 2012; Carnal 2020). The balance of a museum's mission statement, or the design of a gallery or exhibition, will dictate how learning, entertainment and research agendas are prioritised and, consequently, how artefacts, ecofacts or works of art are presented (Smithsonian Institution, 2002; McIntyre 2009; Cline 2012). Overall, the ambition is to use well-designed exhibits or programmes that create an experience sympathetic to the intended theme's needs and one that appeals to all users by creating a space that reflects a sense of fun, awe, or space for critical thought (Monti and Keene 2016; Price *et al.* 2018; Greenhill 1992). Exhibition designers endeavour to attract and capture maximum attention through effective design and using items that inspire and command attention (McLean 1999; Bitgood 2014).

Regarding the display and communication of archaeology, artefacts have been used variably as solo objects, promoting the aesthetic value of an object and displaying it within a space syntax aligned to a work of art, or displayed with other items from a particular site or period within the sphere of cultural heritage (Whitehead 2013; Sweetman and Hadfield 2018). This tension between archaeology as a work of art, or as evidence of non-artistic cultural expression, has pervaded the museological discourse since the beginning (Whitehead 2013; Petersson *et al.* 2020). Palaeoenvironmental remains are at a disadvantage compared to artefacts as they transmit less cultural capital and are unlikely to be appreciated on an aesthetic level (Besterman 1997). A general audience perceives items such as pollen grains and charred plant remains as related to natural history rather than cultural heritage (Crumley 2021; St Amand *et al*. 2020). This presents further challenges, as even within the domain of natural history, professionals feel that the subject of ancient plants is often perceived as being 'deeply unsexy' (McGhie 2006, pp.41).

The challenges of identifying methods to effectively communicate interpretations of palaeoenvironmental remains may have been intensified by environmental archaeology's historic struggle to identify methods that can articulate critical themes and results. As Law (2019) has asserted, it may be the result of environmental archaeologists employing an extractive approach and insufficiently promoting their results to those outside the project. Perhaps then, the subject would benefit from examining the current methods employed to communicate nature conservation and experiments that have successfully articulated palaeoenvironmental remains to identify areas for improvement and best practices.

To appreciate what methods could be employed to articulate archived archaeological palaeoenvironmental remains, an assessment that extends beyond a collection-centred approach that includes multimedia technology and engagement events, which can convey a degree of understanding that an object in a glass case cannot are included (Styliaras and Koukopoulos 2012; Barker 2010; Carnal 2020). The following section examines the typical museum methods and identifies how archived palaeoenvironmental remains can be incorporated.

Object displays

Many palaeoenvironmental remains are microscopic and require microscopes to make them observable. This has been made possible by museums such as the Archaeological Museum Amsterdam Archaeolab, the Netherlands (plate 16). Examples that have used microscopes to present remains such as the Archaeological Museum Amsterdam, require funding to procure and maintain them. Beyond the use of microscopes, a method of providing coherency to environmental archaeology in cased displays is the combined use of replicas (Perry *et al*. 2017). It is common for an archaeology and natural history museum to display replicas either alongside or in the place of authentic remains (for example see Moesgaard Museum, Denmark) (Sandis 2016). Replicas can circumvent the requirements imposed by the needs of organic remains and demonstrate microscopic objects and features without investing in expensive microscopes by using enlarged models (https://3dpollenproject.wixsite.com/main; Gerstenblith 2019). Is there, then, any need for the inclusion of authentic remains? According to recent research, in archaeology, museum visitors value authenticity, indicating that the replacement of the authentic with replicas may disappoint the intended audience (Schwan and Dutz 2020; Hede *et al.* 2013; Holtorf and Schadla-Hall 1999). Unfortunately, no research has been conducted on the visitor experience with authentic or replica palaeoenvironmental remains. However, the wholesale removal of authentic evidence risks erosion of science's openness, a position that has been prioritised over the last couple of decades.

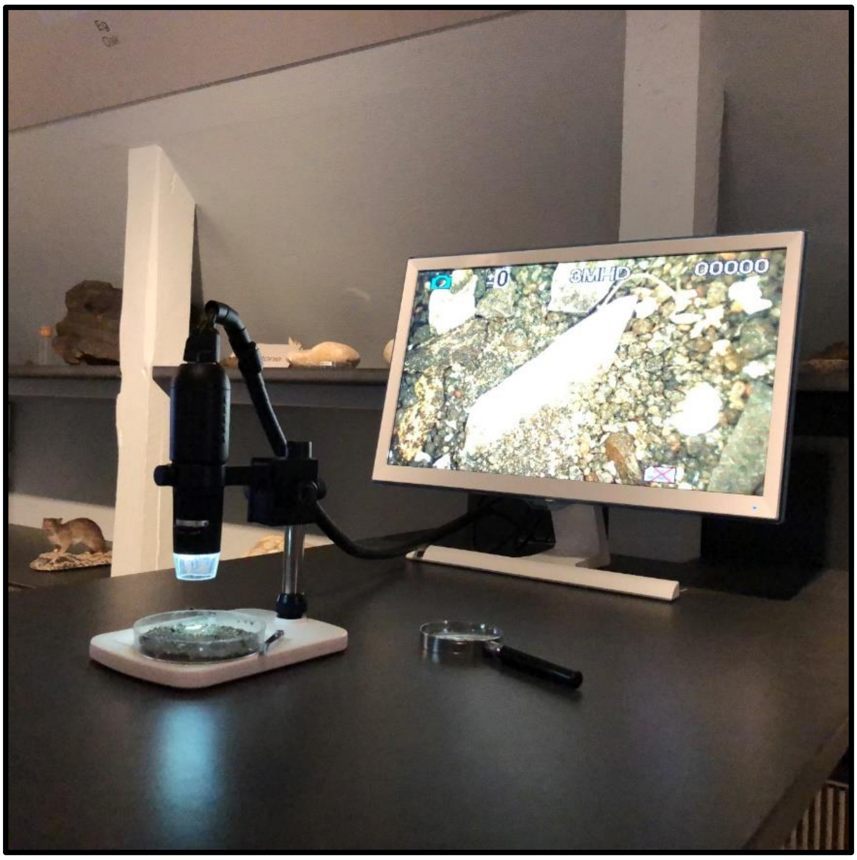


Plate 16. Optical microscope and monitor at the Archaeological Museum Amsterdam Archaeolab

Information Communication Technology

Applications of Information Communication Technologies (ICTs) such as digital media, including interactive computer displays, screens, and internet resources, have proved to be an alluring means of communication for museums and science communicators (Hawkey 2004). ICTs have proved successful on two key fronts, the familiarity that the public has with such media (familiar as they are during many people's day) and the prospects for learning that a sensory experience can provide (Rey and Casado-Neira 2013). In some instances, ICTs have replaced objects (see the Moesgaard Museum exhibition 'The Journey' (https://www.moesgaardmuseum.dk/media/3967/the-journey-press-release-april-2017.pdf). Object-free exhibitions can work in a museum environment as a participant's aesthetic attitude and expectations are appropriately aligned towards a museum experience (Fenner 1996). These benefits, coupled with the ever-increasing digital tools available to museums, such as ubiquitously available Wi-Fi, smartphone apps, and easily creatable QR codes, are making the use of ICTs increasingly attractive. The benefits of ICTs are clear, but they come with a financial cost involved in acquiring and installing screens, associated hardware/software, and content creation (UNESCO 2011). Furthermore, these costs must be rationalised against an acceptable level of technical and knowledge-based obsolescence (Fred and Nawe 2017).

For the communication of concepts regarding environmental archaeology, ICTs can effectively convey intangible heritage themes, complex concepts and scales of ideas across space and deep time, such as changing environments over a millennial scale (for examples, see Creswell Craggs - Derbyshire, UK; Stonehenge Visitor Centre - Wiltshire, UK; Lascaux Cave Visitor Centre - Dordogne, France; Yorvik Viking Museum - York, UK; Hagar Qim Visitor Centre- Qrendri, Malta) (MacDonald 2007, Macdonald and Silverstone 1990). How can palaeoenvironmental remains be incorporated into these dynamic visual formats? This will be explored through the case studies later in the chapter.

Plate 17. Environmental evidence displayed at the Jorvik Viking Centre

Participation through digital technologies

Archaeological objects that are considered for display have been determined as being of a particular significance, or contribute to the transmission of a theme, or to communicate particular points, and on occasion, as a work of art (Smith and Waterton 2012). This means that all too frequently, the less appealing or unattractive items, such as palaeoenvironmental items, are side-lined in lieu of more 'interesting' items. Challenging this, are creative approaches to displaying and allowing participation with unusual items (Grey *et al.* 2006). For example, the work of Carnall (2020) at the Oxford

University Museum of Natural History has used humour, deliberate irreverence, and social media applications to convey serious subjects such as extinctions and threats to biodiversity. An example of this includes the Underwhelming Fossil Fish of the Month blog published on the UCL website, the text of which is included below.

> *Welcome to March's underwhelming fossil fish of the month. For the blissfully ignorant amongst you, this series brings the worst and dullest fossil fish from the Grant Museum of Zoology's [UCL] collections for your viewing displeasure on a monthly basis. Natural history museums are full of this material, not every museum specimen can be the first, last, oldest, biggest or nicest smelling because life can't always about the best. It's important to take some time and some space to think about the mediocre. The run of the mill. The quotidian. The also ran. Sure, the sparkly stuff is what we put on display in museums but it's really the middling masses that are key to understanding life.* (Carnall 2018 https://blogs.ucl.ac.uk/museums/2018/03/27/underwhelming-fossil-fish-of-the-month-march-2018/#more-53585)

Blogs have typically been used by museums to attract new visitors, promote interesting items or newly acquired objects, and allow for public engagement and the museum community outside of the physical walls of the institute to participate (Capriotti and González-Herrero 2013; Russo *et al.* 2007). In the Carnall example, a blog promotes an 'underwhelming' item to create a talking point and promote the lesser appreciated stored natural history items (Laws 2015; Carnall 2018). With creative thinking and input from members of the museum community that have successfully used this medium to positive effect, archaeological palaeoenvironmental remains considered 'underwhelming' could be included in a blog posting.

Social media networks are included as a major part of most museums' networking and communication plans (Ke *et al.* 2017). Published guidance for developing social media strategies for museums is common and can guide non-specialist digital media producers to develop content, create discussion, and invite engagement and can all be achieved with a small budget (Stewart 2012; Pitel 2016). The benefits of a well-designed social media campaign include the opportunities to initiate collaborations, access knowledge networks, communicate with audiences that may otherwise not engage with the museum and enhance their educational outreach (Brown Jarreau *et al.* 2019). Scientists and natural history museums have used social media platforms to communicate themes such as threats to biodiversity and unloved specimens that have not been presented to the public (Laws 2015). Examples of social media campaigns that successfully promoted unusual or unattractive specimens include the National Museum at Cardiff #SciArt Twitter campaign and the international #AskACurator campaign on Twitter and Instagram (Mortimer *et al.* 2016; Brown-Jarreau *et al.* 2019).

Survey of Museum Partners

It is established that themes such as human resilience and human-induced climate change can clearly be articulated using archaeological palaeoenvironmental archives. This part of the chapter investigates to what extent museums have used palaeoenvironmental remains to communicate archived palaeoenvironmental remains. To determine how museums in England have used the archived palaeoenvironmental resource in displays, three questions were put to 14 curators and archive repository managers:

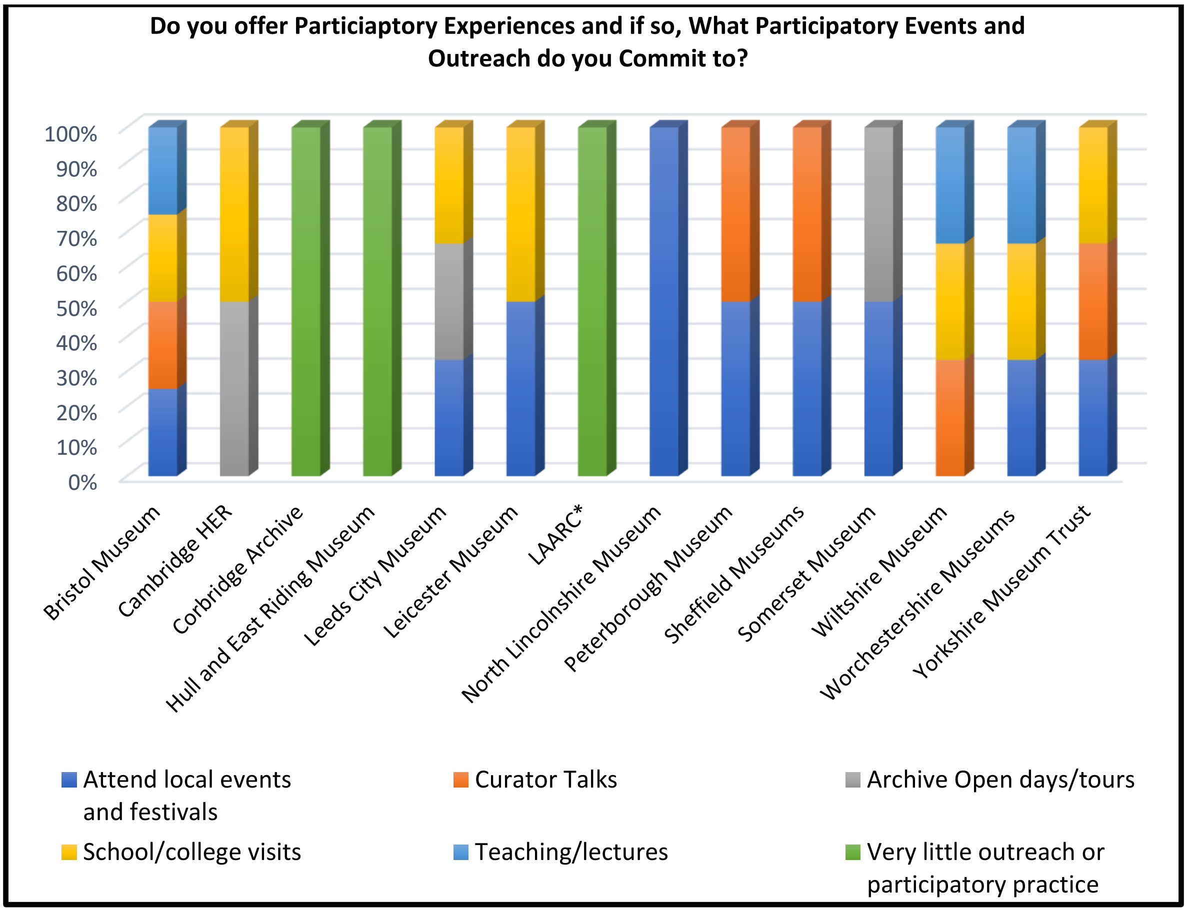
1 – Have you used archived palaeoenvironmental remains in museum displays?
2 – What outreach and engagement do you commit to?
3 – Do you use remains from palaeoenvironmental archives in participation events?

When asked whether they had used archived palaeoenvironmental remains in museum displays, 64% of the respondents reported that they had used palaeoenvironmental remains in museum exhibition displays, and 36% had not. This question is biased by the amount of time that the curator has been in post. Someone with more experience may have had more opportunity to display items and have a more extended memory concerning previous exhibitions than someone who has served less time in post and would not know what was put on display 10, 20 or 30 years previously. Therefore, the results are taken as a starting point to signpost what practices are undertaken.

The curators who responded that they have not used archived palaeoenvironmental remains gave reasons such as being too delicate, or too small to display. The museums that have used archived palaeoenvironmental remains have reported mixed results in their use for display. In an example from Museums Sheffield, the curator explained an occurrence where charred hazelnuts were used in a display, but the exhibition team found them to be 'fragile' and 'visually uninteresting'. The hazelnuts were displayed as objects with other Mesolithic items and exhibited in the same setting and context as artefacts such as flint blades. Without sufficient description and in association with clearly cultural items that are analogous to modern tools, a gap between time, cultural distance, and their meaning emerge in the minds of the observers, meaning they can be overlooked or misunderstood (Whitehead 2013). Reconciling the gap requires articulation via discursive techniques that can interpret and display (Black 2012).

Another example where palaeoenvironmental items from archaeological archives have been used is Peterborough Museum, which used beaver-gnawed wood from the Flag Fen archaeological archive in a display to articulate landscape stories and explain the preservation of archaeological sites. In this example, the scientific themes of changing landscapes and preserving organic archaeological remains were explored using archived palaeoenvironmental remains. This approach is different to the Sheffield example, which treated palaeoenvironmental remains in the collection as an item to be displayed alongside artefactual items. Perhaps then, the role of archaeological palaeoenvironmental remains is to illustrate scientific themes and techniques rather than display objects.

To determine the degree to which items from archaeological palaeoenvironmental archives are used in participation practices, the museum partners were asked if they commit to participatory events. Eleven of the fourteen respondents reported that they actively undertake some form of outreach with three of the museums rarely engaging in participatory events (graph 10). Those museums that did not undertake outreach regularly, reported that outreach is managed by other departments in the broader organisation, such as an education officer or dedicated outreach support team. The range of outreach activities includes attending events (seven respondents), curator talks (five respondents), school and college events (five respondents), teaching/lectures (three respondents) and open days and tours (two respondents).



Graph 10. The 14 museum partners provided the modes of participation that they offer. Six modes of participation were provided (*London Archaeological Archive and Research Centre).

Examples of participatory events include hosting and engaging with the Young Archaeologists' Club, holding evening classes in archaeological skills and themes, and taking parts of the collections to vulnerable or non-participatory groups (https://www.museumsworcestershire.org.uk/2018/07/28/suitcase-stories/). Considering the high uptake of participatory events across the surveyed museums, it was surprising to learn that only 29% of the respondents reported using archived remains in outreach and participation practices. Museum curators reported that they are less likely to use palaeoenvironmental remains for outreach and participation purposes, as "*we do not have the skills*" or *" do not know enough about it".* Interestingly, 80% of the respondents claimed that they would use archived remains from the collections if methods of articulating this resource were better realised, strongly indicating that assistance with how to use the archived palaeoenvironmental remains in events would be warmly received.

Given the low uptake in using archived palaeoenvironmental remains for communication and display, three case studies are supplied that examine archaeological palaeoenvironmental archives' role in an exhibition space. The case studies are used to provide inspiration and examples of how palaeoenvironmental items in the collection can be used. The case studies include cased object displays, ICTs, and participatory initiatives. Examples are gleaned from inside and outside archaeological practices and museum environments.

Case Study – Archaeological Palaeoenvironmental remains in Participatory Events: Guerilla Archaeology's 'Footprints in Time.'

Guerilla Archaeology (GA) is a multidisciplinary public science engagement initiative based at the University of Cardiff and led by archaeologist Professor Jacqui Mulville. The team comprises archaeology students from the University of Cardiff and scientists and artists from multiple organisations (J Mulville 2020 – Cardiff University Professor of Bioarchaeology - personal communication 20 July). The initiative is aimed at young adults and is hosted at events in the UK and European festivals. GA's practice is fundamental to provocative participation that engages participants about contemporary topics, ranging from coastal erosion to attitudes towards death. It crucially uses archaeology to deliver evidence-based content (Mulville 2019). As a case study, GA provides a rare example of an organisation that uses participatory events to focus on contemporary challenges and environmental archaeology and archaeological science. GA operates outside national educational curricula allowing the content to change quickly and respond to developing global events (J Mulville 2020 – Cardiff University Professor of Bioarchaeology - personal communication 20 July).

In 2016 GA exhibited the 'Footprints in Time' project at various events, including the Green Man Festival and the National Eisteddfod (Law *et al.* 2016). Footprints in Time used Cardiff University student Rhiannon Philip's doctoral research data. Dr Philip was involved in the GA project, allowing direct specialist input. The project focused on Mesolithic trails of human footprints left in the intertidal silts at Port Eynon on the Gower Peninsula (https://www.archaeology.org/news/5340-170228-wales-mesolithic-footprints). Footprints in Time utilised the archaeological evidence to examine how environments have changed since the Mesolithic period and investigate the impact humans have had on the environment using ancient footprints as an analogy to examine modern carbon footprints (https://guerillaarchaeology.com/2017/02/13/footprints-in-time/).

As an initial task, the participants were encouraged to examine the environment that existed when the footprints were created by identifying varieties of preserved pollen recovered from within the footprints. Visualising the pollen was made possible by enlarged 3D printed models of pollen grains created for the event to facilitate handling and inspection. Simplified pollen identification guides were given to the participants, who were asked to identify and count the enlarged grains. A 'top trumps' style card game was designed around the activity that involved linking the relative environment to the corresponding pollen. These activities helped the participants understand how environmental archaeologists interpret ancient environments and how environmental changes are determined using environmental proxies (J Mulville 2020 – Cardiff University Professor of Bioarchaeology - personal communication 20 July).

Interesting is the absence of actual fossil evidence in the activities, preferring the use of enlarged replicas. The project team has commented that using actual archived remains is difficult because they are too delicate or too small for object handling in activities that could result in them being compromised or damaged (Mulville 2019). This understandable reluctance to use archived physical remains could present problems regarding authenticity and present obstacles that allow for an authentic, context-rich understanding of the subject (Schwan and Dutz 2020).

Case Study – Worcester City Art Gallery and Museum: Ice Age

In 2018, the Worcester City Art Gallery and Museum hosted the 'Ice Age' exhibition (https://www.iceageworcestershire.uk/ice-age-exhibition). This case study examines the use of ICTs and demonstrates how technologies are used to replace the use of archaeological palaeoenvironmental archive materials. The Ice Age exhibition culminated in a growing regional interest in Pleistocene archaeology, arising from research and resource management projects, including The Shotton Project, the National Ice Age Network, and the Ancient Human Occupation of Britain project (Buteux and Lang 2007; Buteux 2003; https://archaeologydataservice.ac.uk/archives/view/nian_eh_2010/index.cfm). The archaeological remains on display were recovered from numerous excavations and interventions near Stensham and Upton Warren, undertaken in the 1990s and the 1950s, respectively.

Conducted in 1958, excavations within a gravel pit at Upton Warren identified MIS 7 (243kya) river terrace deposits believed to relate to the course of the modern River Salwarpe (Coope *et al.* 1961). Sieving the deposits revealed palaeoenvironmental remains, including larger mammals, molluscs, seeds, ostracods, small vertebrates, fish, pollen, and Coleoptera (Coope *et al.* 1961). Over 30 years later, excavations close to the M5 near Strensham in 1991 revealed deposits that were also dated to MIS 7 (De Rouffignac *et al.* 1995 https://www.iceageworcestershire.uk/ice-age-exhibition). Similarly, to the Upper Warren excavations, a rich host of palaeoenvironmental remains were encountered, including red deer, molluscs, Coleoptera, ostracods, and pollen. However, setting the Strensham excavation apart from the Upper Warren excavations was the discovery of mammoth remains (De Rouffignac *et al*. 1995).

The exhibition aimed to bring together Ice Age evidence gathered from excavations, including Strensham and Upton Warren, that had previously not been displayed, with the critical objective of examining the lives of the Middle Palaeolithic communities in what is now Worcestershire (https://www.iceageworcestershire.uk/ice-age-exhibition). Central to the exhibition was displaying the mammoth remains - alongside a full-scale woolly mammoth model - and a three-dimensional rotatable reconstruction of the MIS 7 environment replete with mammoth and mammoth hunters. The reconstruction used environmental evidence from excavations to create a landscape accurately representing faunal and floristic composition. The model's rotatable facility created an immersive and comprehensive interpretation of the Palaeolithic environment and the environmental context of the mammoth remains. However, absent from the exhibition were the micro palaeoenvironmental remains, preferring digitally recreated environments displayed on screens in place of the remains themselves (R Hedge 2020 Personal Communication 9 November).

Case Study – The Horniman Museum: Nature Base

The Horniman Museum has been selected as a case study as it provides insight into promoting contemporary climate issues using museum collections. Although the material used in the 'Nature Base' exhibition is not explicitly archaeological, examining methods and practices outside the domain may inspire the management of palaeoenvironmental archives and collections.

Opened to the public in 1901, the Horniman Museum in South London originally comprised the collection of philanthropist and politician Frederick John Horniman (https://doi.org/10.1093/ref:odnb/33994; Kerlogue 2008). From its inception, museum policies focused on building a cultural and natural history collection (Kerlogue 2008). The Horniman family was involved in progressive causes of the 19th century, including penal reform and the anti-slavery movement (Merriman 2020). The progressive vision continues today, as demonstrated by the

Horniman Museum Climate and Ecology Manifesto announcement. Published in 2020, the manifesto sets out to *"improve public awareness of the climate and ecological emergency and offer practical ways to make positive changes to our own lives"* (https://theecologist.org/2020/jul/23/museums-and-greener-future). The aims set out in the manifesto are anticipated to be met by institutional efficiencies improving the organisation's environmental sustainability, and a commitment to hosting exhibitions focusing on ecology and climate emergency topics.

As part of the manifesto, the Nature Base exhibition, a hands-on interactive natural history gallery, has been revamped (Horniman Museum 2020, Hatton and Dutton 2010). The family-focused exhibition opened in 2009 to encourage the audience to understand local wildlife (plate 17) (Hatton and Dutton 2010, Hatton 2008). The Nature Base exhibition offers extra-disciplinary comparison outside archaeological contexts, providing case study data regarding how environmental specimens such as insects can be displayed alongside replicas (plate 18).

Plate 18. An image of the Nature Base exhibition. Actual specimens are imbedded in glass in the table, with accompanying enlarged replicas and images mounted on the wall.

The approaches used in the exhibition include static object displays with insects under video microscopes, enlarged replicas, physical specimens from the collection, audio samples of bird calls, a transparent live beehive, and a live colony of beetles. This multi-format approach allows visitors to observe and describe items and maximise learning opportunities. The multimedia approach employed by the Nature Base exhibition can boast many benefits that create a well-rounded and engaging learning environment (https://www.horniman.ac.uk/event/nature-base/). For example, enlarged replicas and video microscopes show physical features and attributes that could not be visualised, allowing for an understanding of taxonomy. This could prove particularly useful for displaying microscopic items such as pollen, grain and seeds.

Discussion

Although curators face challenges in communicating palaeoenvironmental remains, there are many opportunities for these remains to be used to articulate scientific concepts. With global challenges such as climate change and threats to biodiversity and sustainability receiving column inches daily, palaeoenvironmental remains provide resources to articulate essential matters. There are, of course, challenges inherent in the display of palaeoenvironmental remains, their delicate nature and microscopic size. According to the survey data, these challenges appear to be dissuading museum curators from using palaeoenvironmental remains in an exhibition context or as part of a scheme of outreach. The delicate nature of palaeoenvironmental remains has led some to substitute actual remains with ICTs and replicas. As demonstrated by the Ice Age exhibition and the Horniman case studies, ICTs and replicas are useful tools that can convey broader concepts and are 'easier' to use than the physical archived remains. However, there is an argument that the wholesale removal of the physical evidence provides an inauthentic visitor experience and fails to use the unique communicative currency that archived resources have. The omission of physical evidence is a move away from promoting transparent science, a position that needs to be maintained in topics like those that lend themselves to environmental archaeology, such as the climate change discourse. The combination of formats, such as those used in the Horniman museum, demonstrated how inexpensive microscopes linked with video screens could include physical remains and the ICTs. This mixed media approach is authentic and in a format familiar to visitors.

The risk of damage or compromise through the handling of archived remains is therefore made complicated by their importance as research resources. Archaeological archives are unique resources selected for enduring use and reuse and the risk of damage through handling or observations and may be considered too great. In the example provided by GA, there is an understandable reluctance to use archived remains because they are also intended for research and could be destroyed in handling. As outlined in the CIfA selection toolkit, a surplus of material that is more than what needs to be deposited could be ringfenced for handling and treated with impunity. A solution could be sought as part of a selection policy that recognises that a surplus of excavated material is de-selected from the archive but collected by the museum in a separate exchange.

Social media channels and blogs can allow people to engage and participate in the learning of themes through engagement with items that may otherwise not be chosen for museum display or educational programmes. The challenges that face palaeoenvironmental remains, such as their lack of appreciated cultural capital and limited aesthetic value, could be addressed using novel approaches such as those employed by Carnall (2020).

According to the survey of museum partners, there is a desire to use palaeoenvironmental remains in mixed media exhibitions, but there are not enough skills or confidence in museums regarding how to display them. Skills-sharing events from museum professionals and science communicators that have successfully promoted and communicated palaeoenvironmental remains and unloved natural history collections could offer advice and guidance on techniques that lead to the under-utilisation of archives. Similar events in the past, such as 'Environmental Archaeology and Community Engagement Activities and Advice' (Mulville and Law 2013), have proved successful, and a similar event that focused on museum archaeology could prove beneficial.

Chapter Summary

Museum exhibitions and public science engagement specialists are increasingly using an array of techniques and methods to engage and invoke discussions with audiences regarding global challenges. These methods effectively communicate and simultaneously promote science in a trusted and transparent way. As these practices and techniques develop, palaeoenvironmental remains' delicate and fragile nature may result in confinement to object displays or being replaced with analogues or digital formats. A rejection of archived palaeoenvironmental remains for display fundamentally overlooks their distinctiveness and removes evidence from evidence-based narratives. If we wish to use palaeoenvironmental archives to provide context for contemporary environmental challenges, authentic remains should be incorporated in forms of display and participation to maintain transparency and openness. A selected surplus of remains could be used in discursive approaches and through well-designed and creative digital and social media campaigns. Skills-sharing events that include the experiences of professionals who have successfully communicated environmental archaeology or natural history through innovative techniques could inspire the communication of archived palaeoenvironmental remains.

Chapter Nine. Recognising the Challenges and Potential of Archaeological Palaeoenvironmental Archives.

Introduction

The thesis has established a series of aims designed to understand better the challenges confronting the archiving of palaeoenvironmental remains and realise opportunities provided by the resource. The aims set out to recognise threats to the continued preservation of the archived resource, glean more about the findability of archived remains, understand how palaeoenvironmental archives can be better created, and investigate the suitability of new forms of archive storage and how the existence of palaeoenvironmental archives can be communicated. Addressing these aims has revealed how the archaeological and museological community can introduce measures and innovative structures to positively influence the value of the overlooked resource and realise the project's central aim - to maximise the potential of palaeoenvironmental remains for academic research and public science engagement.

Archaeological Palaeoenvironmental Archives and Biodiversity Science

Climate change and anthropogenic activities, including agricultural intensification, are recognised as the principal cause of drying wetland soils and sediments (Salimi *et al.* 2021; Zhongming and Wei 2018; Ockenden *et al*. 2014; Davis 2020), presenting diminishing opportunities for future investigations of archaeological deposits in the fenlands, peat bogs, and marshes; locales that have historically been productive for research in England (Knight *et al.* 2019; Brunning 2013; Pearson *et al.* 1997; Van de Noort 2013; Burke *et al.* 2021). Twenty-first-century Investigations of 'classic' wetland sites at Star Carr (High *et al*. 2016; Milner et al. 2018), Flag Fen (Wagstaff 2016) and the Somerset Levels and moors (Brunning 2019) have demonstrated that waterlogged palaeoenvironmental remains are being compromised by desiccation, rendering these resources progressively scarcer (Van de Noort *et al.* 2002). The threats confronting peatlands and waterlogged palaeoenvironmental remains are made clear by the quantity of agencies and organisations highlighting the ongoing degradation and recommending management strategies (Gearey *et al.* 2010).

Archaeological deposits in urban centres, too, are at risk from climate-linked threats (Van de Noort *et al.* 2002 Kenward and Hall 2000). For example, English cities, including Canterbury, Carlisle, London, Nantwich and York, are all recognised as suffering from unpredictable sub-surface hydrological regimes causing wetting and drying of remains (Heathcote 2012; Holden *et al.* 2006). The process of wetting and drying caused by mutable water tables threatens waterlogged materials as well as calcium carbonate-based and charred items, materials that are often considered to be relatively stable within the soil archive (Van de Noort *et al.* 2002; Kibblewhite *et al.* 2015).

As these non-renewable archaeological resources become increasingly compromised, and palaeoenvironmental remains face potential damage, or total decay, the significance of the archived resource will likely heighten (Holtorf 2001). An appropriately curated and accessible national archive of palaeoenvironmental remains would protect the discipline against the depletion of the soil archive and present opportunities to conduct research and enable public science outreach in perpetuity. Viewing the collection and long-term storage of palaeoenvironmental remains through the lens of decay and terminal loss, the conservation and curation of archived palaeoenvironmental remains, and availability for future research as well as the opportunities for engagement emerge as an important topic that requires study.

Adjacent to the climate-linked challenges confronting archaeological deposits are the threats to extant biodiversity and natural habitat, most prominently caused by a combination of unsustainable agricultural practices and forestry practices and detrimental approaches to water management (Defra 2011; McKie 2021). Declining biodiversity in England will limit opportunities for research on living species; an alarming prospect predicted to exacerbate in the future, positioning natural history collections into increasingly important status (Castillo-Figueroa 2018; Ponder *et al.* 2001). Indeed, UNESCO has recognised the role that natural history collections can have in biodiversity science and sustainable development and has recommended that resources be sought to ensure that natural history museums and collections should be protected and promoted (UNESCO 2016; McGhie 2020).

Natural history collecting aims and objectives differ from those in archaeological practice. A central aim of archaeological archiving is to ensure that artefacts, ecofacts, samples and documentation that reflect the aims of an archaeological project, can be preserved, and made accessible for research and consultation (CIfA 2014). In contrast, natural history collecting, sets out to collect, archive and document biodiversity (Monfils *et al.* 2017). Environmental archaeology does, of course, contribute to an understanding of past biodiversity and the former geographical species range and how these have shifted diachronically, archaeological palaeoenvironmental *archiving* practices, however, do not fulfil the remit of contributing to biodiversity science. For museums and repositories to adequately achieve this, a comprehensive and unbiased archive of accessible physical remains needs to be developed and maintained (Monfils *et.al* 2017; Lendemer *et.al* 2020). To date, as evidenced through the thesis, the archiving of palaeoenvironmental remains has been biased by collection policies and variable standards, preventing researchers from consistently being able to readily access remains for reanalysis and, by extension, from a coherent record of temporal and geographic biodiversity. Perhaps then, the environmental archaeology community, with other interested parties and stakeholder groups, should reconsider the role that archives can play in providing accessible samples and specimen for the purpose of biodiversity studies.

Perceptions and Utilisation of the Archived Palaeoenvironmental Resource

Researchers have highlighted that the prevailing opinions in many European and North American countries ostensibly perceive archival research as an inferior option within the archaeological research ecosystem (Bauer-Clapp and Kirakosian 2017; Swain 2003). This notion seemingly pervades the minds of many archaeologists in England, as evidenced by survey data collected as part of this project, which revealed the infrequency of researcher access to archaeological archives, when compared to the occurrences of access in the Netherlands, which is significantly greater (Chapter Five). Results obtained as part of this study in England have indicated that the palaeoenvironmental components of archaeology are not frequently accessed, with 64% of survey respondents reporting that they have never received an enquiry regarding archived palaeoenvironmental remains or, on average, received less than one request per year. These data derive from 14 of the >161 museums that have collected archaeological archives and therefore only provide a heuristic measure of practices regarding archaeological research in England.

Factors that support the apparent reluctance to utilise archived palaeoenvironmental remains for research purposes are difficult to determine. However, archaeological literature contains examples of research projects (see FeedSax - Feeding Anglo-Saxon England and ZooMS: making eggshell visible in the archaeological record Stewart *et al.* 2013 as examples) that have utilised archived palaeoenvironmental remains, successfully demonstrating that archived items can contribute toward a variety of multiproxy investigations. This research has further demonstrated the efficacy of the archived palaeoenvironmental resource and provided instances that complement the success of the provided examples, as evidenced by the archived material recovered from the Wilsford Shaft (Chapter Four). The Wilsford Shaft – an excavation conducted in the 1960s – comfortably contributes to contemporary research questions, providing data for participation in genetic and isotopic studies, techniques beyond the grasp of archaeological scientists at the time of excavation. With England's palaeoenvironmental archive demonstrating such promise, the following section establishes why a resource with such potential receives such low occurrence of use, it then considers how to improve access to the remains.

Childs *et al.* (2006) and Stone (2018) have suggested that archaeological archives are not frequently accessed due to researchers having an unfamiliarity with museums and being discouraged by the prospect of difficulties in navigating archives. Regarding ecological collections and archives, the work of authors such as Mienke and Daru (2021) indicates that unpredictability in the representation of specimens and the biases that are caused through collection methods and post-accession decay may lead to researchers being deterred. The results of the Somerset Heritage Centre case study (Chapter Five) confirmed that the contents of the palaeoenvironmental components of an archive are unpredictable. This case study revealed that samples retained by specialists prevented successful contribution towards questions in the South West Archaeological Research Framework. In certain circumstances, specialists retaining remains is recognised as a legitimate outcome, although the decision requires agreement with all stakeholders and should be detailed in the final report or supporting archive statement (Historic England 2011). These inconsistencies in the archives can be rectified by identifying the specialists and contacting them to request that the missing items are dispatched to the museum or repository. A further solution could lie in an amnesty hosted by respected specialist societies. Organisations such as the Association for Environmental Archaeology and the Society for Museum Archaeology could be used to ask members and casual readers if they possess palaeoenvironmental components of archaeological archives and if they can arrange to return them to the museum of origin. Given that these archives have been accepted, there should not be any reason regarding ownership that prevents the archives from being transferred. Depending on the size of the palaeoenvironmental component of the archive, storage capacity should not prevent these remains from being reunited with the parent archive.

Further challenges complicating the representation of what palaeoenvironmental materials are represented in archaeological archives is presented by undeposited archives, which likely contain palaeoenvironmental remains. As revealed by Boyle *et al.* (2016, 2017, 2018) and Edwards (2012) Society for Museum Archaeology surveys, more than 161 museums in England hold archaeological archives. The results of the two archive audits conducted at The Somerset Heritage Centre and the York Museums Trust store, in combination with survey data produced as part of the thesis, revealed that between *c.*11% (as evidenced by Somerset) and *c*.33% (as evidenced by York) of archaeological archives contain a palaeoenvironmental component. Furthermore, as indicated by the Federation of Archaeological Managers and Employers (2012), more than 9,000 undeposited project archives are held by commercial practices, local authorities, universities, and charitable trusts (Smith and Tindall 2012). If the 11%-33% proportion is consistent within the undeposited site archives, hundreds or thousands of sites likely contain palaeoenvironmental remains that have not been deposited. This estimate is likely conservative, given that the estimated quantities derive from museum accessions accrued over centuries and includes archives that predate the formal adoption of environmental archaeology as a sub-discipline (Murphy and Fuller 2017; Turney *et al.* 2014; Paddayya 1982). undeposited archives had accumulated mainly in the 21st century when the collection and retention of dry palaeoenvironmental remains were standardised and consequently more likely to contain a palaeoenvironmental component.

Evidence of incomplete and unpredictable archives provides qualitative evidence that begins to reveal the reasons that may dissuade researchers from committing to archival research using palaeoenvironmental remains and adds further weight to the comments from researchers that have indicated that finding material in the post-excavation stage is often more efficient and cost-effective than sourcing archived remains (Lodwick pers comm). These outcomes could be strengthened by conducting further surveys targeted at palaeoenvironmental specialists to determine what factors deter them from committing to archival research. If the survey was managed by a widely respected organisation such as the Association for Environmental Archaeology, it might provoke a greater level of respondents, similar to the successful archaeological archive surveys managed by the Society for Museum Archaeology (2016, 2017, 2018).

Conserving the Archived Palaeoenvironmental Resource

The following section examines how wet and dry palaeoenvironmental components of the archaeological archive separately. The remains have been discussed separately as to focus the needs of the items.

England's Waterlogged Archaeological Resource

As highlighted, natural history researchers have predicted that as threats to waterlogged resources around the world increase, access to archived and collected resources, and their associated research currency will be enhanced (Shultz *et al.* 2021; Meineke *et al.* 2019). As threats to England's waterlogged resources grow and species loss inevitably occurs, rarity may result in archived waterlogged resources being viewed with increased research value. The potential for archived palaeoenvironmental remains to increase in research value is alarming given the relatively limited amount of attention to these archives. Furthermore, not having the complimenting wet samples will prevent a host of analyses from being conducted, and details have recourse to examine morphometric details and internal features that are not preserved through charring and mineral replacement. This study's results have revealed a reticence to retain waterlogged samples from archaeological contexts, and in the examples where waterlogged samples have been retrained, partial or complete degradation of the remains has often occurred. This is evidenced by the assessments of archaeological archives stored at Somerset revealed that waterlogged palaeoenvironmental remains from Meare and Glastonbury Lake Villages were neither preserved in a wet state or, except for timbers, through controlled drying. The example of the archived Coppergate insects (see page 81 in Chapter Three), revealed that retained specimens have decayed due to shifts in curatorial management.

Confronting unsuccessful attempts to maintain wet archives, a question emerges; should museums and repositories continue to try and retain this conservation method or should drying be preferred? Examples within natural history conservation that have used controlled drying techniques such as critical point drying and freeze-drying have demonstrated that once dried; they are more convenient to handle and, if maintained in the correct controlled environment, require less active curation once stabilised (Walker *et al.* 1999). These techniques may prove convenient, although they lead to shrinkage, discolouration, and the decay of internal features (Broda *et al.* 2021; Lechner *et al.* 2013). Methods such as cryopreservation can preserve the genetic material but are expensive and the ecofacts can only be retrieved a finite number of times (Ryding 2019). Therefore, operating a policy that recommends drying all waterlogged items may prove detrimental to future multi-proxy research. A combination of conservation methods is therefore regarded as the best option for the preservation of waterlogged resources. Techniques such as critical point drying and cryopreservation requires further experimentation to determine if they would be beneficial for the preservation of palaeoenvironmental remains and can be added to the suite of available methods of conservation.

There is also an absence of research and experimentation regarding the survival of nucleic acids in archaeological palaeoenvironmental remains. In the interim, a solution could be the retrieval of genetic material at the point at which it is collected, a technique inspired by natural history collecting (Martin 2006). Within natural history collecting practices, living specimens can be retrieved and intact genetic information can be extracted fully intact prior to death, an option not available to archaeological remains. Regardless, recovering genetic material in advance of museum deposition may still have benefits. Given that the decay of genetic material once recovered from archaeological contexts is unknown, this could be a way of retrieving genetic information in advance of any further decay. An archaeological project is unlikely to set out to collect materials for future genetic research, or for purposes of conservation archaeogenomics. Instead, there may be the discovery of significant remains such as the early importation of a species, or discovery of a landrace and may be regarded as having a considerable opportunity for future research. The policies of natural history conservation scientists are to extract genetic code in advance of long-term storage, but in the absence of such policies in archaeological practice, funding and aspiration are absent. The cost for genetic extraction would not be in a project budget and would not, therefore, be affordable. A genetic research fund established by Historic England could allow contractors to apply for funding to have genetic code extracted from a specimen judged to be of a particular research significance or potential and banked before post-accession decay.

The Storage of Waterlogged Palaeoenvironmental Remains

The thesis has identified methods and techniques that can effectively conserve waterlogged remains. The identified techniques could be rendered irrelevant, if the key challenge of identifying a museum or repository that is willing and equipped to accept these archives, continues to be problematic. In addition to identifying museums or repositories that can accept these remains, the facilities must also have the resources and facilities to effectively curate the remains and provide the expertise to monitor wet archives and ensure that they are topped up and that environments are maintained that limit evaporation. In many ways, the necessity for a new store is greater for waterlogged remains than dry archives because they are less stable and will become a rarer occurrence. Perhaps then, an option could take the results from the Dutch case study that indicate that the use of archived remains can be encouraged through sufficiently resourced regional hubs and further test these conclusions by developing a pilot scheme. This pilot scheme could take the form of a dedicated repository that, rather than accepting all palaeoenvironmental remains from museums in England, accepts historic wet archives and can also collect wet archives from the future. This approach would resolve several challenges. Firstly, wet waterlogged remains from across England could uniformly be collected. Secondly, the repository could accept historic wet archives and remedy any issues using a methodology outlined in the Wilsford Shaft chapter. Regarding a site for the facility, this research has highlighted that Fort Cumberland would be an optimal candidate due to having specialist staff, although further research will need to be undertaken to identify if this is a viable solution.

England's Dry Archaeological Palaeoenvironmental Resource

As revealed throughout the thesis, there is less literature and consideration of dry palaeoenvironmental archives. This is understandable given that dry items are considered more stable than wet archives and require less monitoring. Although stable, there is not sufficient data detailing what happens when ancient, charred plant remains are removed from their burial environment and exposed to fluctuating temperatures. This is an area that requires further study. To better understand the extent of temperature and humidity fluctuations, a learned society such as the Society for Museum Archaeology may wish to commit to an additional survey to determine how prevalent this phenomenon is. Although the detailed extent and occurrence of temperature and humidity fluctuations in English museums and repositories has undoubtedly been proven to be an ongoing phenomenon to some degree and may have resulted in unappreciated degradation to internal features.

Compared to the wet remains, charred remains face fewer challenges, but where possible, risk should be reduced by introducing environments with reduced fluctuations. Perhaps proving more of a risk is the packaging that can allow mechanical damage. Charred remains were packaged in paper and plastic bags that do not provide rigid protection from mechanical stress. Shell-based items maintained in plastic may also be at risk from destructive factors such as Byne's disease and require repackaging in a glass or metal container (Shelton 2008). An appraisal of archaeological archives in museums or repositories or repositories could reveal what packaging materials would be required to harmonise standards and identify areas of priority regarding damaged remains and indicate the potential costs of purchasing new materials and the time required to repackage items. An immediate solution to the challenges could be structured appraisal focusing on conservation matters. This would allow for determining items that require remedial attention and repackaging items that require it. There should also be some control over materials that have been analysed to stabilise them and reduce any bias for future analysis caused by post-analysis decay. If items from a dry archive are analysed for isotopic or genetic purposes, they should be maintained in sub-zero temperatures. This will allow for the re-measurement of the sample in the future without any bias caused by the decay of internal features.

New Repositories

A significant challenge is how these disparate undeposited archives are reunited. Storage capacity is preventing the deposition of archaeological archives, an issue that is unlikely to be improved without establishing significant additional capacity (Wills 2018). As demonstrated, a national facility that can specialise in the curation of palaeoenvironmental remains would be the optimal solution, rather than the remit of palaeoenvironmental remains being included in any plans for regional repositories. To develop a business case that can release funding, the frequency of use of the resource needs to be characterised to demonstrate how new repositories can encourage greater use of the archived resource. As highlighted in the Historic England response to the Mendoza review, determining patterns and frequency of access to archived palaeoenvironmental remains can inform how recognised structures within the archival system can be augmented to suit the needs of palaeoenvironmental remains better. Organisations such as RESCUE and Historic England have outlined how newly designed facilities can provide additional storage capacity and the skills to curate the archaeological materials correctly. However, new repositories would need to ensure more significant numbers of users and be largely financially self-sufficient, as asserted by Trow and Sloane (2016).

> *"Part of the answer lies in selectively creating new repository infrastructure, possibly at the regional level. For this to be sustainable in the long term, however, archaeologists must radically review their practices, in order to effectively control future demand."* Trow and Sloane 2016, pp 1

Encouraging further use of archaeological archives is possible, as demonstrated by the Netherlands case study, which indicates that appropriately resourced local archaeological archive depots can enhance occurrence of use. The adoption of a comparable regional system of archaeological archive repositories in England provides a model for regional archive depots, supplying evidence from decades of experimentation. Outcomes such as the combining of three provincial depots at Groningen, Assen and Leeuwarden to form the larger and more frequently visited Northern Archaeological Depot, indicating that fewer, larger depots are more effective – provide useful narratives for future consideration.

Regarding the curation of palaeoenvironmental remains, data from the regional repositories in the Netherlands has demonstrated very variable abilities to curate palaeoenvironmental archives effectively. There are, for example, apparent differences between Noord Braband and other depots such as Delft and Het Valkhov and their ability to actively curate palaeoenvironmental archives. In effect, the Dutch system has encountered the same challenges, and the variability is reminiscent of the challenges experienced in English museums and cannot be viewed as a satisfactory solution to the challenges. To conserve archaeological palaeoenvironmental archives, each repository must support suitable environments to accept all remains and adequately conserve them. To curate archaeological palaeoenvironmental archives in England, each new repository would need separate designated storerooms and refrigerators/freezers. Replicating the same systems would be costly. It would be beneficial to have a single store with the necessary items to sufficiently curate palaeoenvironmental archives. It is therefore proposed, that if a similar system were to be adopted in England, fewer or even a single specialised repository would require fewer specialised resources for the management of archaeological palaeoenvironmental archives and therefore provide a more cost-effective option. A system of regional facilities that can curate archaeological archives could certainly provide much-needed capacity, but as evidenced by the Dutch regional depot system, it could eventually lead to areas of under-resourcing of the skills and equipment needed to effectively curate the full suite of palaeoenvironmental remains in both a dry and wet state. A national repository that could accept the palaeoenvironmental components of undeposited archives and accessioned archaeological archives, as well as archives created in the future, would prevent regional shortcomings and focus funding on a single facility.

In terms of ownership, a similar system to the Dutch 2016 Archaeological Monument Care Act would ensure that remains are the property of the museums in the municipality or province in which they were discovered (Cultural Heritage Agency 2016). A repository dedicated to the maintenance of archaeological palaeoenvironmental archives would be obliged to curate the remains on behalf of the museum corresponding to the county or district in which the remains were found. As indicated by the opinions of the project's Museum Partners, there would need to be provisions for the regional museum to request that items be dispatched in the event of local research requests, or requirements for display.

Results from the Dutch government and the surveyed Dutch archaeological archive depots have indicated that if a similar regional system were adopted in England, a host of outcomes similar to those currently experienced in England, such as inconsistent controlled environments, would likely arise. Perhaps then, rather than a regional repository, a single dedicated national repository or low number of committed repositories that could service archaeological palaeoenvironmental archives would be better suited. A dedicated archaeological palaeoenvironmental archive repository would require controlled environments that can support other dried remains between 19°C - 24°C and a humidity of 45-55%, maintain wet archives at temperatures 0°C-43°C except for insects and materials stored for genetic research which should be maintained at -20°C-30°C and, ideally, a temperature staging room.

A dedicated repository with the correct facilities to curate palaeoenvironmental remains will require financing to bring to fruition. The initial investment for fridges, freezers, cold stores, and the maintenance of rooms at consistent temperatures and humidity would need to be sought with an additional regular income for staff, ground rent and utility costs. Funding for repairs and technological obsolescence of equipment would also need to be factored in. If sited at Fort Cumberland, rent costs would not be necessary as Historic England owns the property, and staffing could, at least partially, be provided through the existing team. As evidenced by observations at the Museum of South-West Denmark at Ribe, utility costs can be kept low with the use of renewable sources, but this is only a small part of the overall investment required to develop such a facility (Ryhl-Svendsen 2013).

Funding solutions could be sought through multi-agency participation. In August 2022, the Future for Archaeological Archives Programme (FAAP) was launched and connects the Department of Digital, Culture, Media and Sport (DCMS) recognise a Memorandum of Understanding between Arts Council England and Historic England, with the aim of realising the Mendoza Review (https://historicengland.org.uk/research/support-and-collaboration/future-for-archaeological-archives-programme/#8dd3e8e1). The FAAP initiative will establish what action needs to be taken to ensure that archaeological archives can ensure a sustainable future for archaeological archives. An outcome could be the development of a robust business case would need to be put forward to secure funding from central and local government. The Dutch case study offers some positive insight into how archaeological archive depots can enhance occurrences of access, but more research into the facility as a business needs to be conducted.

Of the options supplied as examples for a national specialist store for palaeoenvironmental remains - Flag Fen and Fort Cumberland - each demonstrate benefits and weaknesses. The Historic England facility at Fort Cumberland could accommodate the specialist skills and that could effectively curate and promote archives and set agendas for the selection of remains. Fort Cumberland is rarely opened to the public and its use as a centre that can offer access for interest groups, schools and the public is arguably not as effective as the Flag Fen example. Comparatively, Flag Fen has an educational infrastructure and established learning agenda that promote and educate the public about ecology and palaeoecology and the park could utilise archived remains daily. On balance, the need for public access is arguably less of a demand than access for research purposes and given the skills and tools that are available at Fort Cumberland. Unfortunately, Fort Cumberland is located on the south coast and is less accessible to the majority of the country than a more centrally located store. An additional challenge for both options is their status as a Scheduled Ancient Monument's. The scheduled ancient monument status will prevent the fabric of the builds from being altered and may provide challenges for the installation of facilities to create controlled environments. On reflection, an ideal solution would require a repository to be centrally located, not be a Scheduled Ancient Monument, have access to specialists and specialist equipment and, finally, have a some degree of public facing outreach capacity.

Findability and Data Dissemination

As outlined in Chapter Six, researchers have commented that the findability of palaeoenvironmental remains can deter the commitment to archival research. Databases and catalogues that detail location and associated data are insufficient and do not meet the FAIR principles, a guiding set of principles increasingly utilised across a broad range of research domains (Wilkinson *et al.* 2013). Bringing the digital data associated with archived palaeoenvironmental remains into line with the FAIR standards, in addition to database concepts that locate the remains within a museum store, researchers would be assisted by digital data demonstrating extended specimen details. Providing digital data that meets FAIR principles will grant a bottom-up approach that details the contents of an archaeological archive's palaeoenvironmental components, allowing for efficient searches that can improve access to the remains. This could begin to replace the traditional approach that expects a researcher to employ a top-down approach which uses publications to identify archived items and will likely face challenges in locating items leading to lost time, an inability to commit to research and an over-reliance on using the same well-established archives.

A review of the methods typically used by museum workers and environmental archaeology specialists to store and disseminate data has revealed that, for archived palaeoenvironmental remains, there are limitations and systemic flaws that prevent access to the physical remains and related data and duplication of data handling. Systemic flaws are characterised by the relational architecture of the databases, meaning that creating new concepts and backfilling them with data will likely prove time-consuming and costly, and the number of competing platforms that service environmental archaeology. This former point means that a palaeoenvironmental archive that contains a range of materials would require the same information on various platforms, meaning for a single site, databases relating to archaeobotany, invertebrates and molluscs would need to be consulted and backfilled. In addition, the specialised focus of many databases dedicated to environmental archaeology provides the challenge of entering data into separate databases relating to a single site would inhibit and complicate the use of a CIDOC CRM that could extract existing data from museum catalogues to populate desired databases. There are rare examples of systems that handle multiple proxies, such as the Strategic Environmental Archaeology Database, but it does not contain links to archive location and does not, therefore, meet the criteria for a database that can effectively promote archived remains. For the promotion of archived remains, a database that can allow for a full range of palaeoenvironmental remains would be the optimal solution. Although faunal remains fall outside the focus of this project, it is recommended that a database should include faunal remains to ensure that it is comprehensive.

Beyond the domain of archaeology, there have been developments in adjacent practices that can positively influence how archived palaeoenvironmental remains are promoted and associated digital data are disseminated. Advancements in the promotion of natural history collections have embraced the concept of the 'global museum' and championed the use of data aggregators as tools to disseminate data relating to isotopic data (IsoBank) and biodiversity information (GBIF), and genetic data (GenBank). Taking inspiration from developments in biodiversity science, archaeological palaeoenvironmental archives could be worth more than the sum of their parts and have the potential to be valued by members beyond the archaeological community. However, there is some distance to go before this can be achieved. To achieve this, the uploading of data into data aggregation services needs to be written into archiving and collections policy. As adjacent disciplines move towards a methodological and theoretical outlook that encourages data dissemination resources, archaeological practice could become outdated and unable to participate in broader discussions. Implementing data aggregators and sharing ecological data could create opportunities for the archived resource to be networked with natural history collections, allowing it to contribute to significant global topics (McGhie 2019). As indicated by this study, there is little use of data aggregator services within archaeological practice. Furthermore, few museums in England have signed up to the services, a factor requiring resolution to achieve optimal results.

Consequently, web-based links within databases designed to handle museum collection and archive and environmental archaeology data, do not currently have the option to provide a link to data aggregators. Taking all the discussed factors into account, a new database that focuses on archived palaeoenvironmental remains could assist in promoting and accessing the physical remains and associated digital data. A new database would therefore need to ensure it would satisfy the users' needs, ensure that it could comply with FAIR principles and the HIAS and can be maintained into the future. Based on these factors, a dedicated OASIS V module could provide the necessary concepts, accessibility and CRM compatibility required for archived palaeoenvironmental remains.

However, the concept of the global museum extends beyond developments in web-based sharing platforms. Within modern natural history practices and functional ecology, collections are regarded as central to the practices and provide fossil evidence for repeatability and re-testability of experiments (Wen *et al*. 2015; Page *et al.* 2015; Castillo-Figueroa 2018). The global understanding of what exists within shared collections can inform of gaps within collections and inform users of what to collect and fill voids in the biodiversity record (Pyke and Ehrlich 2010).

The updated version of OASIS is embracing the opportunity to bridge the gap between a museum, contractor, and HER by providing open access to the OASIS form by making all data available to all stakeholders throughout the archaeological process. It is expected that this can be achieved by making the process more transparent and inviting museums into the process (OASIS 2016). Another development of OASIS V is the addition of the OASIS + modules. These provide open access platforms to facilitate storing and sharing data specific to a specialist domain or interest group. Designing a dedicated OASIS + module for archived palaeoenvironmental remains, requires the correct domains identified in Chapter Six. An additional benefit of an OASIS + module is that it can be designed to meet the demands of FAIR and HIAS principles. Furthermore, CRMs could be used to locate much of the data in museums and begin to generate an OASIS database and automate much of the process. As a tool that can satisfy the challenges inherent in storing and communicating data relating to physical archived palaeoenvironmental remains, a dedicated module is arguably the most elegant solution. To design, implement and maintain an OASIS + module, there would be financial cost implications, and funding would need to be sourced. In the Discovering England's Burial Spaces OASIS module, funding was provided through a combination of Historic England and the Engineering and Physical Sciences Research Council (EPSRC). If links were provided to other collections with the intention of enhancing the global record of biodiversity, this could enhance the number of available funding bodies through bodies such as the Darwin Initiative, Defra, Natural England and data sharing networks such as the National Biodiversity Network and may be persuaded to see the benefits of a platform that collates and shares archaeological biodiversity data. If OASIS is revealed as being too expensive or unworkable, an alternative must be sought if archived palaeoenvironmental remains are expected to be used with greater frequency. If the only affordable options are museum audits that identify what is present in an archive and updated on the catalogue, then, although a sub-optimal option, this should still be achieved.

Globally, the conservation of biodiversity has a great deal of received academic attention (House of Commons 2021; Sandifer *et al.* 2015), but in England, the role in which archaeology can play its contribution to a comprehensive record of biodiversity has received little consideration. If archaeological practice expects to contribute to England's biodiversity record, we must adopt a similar system to natural history collecting and place the archived evidence at the centre of our activities. An additional benefit of ensuring that a comprehensive record exists is the reproducibility of results in environmental archaeology and palaeoecology. Fundamentally, the environmental archaeology community must collectively decide what is desired from archived material and determine if biodiversity science should be regarded as a principal aim of the discipline. It is recommended that there should be discussion amongst the environmental archaeology community about the value of archived remains and the role environmental archaeology should be playing in the development of England's record of biodiversity. It is the opinion of the author that making existing and newly created archaeological palaeoenvironmental archives globally accessible, findable, and secure must become a priority if we are to secure comprehensive research potential for environmental archaeology.

Selection/archive creation

The selection process – whereby items that reflect the aims and objectives of an archaeological scheme of work are selected for the final archive – is a necessary step in creating efficient, manageable archives free of material of extrinsic value (SMA 1993; Brown and Bibby 2017). The process can ensure that the size of the archive is efficient and guarantee that the contents are relevant to the project's aims. Selection requires consultation between stakeholders such as managers, conservators, local authority archaeologists, specialists, and collections curators who can collaboratively devise a project-specific strategy that, throughout the life of a project – project planning, collection stage, analysis, and report production – and informs what an archive should contain (Brown 2011; CIfA 2019). The literature regarding the process of archaeological archive selection published by Brown (2015), Brown and Bibby (2017), Oniszczuk *et al.* (2021), and CIfA (2019) strongly advocates for the early intervention of all stakeholders to devise a selection strategy that can appreciate the needs of specific items through the archaeological process. In Chapter Seven, the thesis has revealed that two of the stakeholders involved in the process – specialists and collections curators - frequently struggle to offer detail regarding the process at the project's outset. Specialists are more likely to collaborate in selection during the assessment and analysis stage or, as revealed by the Greatham case study (Chapter Seven), not participate in the process effectively.

Regarding the selection of waterlogged remains, the cost of controlled drying needs to be written into a budget if they are expected to be identified to ensure that they can be deposited. The Star Carr POSTGLACIAL project case study demonstrates how an appropriately composed budget can be mindful of conservation costs at the project design stage. In addition to costs, a thorough consideration of archiving at an early stage allowed the authors of the POSTGLACIAL project design to reflect the need to store un-conserved animal bone to allow for future analysis. Organic materials, their conservation needs and requirements for future research are possible, as realised by the POSTGLACIAL project, when attention is given to archiving throughout the project's life rather than at the assessment and analysis stages. In the example provided by Star Carr, a clear case for the best practice for selecting palaeoenvironmental remains emerges. Using a similar methodology that engages with selection at an early stage, appropriately budgets for conservation needs and considering project and material-specific needs for future research, can suit a research project. However, projects within a commercial environment may struggle to achieve these costs in a competitive market. As many researchers have commented, archaeological archiving is all too often overlooked, and the additional pressure of including a budget for conservation in a competitive environment may be challenging to enforce, although perhaps less so in the case of major infrastructure projects. Enforcement could be achieved by the local authority and planning archaeologists by setting out a requirement in policies to include conservation of palaeoenvironmental remains to be outlined in the archive selection strategy and request that adequate provision is made for palaeoenvironmental archiving. This will harmonise the expectations placed upon contractors and ensure that conservation needs can be accounted for in the selection process in a commercial setting.

Conservation and Selection

For their inclusion in the final archive, the controlled drying of waterlogged remains a common solution, but may prove to be an oversimplification given that morphological distortion and the potential degradation of internal features caused by drying techniques (Broda *et al.* 2021). Therefore, consideration should be given to the use of different drying techniques dependent on the material and should also reflect on maintaining a selection of samples in a waterlogged state. This is, however, problematic given that museums rarely collect wet archives. Therefore, decisions regarding the selection and conservation of palaeoenvironmental remains are recommended at the project design stage to identify the most suitable conservation techniques.

Early consideration in the process of archive selection can inform the stakeholders of any costs that may be incurred to conserve items for archive deposition. For example, if a museum does not accept wet materials, items that reflect the aims and objectives of the project or have intrinsic value should be dried so they meet the museum's requirements. If waterlogged remains are likely to be recovered, then a budget for drying needs to be established at the outset of the project. Although drying may appear to be a preferable option, there are potentially detrimental outcomes such as the loss of some internal features and morphological distortion. Factors such as this need to be considered in advance of conservation, and if waterlogged items are judged as having genetic, or isotopic value, consideration towards the extraction of data should be given before drying and archiving.

Decision making

As evidenced by published material, decision-making regarding archive selection can be informed by multiple factors, including an item or an assemblage's intrinsic value and the project aims (Oniszczuk 2021; Brown and Bibby 2017). Additional factors that may be able to guide the selection process include complementing existing archived assemblages. To be able to judge what remains already exist in a store, and enable collections curators to participate in the selection process, collections curators need to know what is in store, something that collection curators struggle to identify. To correct this, museums and repositories need an appraisal to update catalogues. Archive-led research questions could be added to regional research frameworks to guide selection.

To determine relevance, regional research frameworks have proven to be popular sources of information to establish what elements of the working project archive could positively contribute toward regionally recognised research foci. The East Midlands Historic Environmental Research Framework case study example demonstrated an absence of information regarding what exists in stores and how this selection could benefit the existing archives. If museums could produce research policies, or specific research strategies, drafted that include data from the regionally collected archive, these resources could be linked to the research frameworks. This would require high-level archive audits that could examine what is in store, identify what potential this has, and how future collection and selection can bolster the existing archive.

The Selection of Archaeological Palaeoenvironmental Remains for Biodiversity Science

In addition to the factors that influence the selection of palaeoenvironmental remains for archaeological research, the selection of palaeoenvironmental remains and their contribution to England's record of biodiversity should be given consideration. For selection to contribute to a record of biodiversity science, an understanding of what already exists in archives and what would need to be retained to complement archives and collections outside archaeology, needs to be achieved. This requires a database that can guide the decision-making process. Services such as GBIF and data aggregators are designed to promulgate biodiversity information and are centred on items in museums and repositories registered with the service. As demonstrated, data aggregators are less commonly used in archaeology than other biological data. Integrating data aggregators into archaeological practice and following the lead of museums such as those in Norway. Furthermore, backfilling the contents of a museum into this digital space can inform stakeholders of what material exists, what methods have been employed to conserve them and what absences exist within the record.

There are also important considerations regarding the deselection/deaccessioning of palaeoenvironmental remains. Where materials are identified as not reflecting project aims, having intrinsic value, existing in what is regarded as a surplus amount, or being able to contribute to England's biodiversity record, they can be deselected from the working project archive and discarded. Deselection can provide an opportunity to identify items that could be ringfenced for education and handling. These deselected items could be offered to either the same museum or repository as the final archive or be extended to other educational institutes or museums as an exchange separate from the final archive. These items could be handled with impunity and without fear of being destroyed.

Communication

As revealed through the museum curator surveys and the researchers such as Carnall (2020), small, fragile, and challenging to convey to a non-specialist audience, palaeoenvironmental remains require enhanced levels of description to communicate effectively. In the face of global challenges such as climate change and threats to biodiversity, archaeological archives provide a narrative. Elegant methods of using physical remains as part of a broader package of techniques needs to be sought.

The critical challenge inherent in displaying palaeoenvironmental remains is their delicate nature and microscopic size. According to survey data, these challenges appear to dissuade museum curators from using palaeoenvironmental remains in the exhibition space, or outreach. The delicate nature of palaeoenvironmental remains has led some to substitute actual remains with Information Communication Technologies (ICTs) and replicas. As demonstrated by the Ice Age exhibition and the Horniman case studies, ICTs and replicas are valuable tools that can convey broader concepts and are 'easier' to use than the physical archived remains. However, there is an argument that the wholesale removal of the physical evidence provides an inauthentic visitor experience and fails to use the unique communicative currency that archived resources have (Schwan and Dutz 2020; Hede *et al.* 2013).

Additionally, the inclusion of physical remains adds evidential currency, providing substance and validation to interpretation (Hebda 2007; Rockman and Hritz 2020; Laws 2015). The combination of formats, such as those used in the Horniman museum, demonstrated how inexpensive microscopes linked with video screens could include physical remains and the ICTs. This mixed media approach provides authenticity in a format familiar to visitors.

In terms of using physical remains in participatory activities such as counting or species identification using microscopes, the example provided by Guerilla Archaeology revealed an understandable reluctance to use archived remains because they are also intended for research and could be compromised. The remains could be added to school and education resources if deselected during the selection process. The risk of damage or compromise through the handling would be mitigated as they would otherwise have been discarded.

Social media channels and blogs can allow the public to engage with items that may otherwise not be chosen for museum display, or educational programmes. In addition, the challenges faced by palaeoenvironmental remains, such as their lack of appreciated cultural capital and limited aesthetic value, could be addressed using novel approaches such as those employed by Carnall (2020).

According to the survey of museum partners, there is a desire to use palaeoenvironmental remains in mixed media exhibitions, but there are not enough skills, or confidence in museums, regarding how to display them. Skills-sharing events from museum professionals and science communicators that have successfully promoted and communicated palaeoenvironmental remains and unloved natural history collections could offer advice and guidance on promoting the use of unused archives. Similar events in the past, such as 'Environmental Archaeology and Community Engagement Activities and Advice' (Mulville and Law 2013), have proved successful, and a similar event focused on museum archaeology could prove beneficial.

Museum exhibitions and public science engagement specialists are increasingly using various techniques and methods to engage and invoke discussions with audiences regarding global challenges. These methods effectively communicate and promote science in a trusted and transparent way. As these practices and techniques develop, palaeoenvironmental remains' delicate and fragile nature may result in confinement to object displays or being replaced with analogues or digital formats. A rejection of archived palaeoenvironmental remains in the exhibition ecosystem fundamentally overlooks their distinctiveness and removes evidence from evidence-based narratives. If we wish to use palaeoenvironmental archives to provide context for contemporary environmental challenges, authentic remains should where possible be incorporated in forms of display and participation to maintain transparency and openness. A selected surplus of remains could be used in discursive approaches and through well-designed and creative digital and social media campaigns. Skills-sharing events that include the experiences of professionals, who have successfully communicated environmental archaeology or natural history through innovative techniques, could inspire the communication of archived palaeoenvironmental remains. How techniques and approaches take shape should be informed by a wide host of specialists, including public science communicators, environmental archaeologists, museum workers and creatives from other science and non-science backgrounds. Working groups comprising multidisciplinary representatives, led by researchers and teams that have demonstrable success with the promotion and communication of archaeological science should be promoted as a way to identify new and engaging practices.

Limitations of the Study

A limitation of the thesis is the limited number of survey participants. The low number of survey respondents provides general results which can only inform general recommendations. Low frequency of survey respondents has been observed across the museum sector as a consequence of museum stuff having limited time to engage with surveys. Favourable rates of respondents will be improved by leaving the response window open for as long as possible, allowing sufficient time for responses. The response windows being open for extended periods may not be achievable for doctoral research, which is limited by a rigorous time frame to collect data. The archaeological archiving survey that has proved successful has largely been well promoted in advance of the surveys being made available, which ostensibly proved beneficial for respondent buy-in. Despite the limitations inherent in the survey as a method of data collection, they remain the only method to adequately gather quantitative and qualitative data. Future surveys regarding archiving would benefit from having project backgrounds plus aims and objectives promoted to museum workers through learned societies and charitable bodies such as the Society for Museum Archaeology, the Museum Association and ICON. An extended open window of a minimum of six months with multiple updates and reminders would allow for greater participation and engagement and may encourage greater buy-in.

Another limitation was the overall broadness of the thesis's central aim to '*maximise the potential of palaeoenvironmental remains for academic research and public science engagement*'. Given that it is the first substantial effort to investigate practices in archiving archaeological palaeoenvironmental remains, there is a substantial amount of ground to cover. Whilst conducting the research, it became clear that the topic is extensive enough to have contributed to multiple PhDs, each of which could have focused on topics covered by each chapter. Attempting to cover all these subjects in a single piece of research prevented the themes from being interrogated thoroughly enough. The aims have certainly been investigated, but to draw out more specific details, more intensive research of each chapter topic needs to be conducted.

Recommendations

The thesis has revealed six recommendations that can improve methods, practices and theory led practices related to archiving archaeological palaeoenvironmental remains. Each of the six themes is detailed below.

Selection

As indicated by the small-scale survey in Chapter Seven, the process of archive selection does not appear to be well understood in the specialist community. Guidance aimed at archive selection could inspire an in-depth understanding of palaeoenvironmental remains at the project design stage and may encourage a cognitive process involved in creating archives. In addition, selection guidance could guide an understanding of costs at the early stage of the project during the costing of the project. Within the guidance, the Star Carr POSTGLACIAL project could be used as a case study to demonstrate how the selection of palaeoenvironmental materials could be costed for and considered throughout the life of a project.

Conservation

A document highlighting conservation and controlled drying methods will enable specialists, museum workers and project managers to determine what techniques will suit the needs of an assemblage. Additional information should be supplied relating to the curation of wet archives, specifically the facilities, materials and health and safety requirements needed to sufficiently curate waterlogged remains. If sufficiently outlined, it may inspire some museums and repositories to identify the funding required to source the materials and include wet archives within their museum or repository. At present, there are examples of guidance, such as the SMA *Standards and Guidance in the Care of Archaeological Collections,* although there is space for improvement. The SMA guidance does not, for example, include sufficient assistance in recognising deterioration and damage, or help identify sub-optimal packaging.

The display and communication of palaeoenvironmental remains require considerable consultation between science communicators, museum workers and curators from across archaeology and natural history to identify how microscopic items can be best articulated. A broad delegation of specialists that extend beyond archaeology can bring experiences from other disciplines that have worked with similarly complex materials. A series of workshops held either nationally or regionally could advocate standards for curating and using palaeoenvironmental remains in education packages.

Improve Curatorial Practice

Absent archives that specialists have retained could be reunited through the direct appeal to specialists. In some cases, a collections curator may already be aware of certain items that have been retained by a specialist. Alternatively, a national appeal to all environmental specialists through a learned society such as the Association for Environmental Archaeology could reunite missing archives and allow them to be appropriately curated. Where museums have ceased to collect archaeological archives, this task could still be undertaken, given that in most cases, the physical size of these items and assemblages is likely to be small. Furthermore, an appropriately focused audit could also identify any items or assemblages that require repackaging and devise a cost for repackaging. Funds for these small-scale interventions and improvements could be sourced through the National Lottery Heritage Fund or local authorities.

Genetic Material

Genetic material requires much greater consideration regarding its long-term post-depositional conservation, and curation requires research. The role that techniques such as cryopreservation, for example, could potentially offer for the conservation of palaeoenvironmental materials requires further research to demonstrate if such materials could be compromised by ultralow temperatures and how these temperatures could affect ancient DNA preserved in palaeoenvironmental remains. However, in the interim, some recommendations could sustain archived palaeoenvironmental remains. An emergency fund that extracts and banks genetic material from significant specimens in advance of museum deposition could ensure that despite sub-optimal storage conditions, genetic code will be preserved and made accessible to an international standard. The cost-effective area where improvements to the curation of genetic material could be made is the addition of small refrigerators in museum stores. This could be used to store samples that have been analysed for genetic or isotopic research and stabilise them for long-term storage, allowing the remains to be reanalysed in the future without having to factor for decay that may have occurred in the years since the original analysis.

The Development of a Dedicated Repository

A new repository dedicated to archived archaeological palaeoenvironmental remains would be a solution to many of the challenges that face the collection, curation, and promotion of archived palaeoenvironmental remains. This facility could accept the palaeoenvironmental components of all historic accessioned archives, undeposited archives and newly created palaeoenvironmental archives. There are, however, significant challenges preventing the development of such a facility, most notably the cost. Given the potential cost of procuring and maintaining a new archive facility, a business case would need to be developed to identify accurate costs and revenue streams. As part of a business case, a pilot study should be considered that accepts both historic and newly created wet archives and suitably promotes them. This facility would ensure the long-term preservation of waterlogged remains, encourage greater use, and provide a case study for developing a more extensive repository.

The development of a new repository is consistent with the preferred options as revealed as part of FAAP. The FAAP partners have concluded that a single repository would better suit the needs of archaeological archives in general (https://historicengland.org.uk/research/support-and-collaboration/future-for-archaeological-archives-programme/#247c73be). This store should be equipped with the capacity to store wet and dry archives and maintain them in a stable and temperature and relative humidity.

Improve Data Dissemination

The digital data dissemination structures available for archived palaeoenvironmental remains need to be improved to comply with FAIR and HIAS. To achieve this, this doctoral research has identified that a dedicated OASIS V module is the optimal solution. This will allow for data related to archived palaeoenvironmental remains to be findable by researchers in and outside archaeology and make the results interrogable. An OASIS V module would need to be costed for by a dedicated interest group or a combination of interest groups. In addition to the cost of developing and maintaining an OASIS V module, the cost of developing a CRM to automate the collection of existing data and present it in a new digital space should be factored in.

An OASIS module could include digital data aggregator services, which would allow for the archived palaeoenvironmental resource to be promoted to researchers outside of the domain of archaeology and outside of the country. Currently, many museums in England have not signed up to data aggregation services such as GBIF, and without subscription to these services, these modes of sharing are impossible. In an effort to publicise the benefits that subscription to a data-sharing service could bring, a research project that uses Salisbury Museum and the Wilsford Shaft could be used. This project could provide the much-needed remedial work required to ensure continuing preservation of the Wilsford Shaft archive, provide guidance to Salisbury Museum to curate the remains effectively, and complete a subscription to GBIF to have the remains globally available. This would demonstrate the techniques and costs required and highlight the benefits of sharing the data.

Further Research

The thesis has identified five areas of further research and related questions. They are highlighted below.

1) What are the implications for the survival of genetic material in palaeoenvironmental materials, and what methods, practices, and techniques need to be introduced to conserve and record ancient DNA?

A significant area for additional consideration is a business case for new physical and digital repositories. As identified, a dedicated physical repository for palaeoenvironmental remains would be the optimal solution, and fits with the wishes of ACE and HE (https://historicengland.org.uk/research/support-and-collaboration/future-for-archaeological-archives-programme/#247c73be). Developing a business case will require understanding the costs needed to provide secure controlled environments and staffing and maintenance.

2) How can environmental archaeology contribute to efforts to develop a geographic and temporally comprehensive record of biodiversity in England, and what role will palaeoenvironmental archiving play?

Globally, biodiversity is at threat from climate change challenges and anthropogenic activities. These challenges highlight the significance of creating a record of biodiversity that can be consulted for research and public science engagement. Accessible and findable archives and collections are fundamental to developing the biodiversity record. Crucially, environmental archaeologists must decide if and how they want to contribute to England's biodiversity record. Palaeoenvironmental archives and how they are managed will be vital to this discourse and require debate and research.

3) What are the development and maintenance costs of a dedicated OASIS V module and where can funding be sourced?

The thesis revealed that an OASIS V module would be the optimal method of storing, promoting, and disseminating data relating to archived palaeoenvironmental remains. However, research focusing on how this could be developed and maintained and, crucially, how it can be funded, needs to be realised and taken to the next stage. Funding could be sourced through multiple sources, and if an ambition of archaeology is to contribute towards biodiversity, funding could be sourced through a more comprehensive array of potential sources. Further research could reveal specific organisations that would benefit from collaborating with archaeology to create a comprehensive and accessible digital record.

4) To what degree do mineral preserved and charred palaeoenvironmental remains decay over time when not supported in environmentally controlled environments?

Very little research has been conducted into how mineral replaced and charred palaeoenvironmental remains decay or remain stable in environments that fluctuate in temperature and humidity. Further research will reveal if any priorities emerge regarding the long-term preservation of these remains and indicate what measures are required to remedy acute threats.

5) Identify which organisations should input into a business plan to develop a repository for archaeological palaeoenvironmental remains.

A business case that establishes a need for a repository dedicated to curating palaeoenvironmental remains is required if a facility is expected to be developed. This would likely require a wide range of stakeholders to identify a range of potential funding agencies that can contribute to the development of a facility. The results from this thesis can guide the requirements for a new facility, and examples from the Dutch experience of regional repositories could be used to demonstrate how investment can enhance the resources use.

Discussions linked with FAAP are moving towards the idea of having a single building that can accept undeposited archives. The development of this facility will need to factor in the necessary tools and facilities are installed to correctly conserve archaeological palaeoenvironmental remains.

Conclusion

In the 150-year history of archaeological palaeoenvironmental remains being recovered from archaeological excavations and retained for reuse, the priorities, agendas, techniques, and rationales for collection and retention have shifted from impromptu responses to a more formalised procedure of considered selection and curation. Although the direction of travel has been positive, this research has demonstrated that collection policies, in combination with issues relating to the 'curation crisis' and varying curation standards, have resulted in biased and unpredictable palaeoenvironmental archives and archiving practices. Due to collection policies, waterlogged items are at the greatest risk from post accession decay and not being deposited in a museum or repository. These debilitating factors are regrettable and must be resolved if we are to realise the multiple opportunities for archived archaeological palaeoenvironmental remains that have emerged throughout the thesis. Chief among these opportunities is the clear research archaeological palaeoenvironmental potential in England's museums and repositories. As demonstrated by the Wilsford Shaft and the Somerset Heritage Centre case studies, ample material can contribute to significant research questions outlined in regional research agendas. There were also instances, such as Great Yard and Northover cemetery, Ilchester, where coherent research could not be achieved due to items absent from the archive. This can at least partially be resolved through archive amnesties promoted through an organisation such as the AEA to deposit their archives in accessible museums. The palaeoenvironmental components should be reunified with the rest of the site archives, even by museums in which much of the archive has already been accessioned.

Confronting the opportunities inherent in making palaeoenvironmental archaeology more accessible and secure are the variable standards of curation that exist across museums and repositories in England. Threatening the long-term security of archived palaeoenvironmental remains are the demonstrable variable standards of curation that offer unstable environments. Wet archives are at particular risk, with the evaporation of fluids and failure to top-up lost fluid leading to the decay of waterlogged remains. Dry archives, although more stable than waterlogged remains, internal features such as isotopic and genetic information may also be at risk from decay in fluctuating temperatures and humidity. This is an area that would benefit from additional research. Also threatening the security of palaeoenvironmental remains is the variable standards of packaging. The packaging of archived palaeoenvironmental remains has been revealed to be inconsistent and, in some cases, may threaten their long-term survival. Archive appraisals that identify the quality of packaging can reveal items and sites that require attention. Focused appraisals of the palaeoenvironmental components of archives to determine what items that are at risk from decay or incorrect packaging. An appraisal would require guidance that details the correct packaging materials for palaeoenvironmental remains. If appraisals could be conducted across the country, it would allow for standards of packing to be harmonised and promote the survival of the material in perpetuity.

Standards of curation for genetic material have been highlighted as a particular challenge. There is a clear need for additional research into the survival of genetic material in palaeoenvironmental remains once removed from their buried context. Additionally, it should be ascertained if approaches in natural history practices that bank the genetic data from freshly collected or killed specimens can be beneficially applied to items recently recovered from archaeological context. If remains are identified that demonstrate strong potential for future genetic research, the extraction of genetic material prior to museum deposition is recommended to prevent further decay. Currently, the extraction of genetic material and subsequent banking of the code is not budgeted for and will likely require emergency funding. An emergency fund facilitated by Historic England could allow for significant discoveries to have genetic material banked and ensure that genetic material is protected against post-accession decay.

The large quantity of excavated palaeoenvironmental remains across England, as evidenced through this research and other archive-led projects, can contribute significantly to research questions (see Chapter Five). The larger challenge of identifying the funding and capacity to accept the thousands of undeposited archives and unlock the research potential is far more complex and challenging to resolve. A combination of undeposited archives and items being retained by specialists prevents access, reducing the research currency of these excavated remains and preventing their use in multi-proxy analyses. To meet these challenges, aspects of the curation crisis need to be overcome, chiefly identifying available storage capacity to accept all archaeological palaeoenvironmental archives and supply adequate funding to ensure their ongoing curation. This research has revealed that a single repository dedicated to palaeoenvironmental archives would be the optimal solution. In terms of identifying available space within the existing museum structure to develop a specialised repository for the curation of palaeoenvironmental archives, data provided by the museum partners revealed that the current system of museums could not provide storage. A centralised dedicated facility could gather and curate the materials to an acceptable standard would greatly maximise the potential of palaeoenvironmental remains. Introducing a new facility dedicated to conservation and promoting archived palaeoenvironmental remains would likely prove expensive and comes at a time when identifying funding within arts and heritage is competitive (Gross *et al.* 2021; Pye 2020). A robust case needs to be formulated which demonstrates the multidisciplinary value of archived palaeoenvironmental remains and positively recognises how the investment would increase the reuse of the archived palaeoenvironmental remains. A case study should include the examples provided by the Dutch archaeological archive depots, demonstrating that investment has resulted in enhanced use of archaeological archives accessible and promoting them for lifelong learning opportunities and school visits. An initiative that could unlock funding for a repository is a pilot study. It is therefore suggested that a centre for wet archives be established at a facility such as Fort Cumberland. Wet archives regarded as being at risk could be actively curated, and where there are complications related to decay due to fluid evaporation, remedial measures, such as those identified in the Wilsford Shaft, could be employed to remedy damaged archives. This pilot study could ensure that newly created wet archives can be accepted, and existing archived waterlogged material can be better curated and promoted.

Regrettably, the ability of collections management software and curator knowledge to identify archived materials is inconsistent and is falling behind global developments in promoting and sharing ecological data. Initiatives and developments include the Extended Specimen Network and linking archive contents to other collections and archives worldwide. Synchronising with archaeological archives, natural museums, and herbaria across Britain and mainland Europe could allow for multidisciplinary working. Details relating to quantities, conditions, morphometrics, and habitats can provide bottom-up searches. This could be achieved through a dedicated data storage structure and dissemination in the form of a dedicated OASIS + module that would allow for a fully mobilised national archive of archaeological palaeoenvironmental remains that is comprehensive in its findability and accessibility. The development of a repository for palaeoenvironmental remains and the creation of a new dedicated database is, however, an expensive option and at a time that funding is spread between many agencies and agendas.

In addition to the technical developments required to achieve the desired level of networking and align with rapidly evolving practices, archaeologists would need to consider collections and archives as fundamental apparatus in demonstrating repeatability and reservoirs of enduring research potential (Bakkes 2014). This could be rectified by keeping the physical remains at the centre of the ontology in a similar fashion to the biosciences (Meineke *et al.* 2018). Philosophically, this is a shift in the archaeological mindset. This change in perspective, whereby the archived remains and their continued preservation and accessibility occupy a more centralised role in the process rather than a task undertaken at the end of an archaeological investigation,

Archaeological archives dually provide authentic evidence-based narratives of human resilience while simultaneously offering a testament to the scientific process, both of which can be extracted for communication and education purposes (Amand *et al.* 2020; Pearson 2019). Archaeological archives provide evidence of past human-environment interactions, ancient economies, and foodways (Cameron *et al.* 2013; Van de Noort 2013). The archaeological literature contains diverse examples of palaeoenvironmental evidence which informs narratives of human resilience, such as living through periods of food shortages and climate change (Vésteinsson and McGovern 2012, McGovern 1988, Altchul *et al.* 2017, Guttmann-Bond 2010, Cooper and Sheets 2012). Complementing the literature are archaeological palaeoenvironmental archives. These archives comprise biological remains such as pollen, insects, diatoms, fly pupae, wood, charcoal, and seeds that have been collected, analysed, and retained for future research and re-testing. If we glimpse beyond the contents of the archives and consider a broader perspective, we can perceive palaeoenvironmental archives as palimpsests of millennia of human experience and human-environment relations. These archives can be renegotiated to construct narratives that can participate in educational activities and discussions regarding environmental and economic topics such as anthropogenically caused climate change (Byrne 2011; Byrne 2012; Vestergaard and Riede 2017). Climate change is currently at the top of many global agendas, with the media reporting on reports and frameworks by Non-Governmental Organisations and charities, including the Intergovernmental Panel on Climate Change reports (for example see IPCC 2021), and the United Nations Framework Convention on Climate Change (UNFCCC) and the Global Biodiversity Outlook 5 report: Secretariat of the Convention on Biological Diversity (Hirsch et al. 2020). These reports detail biodiversity loss, ecosystem collapse, anthropogenically caused global warming, food shortages, and enhanced species extinction rates. Noticeably absent from the reports are the contributions that archaeology can demonstrate. This thesis can elucidate the topic and provide insight into how archaeologists can engage with these outputs.

Furthermore, the adoption of conservation techniques such as cryopreservation for archaeological palaeoenvironmental remains also needs further research to determine its efficacy. In the short term, however, museums should procure refrigerators to support items that have been analysed to maintain them after analysis to ensure that they can be retested in the future, without the bias of post-analysis decay compromising future research.

A further systemic shift needs to occur in the process of selection. Specialists and collections curators need to be involved in the selection process, and consideration needs to be given to the selection and potential costs of conservation at an early stage of a project. Research frameworks could be used as sources that provide insight into archive-led research projects and highlight gaps in materials in archive collections that can be rectified through the inclusion of collecting missing items as a project aim.

Significance of the research

This thesis represents the most significant attempt to understand practices related to archaeological palaeoenvironmental archiving in England. The research has revealed that there are clear opportunities within archaeology. To realise the potential, clear challenges need to be confronted. For example, collecting needs to be unbiased and able to collect all archives. This requires storage capacity and greater consideration of archiving in general, especially when budgets are determined at the project design stage.

Chiefly, archaeological palaeoenvironmental archives need to be made secure and accessible for the future. With declining opportunities to conduct investigations in productive locales, the value of archived palaeoenvironmental remains is likely to increase. This is occurring against a backdrop where ecological archives are being conceptually perceived very differently from adjacent sciences that are realising successes with the sharing, conservation and accessibility. Re-conceptualising the position of archaeological palaeoenvironmental archiving in our practice can allow for a more systematic form of archiving and palaeoecology to allow results to be more retestable and reproducible, and reusable. Conversations within the sub-discipline of environmental archaeology need to determine how archaeological archiving can future proof against the decay of archaeological deposits, provide insights into global challenges and provide archaeological resources in perpetuity.

Appendix I

Palaeoenvironmental Archaeology* Archives Questionnaire

1) Do you have palaeoenvironmental materials* in your collection?

☐ YES ☐ NO ☐ DON'T KNOW

2) Are you currently accepting palaeoenvironmental* materials with archaeological archives?

☐ YES ☐ NO ☐ DON'T KNOW

3) Are the palaeoenvironmental materials* in you collections catalogued sufficiently to provide location details and quantities?

☐ YES ☐ NO ☐ DON'T KNOW ☐ N/A

4) Are the organic remains in your custody are stored correctly in order to ensure their long-term preservation?

☐ YES ☐ NO ☐ DON'T KNOW ☐ N/A

*Charred and waterlogged seeds, soil samples in bags/buckets, pollen, diatoms, molluscs, insects, foraminifera, ostracods, charcoal, wood, hazelnuts, acorns, fruit stones, mounted microscope slides, rope, parasite eggs, phytoliths

For more information on environmental remains see the website below;
https://historicengland.org.uk/advice/technical-advice/archaeological-science/environmental-archaeology/

Appendix II - A Proposed Methodology for Palaeoenvironmental Archive Appraisal

For the purposes of making the palaeoenvironmental archive appraisal process repeatable, a method for appraisal is provided. The methodology employs a value-led approach inspired by macro-appraisal techniques which are used by archivists to appraise paper archives (Couture 2005; Cook 2005), and for international museum collection valuations (Luger *et al.* 2014; Russell and Winkworth 2010; de la Torre. 2002).

Macro-appraisal employs value-determination theory and focuses on the value that the items possess for broader societal value – such as public engagement through display, study, or communication – and their usefulness to the parties that created them (Cook 2005). Forms of macro-appraisal can be observed in practices beyond the management of paper archives and are found in museum audit methodologies, such as those employed at the Getty Conservation Institute, The Collections Institute of Australia, and the Dutch *Assessing Museum Collections: Collection Valuation in Six Steps* (Arijs 2014; Rijksdienst voor het Cultureel Erfgoed, 2014). Within each of these examples, the overarching aim of valuation is commonly shared, but they individually demonstrate distinctive objectives and methods (Scott 2008). The Australian model, for example, takes an approach that is weighted towards the intrinsic nature of the artefacts rather than public facing value, by employing more reflexive and theoretical approaches common in micro-appraisal. The current Dutch strategy *Assessing Museum Collections: Collection Valuation in Six Steps* (Arijs 2014) offers prescriptive approaches to appraisal and provides balanced consideration towards the objects in the museum and how public value can be leveraged. The following proposed archive appraisal methodology combines lesson learnt from the Somerset audit and a format inspired by the Dutch strategy.

The methodology uses six stages that are designed to develop bespoke value-led appraisals that systematically examine palaeoenvironmental archives in a repository. The first three stages focus on the design of the appraisal and leads by identifying questions, motivations, and stakeholders that the appraisal will service and includes steps that help organise the physical inspection of the archived remains. These questions underpin the appraisal and allow for each stage to cascade into fields that are weighted towards the intrinsic value of items but maintain an overarching societal value. The preliminary stages assist in focusing the needs of the themes' questions that support the appraisal, although it should be considered that multiple aims can be satisfied concurrently. The aim of determining a conservation plan could for example, be conducted simultaneously with the aim of enhancing catalogue detail. Stages four to six focus on aspects of the physical appraisal itself and includes suggestions of factors and fields that should be considered at specific stages through the appraisal. Supporting the six stages are a series of example aims. These example aims are included to elaborate on the stages and provide context and scenarios.

Stage One: Outline the stakeholders the appraisal is expected to serve and state the motivations and questions that support the process.

Stage one requires the appraisers to define questions and the stakeholders expected to benefit from this stage should be named. Clearly defined motivations and stakeholders is vital in the successful delivery of the appraisal. Motivations can include catalogue enhancements, devising conservation plans and developing research plans. Five example motivations are provided below to provoke or provide inspiration for the appraisal.

Example Motivation 1 – Devise a conservation plan. To devise a conservation plan, clearly defined objectives will prove essential. Is, for example, the purpose of the audit to establish what controlled environments should be added to a museum storeroom to support the ongoing conservation of the archived archaeological palaeoenvironmental resource? Or, alternatively, is the plan expected to appraise containers and packaging to determine their suitability? Is the outcome expected to continue towards a costing plan? Questions such as these should be clearly defined.

Given that the plan would likely lead to the improved conservation of a repository's palaeoenvironmental archives, stakeholders that would benefit from this appraisal would include the archaeological and ecological communities, the public, and museum management.

Example Motivation 2 – Devise a condition assessment. In this example, it should be made clear what level of detail will be given to the condition assessment. Will this set out to observe evidence of mechanical damage or fungal growth that has occurred since the archive's deposition? Or, is the aim to determine if items are suitable for certain methods of analysis?

Example Motivation 3 – Enhance catalogue detail. Adding detail to the catalogue would require defined domains that will facilitate searches of the catalogue. Improving catalogues and online collections and archives data can better serve research communities and inspire greater use. Specific deficiencies need to be outlined at this stage. Are there, for example, absences within the archives due to specialists retaining samples and can these absences be noted on catalogues and help to streamline researchers' efforts?

Example Motivation 4 – Establish how archived palaeoenvironmental remains can contribute towards specific research. An appraisal undertaken to determine research potential would require well defined research themes and questions that can be used to appraise the archives. The Somerset example demonstrated how important it is to have well defined questions. These questions could be taken from regional or national research agendas or may be part of a funded research project which is focusing on a particular region and has well defined aims and questions.

Example Motivation 5 – Identify items that can support communication through display, exhibition, or outreach event. If an audit is being conducted to identify items that can be used for display or public participation events, what is the nature of the display and what themes are being communicated and which items will best serve the needs of the exhibition or outreach?

Stage Two: Establish recognised frameworks and published works that can be referenced and devise evaluation of significance criteria.

Valuation criteria need to be added to ensure that the stage one objectives can be graded in terms of their value. Valuation criteria should be based on published works and referenceable material that can be used throughout the appraisal to provide repeatable methods.

Example Valuation 1 – To satisfy a conservation plan, SMA fact sheets (SMA 2020) and the Historic England environmental archaeology guidance document provide enough detail to guide museum staff to determine what remains exist within an archive and assess the quality of the containers that have been used (Historic England 2018b) would. Valuation criteria that would satisfy this aim could include: i) 'critical attention' – whereby the containers are potentially being detrimental to the remains, ii) 'moderate' – indicating that the remains are not at immediate threat but require action, and finally, iii) 'acceptable' – demonstrating that the items require no further action.

The items will require basic description (e.g., charred seeds, shell) and include details regarding if they have received any form of stabilisation or conservation. The results of this appraisal will indicate what, if any, additional storage measures are required by a repository.

Example Valuation 2 – An appraisal that sets out to assess the physical condition of remains could use publications such as Shelton (2008) and SMA (2020), but there is a dearth of published material regarding the condition grading of palaeoenvironmental materials.

Example Valuation 3 – To enhance the catalogue, an appraisal would firstly need to determine what domains need to be satisfied. The domains that are significant require a great deal of consideration to ensure that repositories across the country can effectively communicate with each other, reach the correct audience, and possess sufficient information. This topic is investigated in greater detail in chapter eight and concludes that the domains that were revealed as being significant beyond the contextual and stratigraphic information include quantifications of items in an assemblage, the inclusion of dating information, taxonomic information, and bibliographic and raw data links.

Example Valuation 4 – In the pursuit of items for display and exhibition, national education syllabus or published works regarding the theme of the display may prove useful in determining themes and criteria.

Stage Three: Determine where the appraisal can take place and formulate a retrieval plan.

In the case of the Somerset Heritage Centre assessment, the palaeoenvironmental components of the archives were of a quantity that benefited from being set in a separate dedicated area for their assessment. It should be considered that, as again demonstrated in the Somerset Heritage Centre assessment, up to 178 samples for every $1m^3$ of storage capacity would be required for this. A museum with a large quantity of palaeoenvironmental remains held in archives should consider this in their method statement. If the quantity of archived palaeoenvironmental remains is small and occupies few boxes, such measures are unnecessary.

Stage Four: Physical Search Through Archives and Identify Contextual Information and Ascribe Scores to Each of the Aims.

At Stage Four, the physical appraisal and valuation can commence. For each of the questions provided in Stage One, retrieving a basic level of information pertaining to the archived remains is essential. It is therefore recommended that as part of all enquiries regardless of the questions or aims, basic information is included in the recording process. Basic information should include:

-Site/project name

-Year of excavation

-Context number

-Description of context

-Sample Number

-Circumstances of project (e.g. watching brief, evaluation, research excavation)

-Coordinates

Once the basic data have been recorded, the valuation as outlined in stage two can be undertaken and logged.

Stage Five: Modify with documentary research.

Documentary research conducted through the HER will be necessary to extract enhanced information such as dating and taxonomic information. To address questions that pertain to the intrinsic value of the remains themselves, such as a conservation plan or condition assessment, additional information from the HER may not be required. Appraisals that are conducted to add details to catalogues will need to carry out additional documentary research to reveal geospatial information and dating information.

The bottom-up approach that begins with data-gathering in the museum store with the physical archived items, will create an inventory of remains that is consistent with what is in store and not influenced by a potentially incomplete or incorrect catalogue. In the Somerset example, the inventory can be considered as being comprehensive as it was collated from the physical remains and compiled using information from the bags and associated labels. Linking the archives to the correct physical and digitised reports was streamlined by each of the boxes possessing an accompanying HER number which could be cross-referenced.

Stage Six: Process the data and devise an action plan.

Stage six draws together the results from the appraisal and can introduce answers to the questions set out in stage one. The means by which data is processed depends on the motivations and questions that have been asked at stage one. For example, a conservation plan that set out to identify a need for updated controlled environments would need to group the items into material class and, as informed by the supporting guidance outlined in stage two, decide what improvements to storage environments need to be considered. This could be presented as part of a larger investment plan as within a museum's wider plans to develop.

In the example of an appraisal undertaken to examine the physical condition of items, a value ranking could be undertaken to identify items that require critical care or conservation. A ranking would demonstrate where efforts and finances need to be focused.

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