Measuring the impact of research access for human skeletal remains stored in English museum contexts.

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Abstract:

This thesis evaluates the relationship between research and the preservation of skeletal remains stored in English museums, through the lens of researcher access to those collections. Preservation is an important issue in archaeology; however, it is under-represented in the bioarchaeological literature. This has led to a lack of understanding regarding the factors that most affect the preservation of human remains. Few studies have explored the impact of post-excavation factors on the preservation of human remains, and this study was proposed to address this shortage. The primary aim of this study was to assess to what extent research causes changes to the condition of skeletal remains, and whether the information we gain from research is balanced against the potential damage it may cause.

To achieve this aim, a new methodology was developed that involved the creation of a retrospective baseline condition assessment of the skeletal remains. Utilising this retrospective assessment enabled the change in preservation over time to be calculated without the need for a longitudinal study. The second aim was to evaluate other potential causes of deterioration to see if any had a greater impact than research through access. Where other factors affecting deterioration were discovered, their significance was discussed, as were the repercussions for museum storage and research.

The data collected from holdings of skeletal remains in institutions outside of London, showed that whilst research access did have an impact on the preservation of the skeletal remains studied, this impact was to a lesser degree than other factors evaluated in this research. Predominantly, the start (or retrospective baseline) preservation of the skeletal remains and the quality of the museum storage were the most significant factors that affected the preservation of the remains.

This thesis highlights the problems we, as researchers, as well as the skeletal remains we curate, could potentially face in the future. It recommends that greater consideration be given to the preservation of skeletal remains that are curated. Funding overall needs to be increased, whether this is through core government funding or an alternative source. Furthermore, planning for long term storage of skeletal collections is essential. The quality of museum storage and the amount of space available for storage must also be addressed, as these are significant issues in the long-term preservation and conservation of skeletal remains.

Contents

Acknowledgments: ... iii
Abstract: ... v
List of Figures. ... xiii
List of Tables ... xvii
Chapter 1: Introduction ... 1
1.1 Overview ... 1
1.2 Research Context ... 6
1.3 Importance of this Research ... 7
1.4 Literature Review Summary ... 8
1.5 Research Question ... 9
1.5.1 Aims and Objectives ... 9
1.6 Methodology Outline ... 11
1.6.1 Key Variables and Requirements ... 11
1.7 Scope of Study ... 12
1.8 Hypothesis and Predictions ... 14
1.9 Organisation of Thesis ... 14
Chapter 2: Background ... 16
2.1 Museum Curatorial Practices ... 16
2.1.1 Museum Guidelines ... 18
i. Museum Ethics ... 19
ii. Acquisition and Accessioning ... 21
iii. Collections Management ... 23
iv. Access ... 25
v. Loans ... 26
vi. Deaccessioning ... 27
2.1.2 Problems Facing Museums ... 31
i. Storage Space ... 31
ii. The "Brain Drain" ... 35
iii. Financial Problems ... 36
iv. Summary ... 38
2.2 Care of Human Remains in Museums ... 39
2.2.1 Guidelines for the Excavation, Curation, or Reburial of Archaeologically Derived Human Remains ... 40

2.2.2 Archaeological Human Remains in English Museums 45
i. Acquisition of Archaeological Human Remains 46
ii. Storage 49
iii. Display 50
iv. Research 51
v. Deaccessioning 52
2.2.3 Ethics of Human Remains 53
2.3 Preservation Scales for Human Bioarchaeology 58
2.3.1 Preservation Scales 59
i. Behrensmeyer (1978) 59
ii. Buikstra and Ubelaker (1994 p.7) 60
iii. McKinley (2004) 62
iv. Creating a New Preservation Scale for Human Skeletal Remains 63
2.3.2 Research on the Preservation of Human Remains Curated in Museums 65
2.4 Summary 69
Chapter 3: Methods and Materials 71
3.1 Methods 71
3.1.1 A New Preservation Scale 71
i. Inter- and Intra-Observer Testing of Version 2 (final version) 76
ii. Results 80
iii. Statistical Analysis 84
iv. Discussion 85
v. Scale Success Conditions 92
vi. Summary 94
3.1.2 Museum Data Collection 94
i. Data Collection Part 1 (Museum Data) 95
ii. Data Collection Part 2 (Research Data) 102
iii. Data Analysis: 102
iv. Other Tested Correlations 106
3.2 Materials 110
3.2.1 Verulamium Museum 116
i. Folly Lane 116
ii. Wheathampstead 116
iii. St Stephens 116
3.2.2 Worcester City Museum 117
i. Worcester Technical College 117

ii. Wormington Compression Station ... 117
iii. Sainsbury St John ... 117
iv. Old Yew Hill Wood ... 118
v. Deansway ... 118
vi. Bredon Norton ... 118
3.2.3 Saffron Walden Museum ... 118
i. Wicken Bonhunt ... 118
3.2.4 Great North (Hancock) Museum Newcastle upon Tyne ... 119
i. Hexham Golf Course ... 119
ii. West Wharmley ... 119
iii. The Sneep (Tarset with Greystead) ... 119
iv. Bewes Hill Cist (Beacon Hill) ... 119
v. Summer Hill ... 120
3.2.5 Newark National Civil War Centre ... 120
i. Ad Pontem ... 120
ii. East Stoke battlefield ... 120
iii. The Friary ... 121
iv. Lincoln Road (St Leonards) ... 121
v. Newark Castle ... 121
vi. Staythorpe Power Station ... 121
3.2.6 Summary ... 122
Chapter 4: Results ... 123
4.1 Test of Robustness ... 123
4.2 Primary Comparison: Change vs. Access ... 124
4.3 Secondary Comparisons ... 127
4.3.1 Start preservation ... 127
4.3.2 Time Period (Age) ... 128
4.3.3 Storage ... 130
4.3.4 Time Out of the Ground ... 132
4.3.5 Museum Type and Size ... 133
4.3.6 Soil pH ... 134
4.4 Access Factors ... 135
4.4.1 Access vs Time Out of Ground ... 136
4.4.3 Access vs Start Preservation ... 138
4.4.4 Museum Type vs Access ... 140
4.5 Summary ... 141

Chapter 5: Discussion 142
5.1 Primary Comparison - Access vs. Change 142
5.2 Secondary Comparisons 145
5.2.1 Start Preservation vs. Change 145
5.2.2 Age (Time period) vs. Change 148
5.2.3 Storage Quality vs. Change 149
5.2.4 Time Out of the Ground vs. Change 150
5.2.5 Museum Type and Size vs. Change 151
5.2.6 Soil pH vs. Change 152
5.3 Factors Affecting Access 154
5.3.1 Access vs. Time Out of the Ground 154
5.3.2 Access vs. Time Period 156
5.3.3 Access vs. Start Preservation 158
5.3.4 Access vs. Museum Type 159
5.3.5 Summary 159
5.4 Research Outcomes 160
5.4.1 What was the Primary Cause of Deterioration of Curated Skeletal Remains? 160
5.4.2 Human Remains Storage: Cost Estimation Study. 161
5.4.3 An Unconventional Mean 168
5.5 Wider Implications of the Research 170
5.5.1 What Can be Done to Protect Human Remains Curated in Museums? 170
5.5.2 Cost-saving Strategies for the Protection of Human Remains 172
i. Charging for Research Space or Access 173
ii. Baseline Condition Assessment of Skeletons at Accession 174
iii. Accurate Documentation 176
iv. Catalogue or Database of Collections 177
v. Display and Public Tours 180
vi. Summary 182
5.5.3 Problems Facing Museums 183
5.5.4 Deaccessioning as a Possible Solution to the Storage Crisis 184
i. Benefits of Deaccessioning 187
ii. Issues with Deaccessioning 189
iii. Summary 190
5.5.5 Can Technology Help to Limit the Loss of Scientific Knowledge from Deaccessioning? ... 191
i. 3D Scanning 191
ii. 3D Printing 198

iii. Future Technology 202
iv. Chemical Analysis Problems 205
v. Copyright and Intellectual Property Issues 208
vi. Summary 210
5.5.6 Commercial Archaeology Companies and the Storage Crisis 210
5.6 Summary 212
Chapter 6: Conclusion 214
6.1 Overview of Research and Findings 214
6.1.1 What was Expected? 214
6.1.2 To What Extent Were the Aims of This Study Achieved? 215
i. Supplementary Findings 216
6.1.3 How Effective was the Methodology? 216
6.1.4 Limitations of Research 220
6.2 Recommendations from the Research 223
6.2.1 What Should be Done? 223
6.2.2 What Can be Done? 226
6.3 Curating Human Remains in the Future 230
6.3.1 Change in Policy 231
6.3.2 Deaccessioning as a Solution 232
6.4 Future Research 233
6.5 Final Remarks 236
Bibliography 240
Appendices 283
Appendix 1: Preservation Scale – Version 1. 283
Appendix 2: Guidance on How to Use the Created Preservation Scale. 284
Appendix 3: “Figure 1” from the Preservation Scale Guidance. 285
Appendix 4: Images of the 10 Bones Used in the Observer Testing. 286
Appendix 5: List of Participants Who Tested the Preservation Scale, including their Background and Answers Given. 287
Appendix 6: Observer Recording Form. 288
Appendix 7: Remainder of Graph Set 1 (Fig 3.3): Comparing All Individuals who Participated in the Observer Testing. 289
Appendix 8: Remainder of Graph Set 2 (Fig. 3.4): Participants’ Separated by Experience with Human Remains. 290
Appendix 9: Remainder of Graph Set 3 (Fig. 3.5): Participants Separated by Archaeological Experience. 291

Appendix 10: Remainder of Graph Set 4 (Fig. 3.6): Participants Separated by Museum Experience. 292

Appendix 11: Skeletal Recording Spreadsheet Used for Recording the Current and Past State of Preservation of Skeletal Remains. 293

Appendix 12: Museum Information Recording Sheet. 297

Appendix 13: Collated Museum Box and Packing Information. 298

Appendix 14: Museum Storage Photographs. 299

Appendix 15: Contacts. 301

List of Figures.

Figure	1.1	Number of students attending the Durham University Palaeopathology MSc., from 2000-2019.	7
Figure	2.1	Extent of museum closures across the United Kingdom since 2010; Available at: https://www.museumsassociation.org/campaigns/museum-funding/19062013-museum-closures-map.	18
Figure	2.2	Descriptive categories taken from Behrensmeyer's 1978 preservation scale (Behrensmeyer 1978 p. 151).	59
Figure	2.3	Grade 0 and Grade 5+ from Jacqueline McKinley's preservation scale (adapted from McKinley 2004 p. 16).	62
Figure	2.4	A "Bowron Box" image taken in the Durham University Archaeology Department (Human Osteology Laboratory).	67
Figure	3.1	Version 2 (final version) of the Preservation Scale.	74
Figure	3.2	The equation that expresses the formula for calculating Cohen's Kappa (Cohen 1960 p. 40).	79
Figure	3.3	Graphs showing the frequency of categories assigned for bones 1 to 4.	81
Figure	3.4	Graphs showing the percentage distribution of the categories assigned for bones 1-4, split by the individuals' experience with human remains.	82
Figure	3.5	Graphs showing the percentage distribution of the categories assigned to bones 1-4, split by the individuals' experience in archaeology.	83
Figure	3.6	Graphs showing the percentage distribution of the categories assigned to bones 1-4, split by the individuals' experience working in a museum.	83
Figure	3.7	The methodology used in this thesis and an example showing the process of creating a baseline preservation assessment.	99

Figure	3.8	Equation to calculate Change in preservation (Dv).	103
Figure	3.9	Worked example showing the method used to calculate the change in preservation.	103
Figure	3.10	Demonstration of how the 7 preservation categories were reduced to 5.	104
Figure	3.11	Equation to calculate Pearson's Correlation Coefficient (Neyman and Pearson 1933).	105
Figure	3.12	Map showing the locations of the museums used in this research.	113
Figure	4.1	Number of times sites have been accessed compared to the change in preservation for the skeletons from each site studied.	125
Figure	4.2	Number of times collections have been accessed vs. change in preservation; not separated by site.	126
Figure	4.3	Start preservation compared to change in preservation.	127
Figure	4.4	The time period of the remains in relation to the change in preservation.	128
Figure	4.5	Comparison of storage quality and change in preservation.	131
Figure	4.6	Comparison of the time the remains have been out of the ground and the change in their preservation.	132
Figure	4.7	a: Size of museums compared to average change in preservation; b: Ownership of museums compared to average change ("other" refers to Saffron Walden Museum, which is partly owned by a trust).	133

Figure	4.8	Comparison of the soil pH of the sites excavated and change in preservation.	134
Figure	4.9	Comparison of the time the remains have been out of the ground and the number of times they were accessed.	137
Figure	4.10	Comparison of time period of the skeletal remains and the number of times the collections were accessed.	138
Figure	4.11	Comparison of the average start preservation and the number of times accessed.	139
Figure	4.12	a: Average access to museums run by councils, universities and ‘other’; b: Average access to museums according to the size of the museum. (“Other” refers to Saffron Walden Museum, which is partly run by a trust.).	140
Figure	5.1	Soil pH map of the United Kingdom.	153
Figure	5.2	The approximate population of Britain, at key points throughout history. Numbers taken from Pryor (2004); Broadberry (2015 p. 205); Wrigley and Schofield (1981 p. 208).	156
Figure	5.3	Results of a keyword analysis search conducted using the above time periods as criteria. The results show the number of articles matching each time period from the AJPA (American Journal of Physical Anthropology). Trendline value (R2) = 0.0733.	157
Figure	5.4	Pest control solutions: both the tester trap (left) and the full trap (right). After PEL 2019b; PEL 2019c.	166
Figure	5.5	Comparison of normal and non-normal distributions of data, created from a random sample.	169
Figure	5.6	An example of a 3D scan of an ulna from the Digitised Diseases database. Available at: “Digitised Diseases” http://www.digitiseddiseases.org/mrn.php?mrn=156.	194

Figure	5.7	Breakdown of digital memory needed per bone, skeleton and collection. Created from estimates taken from “Digitised Diseases”.	196
Figure	5.8	Comparison of both a high quality 3D scan (right) and a low quality 3D scan (left). A and D superior view, B and E view from the right, C and F inferior view – all scans were completed on the same mouse skull (*Pseudomys delicatulus*). After: Marcey et al. (2018).	197
Figure	5.9	An example of a low quality 3D print. After: https://www.simplify3d.com/preventing-blobs-on-3d-print/.	200
Figure	5.10	Example of a Google Cardboard Viewer for use with a smart phone. After: https://store.google.com/product/google_cardboard.	203

List of Tables

Table	2.1	Survey Responses - Question: Is it acceptable for human remains to be displayed in museums?	43
Table	3.1	Observer error testing results (for preservation scale 1).	73
Table	3.2	Kα (Krippendorf's Alpha) bootstrapping example.	79
Table	3.3	Breakdown of participants by experience of working with human remains.	80
Table	3.4	Breakdown of participants by archaeological experience.	81
Table	3.5	Breakdown of participants by museum experience.	81
Table	3.6	Cohen's Kappa results.	84
Table	3.7	Easiest and hardest categories to assign.	90
Table	3.8	Strength of Correlations (Evans 1996.)	106
Table	3.9	Summary of the museum information showing the type, size, and quality of the documentation for each of the museums used in this research.	112
Table	3.10	Summary of each of the skeletal collections used in this thesis.	115
Table	4.1	Robustness Test - Change vs. Access – Sample of Data Evaluated using Five Categories.	123
Table	4.2	Number of Times Accessed vs. Change in Preservation.	124

Table	4.3	Start Preservation vs. Change in Preservation.	128
Table	4.4	Time Period vs. Change in Preservation.	129
Table	4.5	Scores for the variables relevant to museum storage	130
Table	4.6	Storage Value vs. Change in Preservation.	131
Table	4.7	Time Out of the Ground vs. Change in Preservation.	132
Table	4.8	Soil pH vs. Change in Preservation.	135
Table	4.9	Time Out of the Ground vs. Number of Times Accessed.	136
Table	4.10	Time period vs. Number of Times Accessed.	137
Table	4.11	Average Start Preservation vs. Number of Times Accessed.	139
Table	5.1	Museum storage cost-effective study.	162

Chapter 1: Introduction

1.1 Overview

Humans bury their dead. They hold funerals. Television shows that feature human remains are extremely popular. Visitors flock to museums which display human remains. The reason for our obsession with human remains is unclear; what is clear is that we undoubtedly feel a connection to our dead and wish to learn more about them. This overview provides a brief introduction to the study of human remains.

Many anthropologists argue that the presence of a mortuary ritual is one of the most important factors in tracing "humanity" amongst our hominin ancestors. "Burial", as a ritual practice, shows the capacity of symbolic thinking, that is, the ability to comprehend beyond the present, to remember the past, and envision the future. Symbolic thinking is argued to be a uniquely human facility (Madison 2018). Burials provide us with twofold evidence. The ritual allows archaeologists to observe belief systems and other cultural aspects of death (Madison 2018); the physical remains provide direct evidence of the lived experience of the individual buried (Roberts 2018).

Every culture on earth, past and present, has some form of death ritual, and although they differ, all have the same aspects of remembrance of and honour for the dead (Cohen 2002; Museum Ethnographers Group 1994). In Christianity the body is not important, as upon death the soul leaves the body and the body is not required during the resurrection (1 Corinthians 15: 42-44; English Heritage 2005). However, funerals remain important, emotive, and often elaborate events in our culture (Hoy 2013; Reeves 2011). Perhaps, simply, the physical remnants of a person we knew represent the last tangible link to them, one that we feel compelled to honour.

Similarly, human osteoarchaeologists see human remains as a tangible link to the past, one that provides clues to how individuals in the past lived and died. The word osteoarchaeology comes from the Ancient Greek words ostéon (bone), archaeo (ancient), and logos (knowledge) and simply is the study of archaeological bone, in any context. This thesis will only concern itself with the context of human osteoarchaeology, that is, the study of historic and prehistoric human remains. However, it should be mentioned that osteology also has a forensics context, involving forensic anthropology and the identification of the recently deceased, usually in a legal context (White and Folkens 2005 pg.1).

Human bioarchaeology "is the study of ancient and historic human remains in a richly configured context that includes all possible reconstructions of the cultural and environmental variables relevant to the interpretations drawn from those remains" (Martin et al. 2013 p.1). Macro analysis, which for the most part requires direct access to the human remains, can provide information regarding the age, sex, stature, and health status of an individual. Chemical analyses can provide information on diet, mobility, and relatedness. The techniques by which this information can be obtained are discussed concisely below.

Age at death can be estimated by a number of methods, applied to various elements of the skeleton, with some being more accurate than others. Dentition can be used to age an individual, by dental development and eruption for non-adults (AlQahtani 2008; Hillson 1996; Ubelaker 1989). Dental development begins in utero with the 1st deciduous incisors and 1st deciduous molars developing between 14 and 16 weeks. Approximately two weeks later the 2nd deciduous incisors begin to develop, followed by the deciduous canines and 2nd deciduous molars. Within four to five weeks of initial development all deciduous teeth should have begun to form (Hillson 1996). As the teeth develop they emerge through an aperture in the alveolar bone surface; this is referred to as alveolar emergence. This is followed by gingival emergence, otherwise referred to as clinical eruption, during which the tooth breaks through the gingivae (gums). Gingival emergence takes place several months to a year after alveolar emergence (Hillson 1996). Eruption of the teeth happens in four distinct phases: the first is the eruption of deciduous teeth, which usually happens within two years after birth (White and Folkens 2005). The second phase occurs between the ages of six and eight with the eruption of the first permanent teeth (incisors and 1st molar). The third phase involves the eruption of most of the remaining permanent teeth which takes place between the ages of 10 and 12. The final stage is the eruption of the 3rd molar which erupts at approximately 18 years (White and Folkens 2005). Although some variation in the timing of these eruptions can be found among individuals and populations, researchers use the stage of eruption to estimate the approximate age at death of the individual. Age at death is estimated by comparing the dentition (both development and eruption) of the individual to an established standard clinical data, the most commonly used of which are Schour and Massler (1941), Ubelaker (1978) and AlQahtani and colleagues (2010; AlQahtani et al. 2014; Hillson 1996). For a discussion of several alternative methods of non-adult age estimation from the dentition see Hillson (1996). Dental development stops after the completion of the third molar; after this alternative methods must be used, one of which is evaluating the patterns of tooth wear created by Brothwell (1981). In this method wear patterns of the molars (1st, 2nd and 3rd) are compared to a chart that shows the range of expected dentine exposure for four broad age groups (17-25/ 26-35/ 36-45/ 45+ years). Although this method has been used with some success throughout the world it should be noted that Brothwell's method was developed for British remains from the Neolithic to the medieval period (Alayan et al. 2018; Hillson 1996).

The degeneration of specific joint surfaces can also be used to estimate adult age; for example, the pubic symphysis can be used following the methodology described by Brooks and Suchey (1990), or the auricular surface applying the methodology developed by Lovejoy and colleagues (1985). Epiphyseal fusion can be used to estimate the age of non-adults. Long bones develop from three or more centres of ossification (including the diaphysis, proximal and distal epiphyses); these centres fuse during adolescence following a consistent pattern. For instance, the proximal epiphysis of the humerus fuses to the diaphysis between 10 and 15 years of age (Scheuer and Black 2000 p.297). By looking at which bones have fused, and how much fusion has occurred, an age can be estimated. Finally, the degree of closure of cranial sutures can give an estimation of adult age, as it is an ongoing (though extremely variable) process that progresses throughout adulthood (Ruengdit et al. 2020; Todd and Lyon 1924). Full methodologies for both of these techniques, as well as how to apply them, can be found in Buikstra and Ubelaker (1994). These are but a few of the many methods to estimate age at death, and a more complete directory can be found in Buikstra and Ubelaker (1994) and Roberts (2009 pp. 132-136).

Sex can be estimated in a number of ways, including both morphological and metrical methods. The most accepted methods use analysis of the skull and/or pelvis, and for the most accurate determination both should be used; however, in archaeology this is not always possible due to imperfect preservation or recovery. Descriptions of which features of both the skull and pelvis to use can be found in Buikstra and Ubelaker (1994 pp. 16-21), whilst discussion of the accuracy of each method can be found in Mays and Cox (2000 pp. 117-130).

Stature can be estimated by two methods: the mathematical and the anatomical. The anatomical method, created by Fully (1956) involves the measurement of all skeletal elements that contribute to the stature of an individual, from the top of the skull down to the bottom of the calcaneum. The mathematical method involves measuring any long bone and adding the value into the corresponding regression equation created by Trotter and Gleser (1952; 1958) and Trotter (1970). Specific equations have been calculated for each long bone and the equations differ slightly for each sex and for different population affiliation.

Some pathologies can be observed in the skeletal remains. However, this is limited to diseases that cause osteological changes (Roberts and Manchester 2007). Furthermore, osteological responses to disease are relatively slow, and acutely lethal cases may not leave any indication on the skeleton (Wood et al. 1992). Mann and Hunt (2013) summarise many of the diseases and pathologies that can be observed in a human skeleton. Gross observations are not the only methods that can be applied to human skeletal remains. Radiographic analyses look at radiographs of the bone, to analyse the internal structure of the bone (Licata 2016). Radiographs can be used to observe post-mortem changes, to estimate age at death of both adults and non-adults, and can also be used to differentiate between human and animal bone (Beyer-Olsen 1994; Chilvarquer et al. 1991; Walker and Lovejoy 1985). Bone changes, caused by a range of pathological conditions, can also be observed through radiographic analysis (Mays 2005). This method is non-invasive and does not physically damage the bone – although there is debate in the literature as to whether ancient DNA (aDNA) may be damaged by radiography (Immel et al. 2016 contra Beckett et al. 2020). Histology, or microscopic analysis is a more invasive technique that involves looking at thinly cut sections of bone under a microscope. When looking at the structure of bone more closely pathologies such as osteoporosis and vitamin deficiencies can be more easily observed, and because of this, histology is becoming an increasingly important method for the detection of some diseases in human skeletal remains (Mays et al. 2013 pp. 12-13). Finally, the dental calculus found on the teeth of human remains can preserve proteins, aDNA, and microscopic debris, allowing for investigations of diet, environment, and disease. Debris and proteins from the calculus can provide evidence of the diet, including milk, cereals, and plant products (Hendy et al. 2018). Debris in the calculus can also provide information about the environment; for example, microcharcoal and burned phytoliths can show evidence of cooking practices and smoke inhalation (Mackie et al. 2017). Pathologies can be inferred by the presence of aDNA or proteins associated with pathogens such as *Porphyromonas gingivalis, Streptococcus mutans, Neisseria gonorrhoeae, Corynebacterium diphtheria,* and *Listeria monocytogenes* (Mackie et al. 2017). As calculus is often present on multiple teeth, an abundance of material for analysis can be found. Furthermore, as calculus is considered an ectopic growth, these analyses do not technically destroy human skeletal remains (Mackie et al. 2017).

Isotopic analysis can look at the diet or origin of a skeleton, amongst other things. These analyses use collagen or mineral compounds taken from the bones or teeth and, via mass spectrometry, provide us with an isotopic signature. This analysis is, however, destructive and requires an amount of bone or tooth to be permanently destroyed. Modern carbon and nitrogen isotope analyses require only a small sample of bone, approximately 0.5g (Mays 2013). In contrast, the earliest applications of carbon stable isotope analysis in archaeology utilised complete human ribs from each individual (Vogel and van der Merwe 1977). Generally, carbon and nitrogen stable isotope ratios can be used to investigate questions relating to diet, particularly in relation to consumption of plants, animal products, and fish (Knudson et al. 2009; Lee-Thorp 2008; Mays 2010a pp. 269-277), whilst oxygen and strontium stable isotope ratios are used for tracking ancient migration and mobility patterns (Mays 2010a pp. 277-288). Radiocarbon dating is another type of isotopic analysis that can be conducted on human remains. Radiocarbon analysis can help date archaeological material that is between 400 and 50,000 years old (Blockley 2019). The method uses the half-life of carbon-14, a radioactive isotope, which decays at a constant rate of 5568-5730 years. By looking at the remaining carbon-14 left in the sample, an estimation of the age can be calculated (Blockley 2019). Early radiocarbon analysis (using liquid scintillation counters) required many grams (g) of pure carbon, meaning 100-200g of bone was sometimes needed. However, with the development of accelerator mass spectrometry (AMS), now only a few hundred milligrams (mg) are needed (Mays 2013 p.8; Renfrew and Bahn 2008 pp. 142-143). Despite its usefulness radiocarbon dating does have to be used with caution. The original method created by Willard Libby assumed that the proportion of carbon-14 in the atmosphere was constant; however, this has proven to be false and dates can be out by as much as 900 years (Renfrew and Bahn 2008 p.143). Furthermore, having a diet containing C_4 plants (such as maize or millet) can produce artificially young radiocarbon dates (Van der Merwe 1982). Therefore, to ensure accuracy, the results need to be calibrated using another dating method; the most common alternate method is dendrochronology – tree ring dating (Renfrew and Bahn 2009 p.143).

Ancient DNA analysis can look at the genetic makeup of an individual, looking at relatedness or migration amongst communities and, more recently, the genetic development of diseases (Sawchuk and Prendergast 2019). As with isotopic analysis, this method is destructive and leads to the loss of a small amount of bone.

By utilising the techniques discussed above, human bioarchaeologists can reconstruct portions of the past life of an individual or population. The above description provides only a brief overview of the multitude of techniques available to human bioarchaeologists today. Many of these techniques are complex, requiring specialist training, but when used appropriately they are able to provide a wealth of information. Furthermore, new techniques are continually being developed, allowing for new avenues of study.

Yet, human remains are not limitless. They are a finite scientific resource and therefore one that should be protected from any unnecessary damage. The information we can access from human skeletal remains is significant, but these insights are not gained without a cost. Ethical implications of studying human remains are much greater than for other archaeological evidence (Fforde et al. 2002; Fossheim 2020; Scarre 2006; Squires et al. 2020a; Tarlow 2006; Walker 2000). They are, after all, the remains of a once living person, who had a family, religious beliefs, and moral values (Lambert 2012). Due to the nature of human remains, personal sentiment is inseparable from the discussion and, as such, impacts one's attitude about death, how the dead should be treated, and whether or not they should be used for scientific research (Lambert 2012). Therefore, the study of human remains needs to balance potential knowledge acquired with respect for the individual, and any living relatives or descendants (Antoine 2014). Furthermore, researchers must conduct their investigations whilst protecting and preserving the skeletal remains for the future.

The remainder of this chapter is divided into eight sections. Section 1.2 outlines the context of this research, looking at how the subject of human bioarchaeology has developed. Section 1.3 explains the importance of this research. Section 1.4 presents a literature overview, noting the key pieces of literature that informed this thesis. Section 1.5 presents the research question to be addressed, with subsection 1.5.1 looking at the specific aims and objectives of the research. Section 1.6 outlines the methods that were implemented throughout this research, including key concepts and variables. Section 1.7 defines the scope of the study. Section 1.8 presents the hypothesis. Finally, Section 1.9 introduces the layout of the rest of the thesis.

1.2 Research Context

Osteology is not a new discipline. Its roots can be traced back to the early 19th century, when medical academics, physicians, and anthropologists employed many of the techniques human bioarchaeologists commonly use today. Marc Armand Ruffer was one such individual and is commonly associated with the foundation of human osteology's sub discipline, palaeopathology, and the founding principles on which it stands (Baker and Judd 2012 p.212; Roberts 2018 p.7). The subject went through a dark period during the middle of the 19th century through to the early 20th century, being used in the so called "race science" and the genetic aspects of polygenism (see Jackson and Weidman 2005 pp. 41-42; Roberts 2018 p. 7).

Human bioarchaeology went through a resurgence in the mid-20th century with two key names leading the subject in the United Kingdom, Wells and Brothwell (Roberts 2006 pp. 423-431; Roberts 2018 p.9-10). Brothwell's contribution to the field has been summarised by Dobney and O'Connor (2002) as well as Dobney (2012). In the last few decades names such as Roberts, Mays, Manchester, and McKinley have become widespread in the UK literature. In addition, there are all the sub-disciplines or specialties in human bioarchaeology, such as isotope studies or ancient DNA (aDNA) analyses, all of which have their own specialists and academics. These developments have led to an increase in the popularity of the subject, as seen in the upsurge of university departments in the UK which teach bioarchaeology (which in the UK includes the study of plant and animal remains in archaeology). This has led to a related increase in the number of students studying these subjects. Figure 1.1 shows MSc palaeopathology student numbers for Durham University in recent years, which shows an upward trend between 2000 and 2019.

An increase in students is beneficial to the discipline, providing future academics, researchers, and commercial osteoarchaeologists. A healthy growth of the discipline means more ground-breaking research can be developed. However, students, both during their studies and throughout their later careers, require access to human skeletal remains for research projects. As researchers increase, the need to access curated human remains will also increase. However, the impact increased access will have on the skeletal remains studied is poorly understood, with only a handful of papers being dedicated to the topic (most notably Caffell et al. 2001). Thus, this research focuses on the preservation of human skeletal remains stored in a number of English museums, in order to address this lack of understanding. For context, this study also investigates other factors that could impact preservation, along with potential solutions.

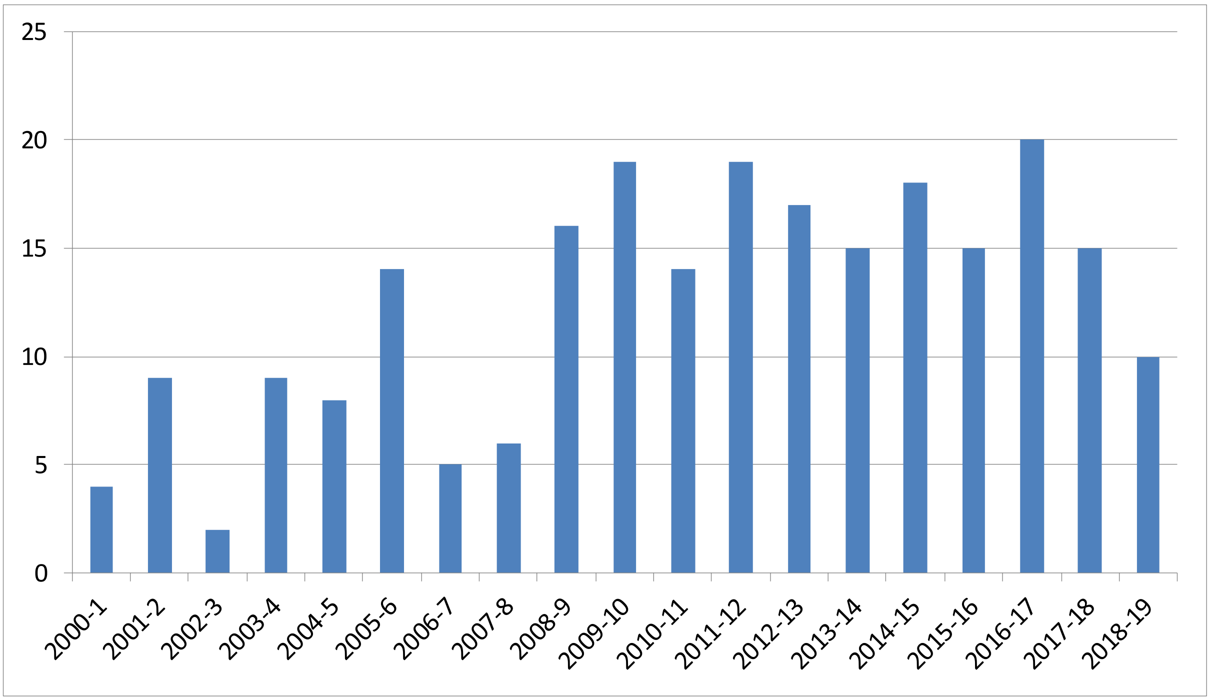


Figure 1.1 Number of students attending the Durham University Palaeopathology MSc., from 2000-2019. Courtesy of C. Roberts pers. comm. 2019.

1.3 Importance of this Research

Preserving and caring for curated skeletal collections extends their life-span, ensuring their survival for future research. Further study provides the opportunity to generate more knowledge, by applying newly developed techniques to the skeletal remains. One example of this is strontium isotope analysis, which was only introduced to archaeology in 1985 (Ericson 1985). Strontium analyses are now used to look at mobility in archaeological populations, with dental strontium values reflecting the geology of an individual's origins. Thus, if an individual is found to have strontium values inconsistent with the geology of the area where they are buried, the individual likely migrated to the area. However, importantly, strontium values cannot be used to confirm the origins of an individual, only to exclude potential areas of origin (Bentley, 2006). Research continues and the potential for greater insight gained by comparing a variety of isotope analyses from the same population is yet to be fully explored (Bentley 2006; Lahtinen et al. 2021).

As demonstrated above, human skeletal remains can offer us a massive amount of information and can give us a real insight into how individuals in the past lived, died, and interacted with the environment. Despite this, little attention has been given to the study of preservation, or deterioration – the negative change in preservation, of human remains stored in the museum context (see the brief literature summary below: section 1.4). Therefore, "preservation" represents a gap in our current understanding of curated human remains. We need to understand what factors can affect or impact the deterioration of human skeletal remains. This study seeks to quantify the impact researcher access has on preservation or deterioration. In other words, looking at whether research – as studied through the proxy of access – has a serious impact on preservation. Depending on the impact observed, this study can inform curators or collections care specialists whether research access to human skeletal collections needs to be controlled more stringently. This question is becoming increasingly important due to the influx of students studying subjects or courses that involve the use or research of human skeletal remains (as cited above). This influx will likely lead to an increase in the amount of access to, and research on, human remains in the future. We need to know how damaging this access actually is to the integrity of human remains stored in museums. To contextualise the impact of access, other factors are also quantified – this is discussed in greater detail in Chapter 3.

Understanding all these contributory factors is important. If we do not know what the problems are, or the scale of their impact on preservation, then how can we control or mitigate them? If we can quantify the key factors that cause deterioration, we can then take steps to address them. Some methods for mitigating detrimental factors are presented in this thesis.

1.4 Literature Review Summary

Despite the importance of the study of preservation and deterioration of human remains, comparatively little research has been carried out in this area. The key study was published by Caffell and colleagues (2001). Caffell and colleagues looked at the effect of use access on the integrity and preservation of two collections of human remains curated within the Department of Archaeological Sciences, University of Bradford. Since this study, now close to 20 years ago, there has been no similar research. However, some studies have looked at specific problems; for instance, Bowron (2003) a Master's student at Durham University, used Caffell and colleagues' (2001) research as a starting point to improve the quality of the storage boxes for human remains. Both papers are discussed in more detail in Section 2.3.2. Both these studies are becoming outdated and more recent data are needed.

Preservation scales for human remains are of vital importance, if studies on preservation are to be effective, as the scales are needed to record and chart the preservation. Yet once again, there is a dearth of research into preservation scales. Currently, there are three scales that have been used in some way to measure preservation. The first was published by Behrensmeyer in 1978, although this scale was designed for large mammal corpses in an African basin. More detail regarding this scale and the research that led to it can be found in Section 2.3.1 (i). Behrensmeyer's scale was used widely until McKinley created a preservation scale in 2004, dedicated to archaeological human skeletal remains (McKinley 2004; McKinley 2017). Information on this scale, as well as the preservation categories used, can be found in Section 2.3.1 (iii). The only other scale used in archaeology was less of an actual scale and more of a coding system to indicate completeness. The scale published in 1994 by Buikstra and Ubelaker, charted the completeness of the bone and was used alongside Behrensmeyer (1978). Once again, more detail regarding this scale can be found in Section 2.3.1 (ii). Nevertheless, despite these scales' usefulness – demonstrated by their continued use over the past 40 years – no new scale has been created, nor an existing scale updated, in the last 15 years. Even if the creation of a new scale is deemed unnecessary, we should still endeavour to update the descriptions and photographs used regularly. As camera technology has improved, so has the resolution and detail that can be captured. Clarity in the images used to define a preservation scale is essential for the consistent application of its categories.

1.5 Research Question

The key question with which this research is concerned is: To assess the change in preservation of human remains stored in English museums and to evaluate if research, as observed through access, is the primary cause of deterioration, and if not, what is the primary cause of this deterioration? Furthermore, are there any cost-saving methods that can help resolve or mitigate these causes?

1.5.1 Aims and Objectives

Four primary aims were identified for the completion of this research.

1. To create, develop and test a new preservation scale for human remains that records not only surface damage, but also the completeness of the bone.

Objectives:

- To summarise all skeletal preservation scales currently used or that have been used in the past, evaluating their strengths and weaknesses.
- To use this information to design a new preservation scale.
- To conduct observer error testing of the scale, using people with a range of backgrounds and experiences.
- To evaluate the scale, making any adjustments if necessary.
- To use the scale in the further research in this thesis.

2. To assess the relationship between research – through access – and deterioration (change) in preservation, using the newly developed scale.

Objectives:

- To use museum skeletal collections and the described methodology (detailed in Chapter 3) to calculate a statistical value for preservation change, by comparing a retrospective baseline preservation assessment and a recent preservation assessment.
- To create an estimate of the amount of access for each of the selected collections, based on museum documentation and/or curator knowledge.
- To use the chosen statistical test – Pearson's Correlation Coefficient – to calculate a value signifying the strength of the correlation between access and change in preservation.
- To describe and discuss what the results signify.

3. To evaluate other potential causes of deterioration to establish if any had a greater impact than researcher access.

Objectives:

- To locate and collect the comparison data needed (soil pH; museum type and size; the time the collection has spent out of the ground; the museum storage value; the time period of the collection), so as to evaluate the other factors or causes of deterioration.
- To compare these factors to the change value calculated by comparing the retrospective baseline assessment of preservation to the current observed level of preservation (Aim 2).
- To use Pearson's Correlation Coefficient, to calculate the strength of the correlations.
- To discuss which correlations had the greatest impact, and if any were greater than researcher access.
- To discuss what these outcomes mean for the research and for archaeology as a whole.

4. Using the information gathered as a result of achieving the other three aims, evaluate what might be done by museums to lessen deterioration, as well as any limiting factors.

Objectives:

- To consider which factor or factors had the biggest impact on the deterioration of human skeletal remains.
- To discuss and evaluate any approaches or interventions that could be developed to lessen the effect this/these factors have, while also considering the affordability of each approach.

It was expected that wider museum problems would become apparent during the course of this research, some of which would impact on the preservation of human skeletal collections. These problems are discussed on a case-by-case basis, and, where applicable, potential solutions are presented.

1.6 Methodology Outline

To meet the aims and objectives outlined above, a new methodology was needed: one that allowed a value for deterioration or change in preservation to be calculated. Normally to conduct such a longitudinal study, one would create a baseline assessment of the preservation of a collection, wait a determined period of time, then re-evaluate the collection to chart any change in preservation. However, this type of study would require several years, ideally longer, for it to be representative. This longitudinal type of study was not practical for this thesis, as it would extend beyond the allotted 3-4 year timespan for doctoral study. Therefore, a new method was needed: one that removed the extended interval between preservation assessments. A method was consequently developed that allowed the creation of a retrospective baseline assessment. The method applied in this study endeavours to use various types of documentation (such as skeletal reports, excavation reports, photographs, drawings, or any other available documentation) to create a retrospective baseline preservation assessment. This retrospective baseline was then used to estimate the change in preservation of the skeletal remains of interest without the necessity to wait. This method was used throughout this research and its effectiveness evaluated (see Chapter 6).

1.6.1 Key Variables and Requirements

The most important variable for this research is change in preservation (deterioration) of the human skeletal remains. The collections chosen for this research were all selected because they had the necessary information available to calculate the "change in preservation" through the creation of a retrospective baseline. This was regarded, for the purposes of this research, as excellent documentation, which was vital when creating the retrospective baseline preservation estimate. This need for excellent documentation, among other factors, limited the number of collections that could be used for this research, as many museums simply did not have the required documentation.

Another key variable/requirement is the necessity to separate deterioration of bone into several components. This may be technically inexact, in that all the components are linked and will interact in some way. An argument can therefore be made that they can never be truly separated. Yet, this has the disadvantage of not being able to see which factors have the biggest impact. To properly evaluate change in preservation, and to understand what factors have the biggest impact on deterioration, it is necessary to evaluate them as individual components. This then helps us to consider what actions can be taken to improve the preservation conditions of human skeletal remains in English museums. Therefore, evaluating the factors separately, although debatably an inorganic distinction, was the best way to get actionable results.

1.7 Scope of Study

This thesis considers museum collections of human skeletal remains found across England. Whilst time period, collection size, original burial conditions, and other variables are recorded they did not affect which collections were chosen. Instead, the quality of the available documentation was most important. All collections were chosen prior to the start of this research. Museums in England were chosen primarily for two reasons:

1. Collections in museums in other countries can have different policies and laws surrounding them compared to those in England. For instance, the considerable impact of the Native American Graves Protection and Repatriation Act (NAGPRA) in the United States affects the way remains are protected (Billeck et al. 2010; Kakaliouras 2012; Krmpotich et al. 2010; Mihesuah 2000; Rose et al. 1996). Summarising all of these different regulations would have been beyond the scope of this thesis. Furthermore, different regulations could impact certain recorded variables, such as storage conditions, complicating comparisons between collections from different countries.
2. The list of museums used in this thesis was taken from L. White (2011), who compiled a list of all museums in England that stored or curated human remains. White's paper explored the effectiveness of two key pieces of human remains documentation - The Human Tissue Act of 2004 and the Department of Culture Media and Sport's 2005 Guidance for the Care of Human Remains in Museums. Specifically, the impact the documents had on museums in England and more precisely the human remains they house was recorded. The documentation, amongst other things, gave the nine

national museums the power to deaccession and repatriate human remains less than 1000 years old (DCMS 2005 p. 12). White found that, other than financial changes, the two documents had little overall impact, as many museums had still not implemented the recommended best practice at the time of the thesis' publication (White, L. 2011). White's work of compiling and listing the approximately 300 museums that claimed to hold human remains expedited the process of contacting museums for this study and the creation of a suitable sample size.

No university collections were used in this research because they differ from other museum collections in their patterns of use. University skeletal collections are accessed much more frequently than other museum collections, sometimes daily for teaching. The disparity in the volume of use likely would skew the results in a comparison between university collections and other museums. Furthermore, Caffell and colleagues' (2001) work focused on university collections – specifically the University of Bradford. The one exception is the collections housed at the Great North Museum in Newcastle upon Tyne. These collections are not teaching collections but are jointly owned by the Great North Museum (through Tyne and Wear Archives and Museums) and Newcastle University. This collection therefore falls into a special category. For the rest of this research the Great North collections are consequently referred to as "shared university" collections.

Observations are made on adult skeletons only, as non-adult bones are more fragile and degrade in a different manner (Lewis 2017a pp.112-132). Due to time constraints set by the museums, only a limited research window was available for some of the museums. Therefore, only the long bones of the skeletal remains were evaluated. Long bones were selected as they are some of the largest bones of the human skeleton, and therefore have a greater chance of being present for analysis. They are also easier to identify and side, and therefore quicker to record (Mann 2017; White et al. 2011; White and Folkens 2005). An argument could be made for the inclusion of the skull and pelvis in this research. Both of these areas of the skeleton are used for sex and age estimation of an individual and so are likely to be handled when skeletons are analysed. However, the skull is made up of several bones and when broken post-mortem can be difficult and time consuming to reassemble. Likewise, the pelvis is made up of three bones, some parts of which can be quite fragile (e.g., pubic area) and would therefore similarly be time consuming to evaluate. Furthermore, both cranial and pelvic areas are comprised of bones that are unusual in shape, which complicates the quantification of deterioration relative to long bones. Nuanced evaluations of these skeletal areas would have increased the time taken to evaluate each skeleton, reducing the number of individuals that could be included in this study. Future studies, however, should endeavour to include these areas of the skeleton.

Whilst the primary focus of this thesis is on skeletal collections held in English museums, there are other organisations that store human skeletal remains. Commercial archaeology companies also hold human remains. Prior to excavation, commercial archaeology companies and museums must come to an agreement on where to store any excavated materials, including any human skeletal remains. However, increasingly commercial archaeology companies are having to store human remains and other excavated materials themselves. This can be attributed to two main factors: first, the increased time required for post-excavation analyses, and second, the ever shrinking amount of storage available in museums (McKinley 2013). Skeletal collections held by commercial archaeology companies are not used in this research, primarily because the rules and regulations differ from those used by museums. Furthermore, the storage facilities used by commercial archaeology units are classified as temporary, held only until the allocated museum can take possession. Therefore, these temporary storage facilities may not be up to the standard expected from museums, which is in and of itself a problem, but one that is beyond the scope of this thesis.

This thesis endeavours to take the results and information collected, alongside information about any problems encountered, to recommend approaches which could be implemented to help preserve and protect skeletal collections for the future. The costs and financial implications of these methods are outlined, and their potential usefulness discussed.

1.8 Hypothesis and Predictions

It was hypothesised that access to human remains for study will have an impact upon skeletal preservation. This is supported by the, albeit limited, literature cited here. The magnitude of the impact, however, needs to be confirmed and quantified. It was also predicted that other factors would have a degree of impact on the preservation of the skeletal remains. Some factors may even have a more substantial impact than researcher access. The extent of these factors needs to be quantified. Hypotheses for these individual factors are presented in the Methods and Materials chapter (Chapter 3).

1.9 Organisation of Thesis

Chapter 2 presents background information related to the preservation of human remains, in the form of a literature review. Writings on the preservation of human remains are compiled and examined. Relevant museum documentation that pertains to human remains is summarised. All preservation scales that are, or have been, applied to human remains are examined, and an explanation is provided of what would be needed for a new preservation scale.

Chapter 3 focuses on the methods and materials used in this research. The methods section is presented first and contains two sections. The first documents the creation, testing, analysis, and discussion of a new preservation scale, a scale that can be used to evaluate the preservation and completeness of human skeletal remains. The second section explains the processes, methods, and statistical analyses that were used in the rest of the research. Finally, the materials section of this chapter presents the museums and collections used in this research, giving a brief overview of each.

Chapter 4 presents the data collected through the course of this research. Comparisons are made of preservation risk factors and calculated changes in preservation (current preservation value minus retrospective preservation baseline equals change in preservation). These allow correlations to be created, and the strengths of the correlations to be evaluated. Alongside this, the recorded factors are compared to access. These comparisons are less reliable than the rest of the data but are interesting as they give us a glimpse into what influences access.

Chapter 5 discusses the results presented in the previous chapter, explaining in greater detail the patterns and correlations found. The correlations are then interpreted in the context of this thesis. The outcomes of the research are discussed. Finally, the wider implications of the research are discussed, including the problems museums are facing in relation to preservation and storage, as well as possible ways to control these problems.

Chapter 6 considers all the information presented in this thesis and reflects on whether or not the primary aims of this research were met. Furthermore, this chapter summarises recommendations made for museum practice, and considers how feasible they are in a museum context. Finally, this chapter discusses and outlines the future research that needs to be undertaken, which became apparent during the course of this research.

Chapter 2: Background

This chapter provides a background to the research conducted in this thesis, split into three main parts. First, museum curatorial practices are discussed in order to outline how museums in England function on a day-to-day basis and the guidelines they follow, particularly with regards to collections of human remains. This includes common principles and practices, such as: acquisition of objects, accessioning of objects, providing access to the general public and researchers, practicing museum ethics and ethics of conservation, undertaking loans, and deaccessioning of museum objects. Furthermore, to make this research current, the challenges museums are facing are summarised. Second, guidelines that apply to the effective and respectful curation of human remains, specifically skeletal remains, are considered. Third, this chapter explores all the published and available past preservation scales that have been applied to human bone, summarising, and evaluating each one in terms of its advantages and limitations. This information is then used to summarise what a new scale should contain to be effective for use. In order to contextualise human bone preservation scales within this study, as well as within the context of museum curatorial practices, a short overview of human bioarchaeology is provided, focusing on particular areas pertaining to museums. These include the guidelines that exist concerning human remains in a curatorial context, from excavation to reburial, and general ethical considerations covering human remains, which are discussed in terms of their implications for museum staff.

2.1 Museum Curatorial Practices

In order to investigate museum practices, a general understanding of museums and their role as public institutions is essential. The modern museum, with which we are familiar today, grew out of the personal accumulations of 16th century collectors, commonly referred to as 'Cabinets of Curiosities'. The 2007[1] definition of a museum, from the International Council of Museums (ICOM) is:

> *"a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment" (ICOM 2007)*

From this statement it is clear that a museum has a few key responsibilities: education, acquiring "objects", conservation, and research. Museums are also an important part of a community: they educate populations about the lives of individuals in the past and the history of an area, especially if they are a small museum in a rural area; and they allow for research to be conducted on their

[1] Whilst a new definition was drafted in 2019, it has not yet been confirmed by the member museums of ICOM.

collections. However, we must remember that the value of museums is not just in their ability to disseminate information. Museums can also provide many economic benefits to an area. Eight out of the top ten visitor attractions in the United Kingdom are museums, attracting not only local people, but also tourists from across the globe. The popularity of museums in the UK resulted in the creative and cultural industries generating £21.2 billion for the economy during the year of 2016 (Centre for Economics and Business Research 2019).

Despite the benefits museums can offer the local area, many have been struggling. The amount of government funding going to museums has dropped over the last eight years, with some institutions facing cuts of up to 80% (Economist 2019; Knight 2015 per comm; Mendoza 2017 p.9). Current political events have not helped the situation, and the long-term impact of Brexit and Coronavirus (COVID-19) on English museums is as yet unknown.

Museums seem to be low on the list of priorities for the government in relation to Brexit. As such, very little information has been given by the government to alleviate museums' fears (Brown 2019). The most practical concern is with visitors from the European Union, and whether or not they will still be able to visit with ease. Yet, the most pressing concern is how lending, borrowing, and importing museums' objects will work under the new rules. The latter concerns could prevent the lending of objects between the European Union and Britain (Brown 2019; Gibson 2017). More immediate impacts can be seen in British museums losing out on European funding or opportunities; see the Leeds Museum losing out on funding from Europe after Leeds lost the European Capital of Culture (Brown 2019).

Preliminary research on the impact of COVID-19 by ICOM (survey to 1600 museums across the world) has shown that approximately 95% of cultural institutions were forced to close due to the pandemic, impacting the primary role of museums (ICOM 2020a). This led to around 6% of permanent museum staff having their contracts terminated or suspended world-wide (ICOM 2020a). This crisis made an already difficult situation worse. Those museums that had an online presence, either with digital collections or online activities, fared better (UNESCO 2020 pp.14-15). This shows the importance of having a digital collection that can be viewed online; this idea will be explored further in the discussion with a focus on digitising human remains collections.

In England these problems started long before the referendum on Britain's membership in the European Union or the Coronavirus pandemic. Although difficult to pinpoint, some of the cause was due to the 2008 banking crisis, and the resultant 2008-2009 UK recession, followed by the decade of austerity thereafter (Economist 2019; Kendall, G. 2018a; Museums Association 2017b). In the years that followed the 2008 recession, the Museums Association (MA) found that nearly 30 museums had closed between 2010 and 2012 (Museums Association 2019a). This was mostly due to budget cuts by local councils, at both district and county levels. The MA now believes approximately 76 museums have closed since 2005 in the United Kingdom (See Figure 2.1). This has had a knock-on effect on the remaining open museums and their staff; rather than encouraging research and acquiring new material, many curators have been more focused on survival. Furthermore, by fighting to stay open, less money can be invested into preservation or conservation, leading to possible irreversible deterioration in their collections. Finally, this loss of funding has also had an effect on independent museums, with many smaller museums struggling to attract the visitor numbers they were previously accustomed to, further hindering the fight to stay open (Adams 2019).

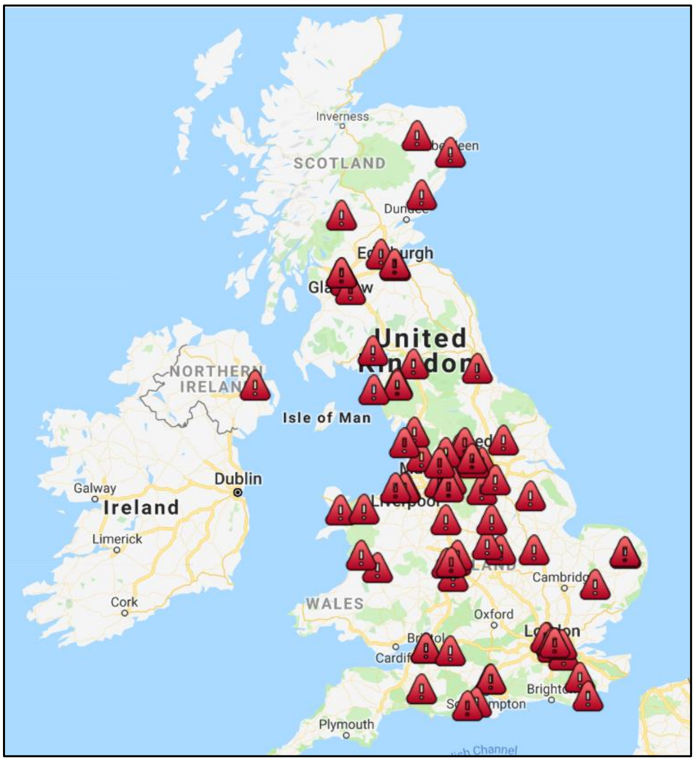


Figure 2.1: Extent of museum closures across the United Kingdom since 2005; note clusters in and around major cities. Available at: https://www.museumsassociation.org/campaigns/museum-funding/19062013-museum-closures-map

2.1.1 Museum Guidelines

Museums fall into several categories. National museums are funded by central government. Local authority museums also receive government funding, but through local councils; these museums contain collections focused on the history of the local area. University museums are owned and managed by universities and typically centre around areas of academic interest. Independent museums are owned by registered charities or trusts. Other historical sites, properties, monuments, gardens or armouries may also be considered museums with a variety of funding structures (Museums Association 2020). The type of museum and, therefore, how it is funded may have a significant impact on preservation and storage; this correlation will be investigated in this thesis.

All museums regardless of category are strongly encouraged to become accredited; this relates to a scheme put together by a consultation of national bodies from England (Arts Council England), Ireland (Northern Ireland Museums Council), Scotland (Museums Galleries Scotland), and Wales (Llywodraeth Cymru Welsh Government). Whilst the accreditation scheme is entirely voluntary, the benefits to the museum can be great (Arts Council UK 2011; Arts Council UK 2014). Accreditation puts in place certain standards for the conservation, protection, and documentation of all objects[2] in a museum's collection. Whilst these guidelines should be followed as they represent best practice in general, each museum must also amend and improve these practices for their own individual situations (Clegg 2020). All of this could potentially be considered by a researcher before starting their research, as researchers need to start promoting responsible collection management. Additionally, as accreditation is a sign of a museum's responsibility for their collections, this can help a museum in a number of other areas, both internally and externally (Accredited Archive Service 2014):

- It can help a museum look at and increase its profile.
- It can raise its confidence and credibility and help development.
- It can encourage the museum to look at the people it affects, both staff and visitors, to help meet their needs and interests.
- It helps with future planning and development by encouraging museums to formalise aspects of management such as procedures and policies.
- It helps with patronage and grant applications, by allowing the museum to demonstrate that they have met the national standard.

Guidelines have been produced for most aspects of museum practice, but not all pertain to the collections themselves, in particular collections of human remains. These guidelines are designed to recommend best practice to museum staff and anyone else who handles, curates, or cares for museum collections; thus, their implementation may have a significant impact on the preservation of these collections. Due to the large and varied number of guidelines, only those guidelines that directly relate to collections management and care will be discussed in the next section, such as acquisition, accession, access, ethics, loans, and deaccession. The examples used in this section relate to human remains, as these remains are the central focus of this thesis; however, this section is designed to give the context of general museum guidelines, with more specific guidance for collections of human remains given in Section 2.2.1. General museum guidelines are not written specifically with human remains in mind, but where museum collections include human remains these guidelines would influence their care and curation. Therefore, it is important to have an overview of museum guidelines.

i. Museum Ethics

Guidelines for ethical practices in museums are quite broad; this is because each area has its own subject-specific set of ethics. This is particularly true for ethical issues related to human remains.

[2] "Object" is used throughout this section to refer to any artefacts held within a museum's archive. The term "object" is not appropriate for referring to human remains; however, this section deals with general museum guidelines rather than guidelines for human remains specifically, therefore "object" is used. Guidelines specific to human remains are discussed in Section 2.2.1.

General museum ethics cover three main areas: public engagement and public benefit; stewardship of collections; as well as individual and institutional integrity.

Ethics relating to public engagement and public benefit state that everyone working in a museum, or representing a museum, should follow the guidelines and uphold basic principles. They should provide the public access to all areas of the museum and collections, and provide information about collections without discrimination or bias (Museums Association 2016; Woollard 2004). All information conveyed by the museum should be correct and without bias and this should be checked regularly to confirm the information is still correct and up-to-date (Lewis 2004; Museum Associations 2016). After all, museums are run as a service to the public, funded by the public and it is the public's history that is being preserved and disseminated (Museums Association 2016).

Stewardship and collection ethics focus on the material and collections the museum curates. These collections form a tangible link between the past, present, and future and, therefore, should be protected (Museums Association 2016). However, this protection should be balanced with the need for access for research and display of the materials, allowing information to be conveyed (Austin et al. 2019, p.1473). Only material that fits the museum's theme and policies should be collected and accessioned; for example, a English Civil War museum should have policies in place to only collect objects related to the English Civil War. These museum policies should be regularly updated and refined to make sure they are fit for purpose (Ladkin 2004; Museums Association 2016). In addition, museums should consider if they can provide adequate long-term care for objects accessioned, without compromising the care of other objects it already curates (Lewis 2004; Michalski 2004; Museums Association 2016). Potential deaccession of the object should also be considered, as this factors into the long-term care of the object; the costs and complications related to deaccessioning objects should be carefully considered before the object is first acquired (Ladkin 2004; Lewis 2004; Museums Association 2016). This includes deaccessioning and reburial of human remains, which can often be expensive, ethically challenging and will be subject to legal restrictions as outlined by the burial or faculty licence (Jenkins 2011; Mays and Smith 2009), or in the Parliamentary Act for that museum and the power given to them under the HTA 2004.

Ethics relating to individual and institutional integrity focus mainly on the standards the museum and its staff should attain and what they need to do. Museums, and in particular museum staff, should avoid any behaviour which suggests, or could be interpreted as, a declaration of ownership of the collections, even if this is the case (Museums Association 2016). Often museums will need financial assistance of some sort; however, they should be wary of where this money comes from, particularly if the financial aid comes from a commercial organisation, as some commercial entities have negative connotations, such as oil companies (ICOM 1970; Lewis 2004; Museums Association 2016).

ii. Acquisition and Accessioning

The guidelines that pertain to acquisition and accession look at the ethical, legal, and practical issues related to acquiring new objects for the museum collections. The guidelines first make a distinction between acquisition, which is the process of gaining the legal title to an object, and accession, which is the act of formally introducing the object into the museum's collection (ICOM 1970; Museums Association 2004). The basic principles for the acquisition of any object are as follows. The object in question should be in line with the museum's published acquisition policy; for example, a Roman museum should endeavour to collect Roman objects, not Victorian. It should be possible for the object to become a valuable part of the museum's collection, and the museum should acquire it based on its long-term value (ICOM 1970; Lewis 2004). The museum should recognise the benefits of not accepting the objects and understand that other individuals or groups may in fact have a stronger claim over the objects; the same goes for other museums, which should cooperate rather than compete with each other (Museums Association 2004). Furthermore, the museum should not acquire any object if there are legal or ethical concerns, such as doubts regarding a seller's or donor's rights of ownership (Collections Trust 2017d).

When acquiring an object, the museum should understand the type of acquisition and the different implications it has for the museum. If the object is a proposed donation, the donor should be made aware of the financial and cultural value of the object to confirm they wish to transfer ownership (Museums Association 2004; Roberts 2004). It should be noted that a museum has no obligation to accept any object, whether it is through a donation or any other form (Museums Association 2004). Donations (or gifts) can come in three main forms: unconditional, conditional, and unsolicited (Comité International pour la Documentation 1995; Ladkin 2004). Unconditional donations are those to the museum from a person/institution that expects nothing in return. However, even in these situations the museum should make sure everyone involved understands the terms of the exchange to avoid any future misunderstanding or legal issues (Ladkin 2004; Lewis 2004; Museums Association 2004). Conditional donations are similar except that the donor has attached conditions to the object that must be respected if the object is to transfer ownership. (Ladkin 2004; Lewis 2004; Museums Association 2004). In both cases, the museum should ensure it has a record of both a signed offer from the donor and a signed acceptance of the object by the museum; in the case of conditional donation the terms specified should also be recorded (Collections Trust 2017d). The final form of donation is an unsolicited anonymous donation; these types of donations are heavily discouraged by the Museums Association (MA) because, not only is there difficulty assessing background information, these objects can often be legally problematic and true ownership may not be easily determined (Museums Association 2004). Donations of human remains are not typical, but are possible, and when they occur can be especially problematic when background information cannot be verified; this is discussed further in Section 2.2.2 (i). Objects may also be given to the museum as a bequest; in these situations, the museum should obtain a legal copy of the will and a copy of probate, if possible (Collections Trust 2017d). Purchasing is another form of acquisition, but this can sometimes be problematic for the museum. Before any money is handed over to the individual dealer or auction house, the museum should inspect the condition of the object (note: this does not include human remains) and enquire about its conservation history (Museums Association 2004). The museum should retain a signed statement from the vendors certifying legal ownership of the object, a signed statement reporting the provenance of the object, and the original invoice and receipt (Collections Trust 2017d). This acquisition method does not apply to human remain, as the sale of human remains is illegal, extremely unethical and should not be undertaken (Hugo 2016).

Fieldwork, including excavated objects, is the final form of acquisition (Roberts 2004). In these cases, it is the responsibility of the museum to ensure all material excavated came from a legal excavation, that had all the correct paperwork completed (such as permission from the landowner), or if the material excavated included human remains, a burial license. The museum should retain documentation proving that all material was collected legally (Collections Trust 2017d). The museum should also not accept any object where it is suspected that its retrieval resulted in the damage of its original natural, historic, or cultural context, as a museum should not be seen to be condoning, supporting, or partaking in this (Museums Association 2004; Roberts 2004). Finally, the museum should make sure who the rightful "owner" of the material is, and for human remains who holds the authority, as this may not always be the excavator and could be the individual who owns the land on which it was found. This right of title/authority should be documented, and a copy held by the museum. Acquisitions from fieldwork should include a reference to the collection's site, such as grid references or site codes (Collections Trust 2017d). This latter form of acquisition is the most common way museums obtain their human remains; the museum should ensure it retains any and all permits pertaining to the human remains (Clegg 2020 p.70).

At acquisition, information about the object should be recorded, including object number, number of objects, object name, and a brief description (Collections Trust 2017d). The acquisition method, source (name and contact details) and date should be recorded (Collections Trust 2017d). Additionally, other documents specified for each of the acquisition methods listed above should be included in the acquisition record (Collections Trust 2017d). After the archive is acquisitioned, it can then be accessioned, and the museum has a duty to update its documentation and add information about the object to its archives, whatever form they may take (Museums Association 2004). The formal record of each accessioned object should include: entry number, object number, date acquired, who it was acquired from, name or title, descriptive information, any other historical information, and any other relevant information (outlined by the Collection Trust 2017d).

iii. Collections Management

The guidelines that cover museum storage vary depending on the material that is being stored. How well museums adhere to these guidelines depends on a number of factors, primarily finance as storage can be expensive. Yet, storage is an essential part of a museum. These guidelines act as the basic professional standards that museums should endeavour to meet to remain accredited, but often museums need to adapt these guidelines to their own needs and abilities.

Conservation staff or collections care managers are in charge of looking after the collections the museum holds (Redfern and Bekvalac 2017 p.373). These staff members, rather than the curator, may handle the day-to-day upkeep of the collections. Conservation practices can, however, vary greatly between different museums; for instance, not all museums employ a professional conservator. Conservation staff are trained in a wide range of materials found in a museum, as by understanding how the object is made and what it is made from, they can facilitate its long-term preservation (British Museum 2021; ICON 2020). However, there are hundreds if not thousands of objects and types of material found in a museum, too many to realistically have suitable training in all artefacts. Therefore, the conservator should tailor their knowledge to the material the museum holds. If the conservation staff (or collections care manager) do not have training in an area, for example human remains, thanks to specialist network groups such as the Collections Trust, they can receive training in the areas they need. This training is delivered as part of their continuing professional development (CPD). These courses allow the museum to train their staff in specific areas, rather than having many specialists or conservation staff members, which can be prohibitively expensive for smaller museums. Collections care specialists are invaluable, as they are trained in conservation and can use their knowledge and training to help protect and preserve artefacts in a museum collection. Specific to this thesis, a collection care specialist in human bioarchaeology is able to provide knowledge and experience relating to the appropriate care of human remains. Such a specialist is able to take action for the preservation of collections of human remains by evaluating their condition, managing the storage environment and packaging to maintain best practices. Specialists are referred to throughout this thesis, with regards to human remains or human bioarchaeology. For the purposes of this research, a specialist was defined as anyone who had training in the care and handling of human remains, whether from a specific human bioarchaeology degree, a CPD course, or some other formal training.

Regardless of the material being stored, the basic requirements for any storage facility are the same. A storage facility should be: accessible, light controlled, regularly monitored (temperature, humidity), watertight, clean, pest free, safe and secure (Bonney et al. 2020 p. 227; Boyle and Rawden 2020 pp.39-46). A storage facility should be able to provide access to anyone that needs it. This could be museum staff, a researcher, or a member of the general public. By being accessible, a museum can encourage the research of their collections, furthering knowledge (Museums Galleries Scotland 2020a). Sunlight can damage objects in a storage facility, and it can cause temperature and humidity fluctuations, both of which can negatively impact objects. Therefore, where possible sunlight should be blocked out and artificial light (that can be controlled) used instead (Museums Galleries Scotland 2020a). Regular monitoring of the storage facility is important to notice any problems; the accessibility of the store impacts the ease with which regular monitoring can be achieved. The temperature and humidity should be regularly monitored, as fluctuations can damage objects that are held in the storage facility (Museums Galleries Scotland 2020a). A storage facility needs to be watertight, as leaks and flooding can destroy collections (Museums Galleries Scotland 2020a). The storage facility should be kept as clean as possible at all times. A regular cleaning schedule should be created to ensure no area of the storage facility is missed (Boyle and Rawden 2020 pp.39-46). Pests are another problem that can damage a collection. Therefore, action should be taken to ensure that pests cannot access the store and, if found, immediate steps should be taken to remove them (Boyle and Rawden 2020 pp.39-46). The storage facility holds all the objects of the museum that cannot be put on display. This can be a significant part of the collection; therefore, the security of the building and objects within should be paramount. Some of the above considerations, mainly blocking out windows, can help with the security (Boyle and Rawden 2020; Museums Galleries Scotland 2020a).

The factors outlined above are the general requirement of a museum store; however, each object being stored may also have special requirements. The specific guidance for the different materials found within museum storage facilities have been summarised by the Society of Museum Archaeology (SMA). The SMA summarises how the material should be stored. Information is included detailing the boxes and plastic bags that should be used (dimensions, materials, thickness and gauges of the packing material), any special considerations the material needs, such as the level of humidity, and the common problems that may be found (CollectionsTrust 2020a). Human remains are included on the list, as they require specialist care and, ideally, dedicated storage. The details of this care and storage are summarised later in this chapter, where the specific conditions relating to human remains are explained (Section 2.2.2 ii). This information is necessary for comparing museum storage factors against the change in preservation observed in the collections they curate.

Collections management is not just about the store; it also includes the conservation and care of the objects held within the museum. The care of a collection involves the creation of the best environment for the collection, ensuring the long-term preservation of the objects and artefacts held by the museum. This can include long-term strategies for the ongoing care of the object as well as any guidance on its handling, packing, transportation and conservation (Museums Galleries Scotland 2020b). The Collections Trust and Spectrum (the UK collection management standard) suggest creating a written document outlining the collections care policy and present a number of questions that should be considered and answered in the document (Collections Trust 2017d).

Conservation covers two main areas: remedial conservation and preventive conservation (ICOM 2020b; Museums Galleries Scotland 2020b). Remedial conservation covers the work conducted to correct damage or to stabilise the condition of the artefact. Usually, this form of conservation is conducted after there has been a serious problem (ICOM 2020b; Museums Galleries Scotland 2020b). Preventive conservation is work that can be done to anticipate and prevent any possible issues within the collections, avoiding the need for remedial conservation. Many of the steps that can be classified as preventive conservation are covered above under the basic requirement of a storage facility; these include environmental monitoring, pest control, and other storage requirements (ICOM 2020b; Museums Galleries Scotland 2020b).

This section covers the basics of collections management within a museum or museum store. The guidelines and documentation describe the necessary professional standard that accredited museums must follow. Yet, it is important that museums take these guidelines and adapt them for their own needs, as no two museums are the same. The Collections Trust has many resources available for museums, as well as documentation to help understand and follow Spectrum.

iv. Access

Guidelines on access cover two main areas. Firstly, and most importantly for museums themselves, is the access given to visitors and how to take care of their needs. The second is access to researchers and opening curated collections to individuals. Access can be separated into two main parts: the physical access and the philosophy of access. Physical access includes opening times, ramps and elevators for disabled visitors, and a welcoming entrance. Philosophical access is more of a concept which includes the language of a display and advertising, the criteria used for displays and other non-physical ideas that can be used by staff to attract new visitors. Although most of the guidelines on access cover how to encourage and look after visitors to museums they will not be summarised here; this is because they have no direct effect on this study or the preservation of human remains. Instead, only the access guidelines that concern researchers will be considered.

Museums should endeavour to provide access to all their collections (even those that are currently not on display) to everyone conducting bona fide research (MEG 1994 p.23). However, this has to be balanced with ethical issues, such as the security of the material and its long-term preservation (Ladkin 2004). Access to some material, in particular human remains, may not be appropriate for everyone, due to ethical or emotional reasons; thus, such material should be restricted to some degree (MEG 1994; Stienne 2016 p.42). Museums have a duty to research their collections themselves and learn as much as possible about what they curate (Lewis 2004). Museums should also encourage research of their material and collate past research to understand their collections as completely as possible (Brüninghaus-Knubel 2004; Ladkin 2004).

Museums have a responsibility to assist anyone they can; this can range from a simple request for information about an object, to something as complex as access to objects they hold for research (Reeve and Woollard 2015; Woollard 2004). If the museum or museum staff cannot assist the individual with the request, they should inform the individual of other locations or people who could help them with their question or request (Reeve and Woollard 2015; Woollard 2004). Whilst museums should always encourage research, when the reasons for denying access are legitimate, those reasons should be explained and published, so the enquirers understand, and future enquirers know this information beforehand.

v. Loans

Museums have an obligation to share their collections and allow them to be accessed by as wide a population as possible. However, loans can be problematic. To help ease this process, the Museums Association have a set of guidelines to help facilitate long-term loans (Museums Association 2007). Other guidelines have been produced by the Collections Trust and cover the processes involved with loaning objects, including loans in, loans out, and condition checking. Although, loaning an object is not an easy process and can be fraught with legal issues and the risk of damage, curators should consider the potential benefits to the museum receiving the loan and its visitors (Ladkin 2004; Museums Association 2007). When a loan takes place the museum hands over responsibility of the object to the recipient, and this means both parties involved in the loan have much at stake. Documentation of this process provides a legally binding agreement for the loan and imparts liability on the borrower, as well as stating the conditions that are expected to be maintained (Collections Trust 2020b; Ladkin 2004; Museums Association 2007; Roberts 2004). The museum should ensure it has an up-to-date policy on loaning objects; this can be either a standalone policy or part of the larger collections management documentation (Collections Trust 2020b).

The actual care of, as well as the responsibility for, collections or objects from collections should be handed over to the borrower over the loan period (Ladkin 2004). This is so that care of the object/collection can be applied when necessary, rather than waiting for permission from the lender, which could lead to more significant or permanent damage (Museums Association 2007).

As this research pertains entirely to human remains, it is deemed pertinent to discuss policies for loaning human remains, including samples for destructive analysis (Mays et al. 2013 pp.16-18). Whilst some museums may have individual guidelines applicable to loans, no country-wide approach exists, and a standard loan agreement may not be entirely sufficient (a copy of which can be found on the Museums Association website – www.museumsassociation.org/collections/smarter-loans). The published guidance regarding the loaning of human remains refers to loans of materials for research, whether destructive sampling is part of the analysis or not; however, human remains may also be loaned to other museums for the purpose of display (Bailey 2019). Loaning human remains can be problematic, particularly because a monetary value has to be placed on them for insurance, but they do have great potential benefits as often they can attract large volumes of visitors when displayed (Bailey 2019). This should be carefully considered alongside the potential issues relating to stewardship, ethics and the display of human remains, all of which will be discussed later in this chapter (Society of Museum Archaeology 2020).

vi. Deaccessioning

When considering museum guidelines and related ethics, one of the most important and underrepresented sections is disposal or deaccessioning of an object; that is, the process of removing the object from the museum's collections. Whilst this section is an important part of the museum process, it is often not fully understood by the general public. Deaccessioning of an object is important for the longevity of the collection as a whole, due to the freeing up of resources, as a way of returning objects that have been taken through questionable means in the past, and removing material that no longer meets with the accepted standards for the museum.

A good example was the deaccessioning of the disarticulated and un-stratified skeletal remains from the Museum of London in the early 2000s. The project came about thanks to a grant from the Wellcome Trust that allowed the museum to evaluate its collection and create an osteological database. This project involved examining the extensive collection of human skeletal remains held by the Museum of London to generate a complete inventory and assessment of these remains (J. Bekvalac pers. comm. 2021). During the process it was found that the museum held many boxes of un-stratified and disarticulated skeletal remains. Many of these remains lacked associated documentation and several were fragmented and in poor condition (J. Bekvalac pers. comm. 2021). In a modern excavation, these remains would likely have been recorded but left *in situ*, as they would not have met the accepted standards for excavation. Therefore, the research osteologists led by senior curator Bill White decided to rationalise the collection by reburying the disarticulated and un-stratified skeletal remains (J. Bekvalac pers. comm. 2021). The museum had set policies for rationalising any material within their collections. The policies suggest that any suitable material held within the collection that could be used in a teaching or handling collection be retained for this purpose. The skeletal remains were first assessed by the Museum of London's osteological team; any remains that were well preserved were retained and moved to a teaching collection (J. Bekvalac pers. comm. 2021). Following this, a consultation took place involving the senior curator (Bill White), head of the Early Department, the collections committee, and executive board. This group confirmed that these skeletal remains were suitable for deaccessioning and reburial as the remains were disarticulated, un-stratified, lacked associated records, and were deemed duplicates within the collection. The other criteria that were considered included: the osteological, scientific value, and significance of the remains; the provenance, context, or stratification recorded for the remains; the research value, display value, and rarity of the remains (J. Bekvalac pers. comm. 2021). Although a large volume of disarticulated remains was selected for reburial, the Museum of London was fortunate that the East London Cemetery, a non-denominational burial ground, could accommodate these remains, and the location of the interment was documented (J. Bekvalac pers. comm. 2021).

Deaccessioning should not be taken lightly and not in isolation, and the museum should convey the decision to as many people as necessary, including specialists interested in that particular "object", other museums who have experience with the process, and the general public; this can be done through a panel discussion or now online. If the staff, specialists, and other museums agree that deaccessioning of an object is the best course, then the process should proceed (Museums Association 2014) as was the case with the disarticulated remains at the Museum of London (J. Bekvalac pers. comm. 2021). When considering deaccessioning an object a museum also needs to consider whether it is legal and ethical to do so. Objects in a museum's collection can be from donations, or bequests. Therefore, it is important to establish whether or not the museum has the permission to deaccession the object, as the conditions of the donation may affect this. The wishes of and promises to patrons in the past should still be respected (Ladkin 2004; Lewis 2004; Museums Association 2014). While most objects can be donated, human remains can be more challenging – as ownership is not applicable to human remains, and instead authority must be proven. Human remains are typically acquired from excavations, although in some cases older skeletal remains may have originated from collectors in the past (McAllister et al. 2015). For this reason and the nature of dealing with human remains, deaccessioning and disposal of human remains is much more complicated, expensive, and ethically challenging. Furthermore, excavated human remains are governed by burial and faculty licences, which will restrict what can happen to the remains. Burial and faculty licences are discussed in Section 2.2.1, and how these licences impact the deaccessioning of human remains is discussed in Section 2.2.2 (v).

As well as ethical considerations, the museum must also consider the legality of deaccessioning an object, which once again may affect whether the deaccession of an artefact can go ahead (Lewis 2004). The laws that affect the legality of the deaccession depend on the type of museum. National museums are held to laws created by the government, such as the British Museum Act of 1963, which forbids the deaccessioning of material from the museum (British Museum Act 1963). The Human Tissue Act of 2004 gave the nine national museums the ability to deaccession human remains specifically for the purpose of repatriation (Harris 2015). Museums that are charities and are run by a trust may have restrictions set out when the trust was first created, as well as laws that govern charities in general (Charity Commission 2002). As outlined previously, there can be many benefits to deaccessioning of an object and the deaccessioning can take many different forms. The primary outcomes of deaccessioning are generally considered to be as follows:

- Improved care for the object if it is being transferred to a new location where better trained or equipped staff can take care of the object (Museums Association 2014).
- Improved access, leading to greater enjoyment and engagement with the object, by the public.

These outcomes benefit the wider museum, such as the freeing up of a resource which can be better utilised in other parts of the museum or in other museums (Museums Association 2014).

Reasons for deaccessioning vary between institutions and depend entirely on the situation of the museum, but a few general reasons can be described for the ethical deaccessioning of an object. Firstly, if the object does not fit with the museum's core collection policy, which all accredited museums have, then it is acceptable to deaccession an object (Ladkin 2004; Museums Association 2014). If an object is duplicated in a collection, then it is also legitimate to deaccession it. However, other scenarios should be considered before deaccessioning is chosen, such as: will the object be useful in the future, or can it be used in another capacity such as for teaching (Museums Association 2014)? Underused objects can also be deaccessioned, especially if the object has never and will likely never be used. In these cases, the object is simply taking up space and resources that could be put to use in other areas of the museum. This is a particularly big problem in relation to human remains, as although no true estimation can be calculated, a large proportion have never been studied, or even known about, because of the lack of a central database (Roberts and Mays 2011). If the museum is no longer able to care for an object adequately, then once again it is legitimate for that museum to deaccession the object. The most common way to do this is by transferring it to another museum or other curating body that has the resources to properly care for the object (ICOM 2004; Lewis 2004). If an object becomes too badly damaged, or has deteriorated beyond the ability to repair, then it is also reasonable to deaccession the object. However, this is only to be done as a last resort, as preservation and conservation of objects should prevent this happening on a frequent basis (Ladkin 2004; Museums Association 2014). Provenance and context are an important part of an object's story, and if this is unknown then very little valuable information can be derived from it. In these cases, it is appropriate for the museum to deaccession the objects as they take up valuable space (Museums Association 2014). Several of these reasons were involved in the Museum of London's decision to deaccession disarticulated and un-stratified skeletal remains from its collection: the remains were in poor condition, lacked documentation, and the provenance and context were unknown (J. Bekvalac pers. comm. 2021). The reasons for deaccessioning are vast and varied and museums will have different reasons for deaccessioning an object. However, once the reasons for deaccessioning have been established, the best method of deaccession should be chosen. The correct method depends on: the reasons for deaccessioning; the intended outcomes of the deaccessioning; and the object itself, as deaccessioning pottery would differ to deaccessioning human remains.

The first and preferred method of deaccessioning suggested by the Museums Association is gifting the object in question to another accredited museum, ensuring the object stays within the public reach. Alternatively, the object can be swapped with an object that is currently stored in another museum; again, this is preferable as not only does the object stay in the public reach, but both museums gain something out of the "exchange" (ICOM 2004; Museums Association 2014). If no accredited museum can be found to take the object, it is then suggested that the museum look for an institution or organisation that still lies within the public domain to take the object, such as a university (Museums Association 2014).

Once all public domain courses of action have been taken, the museum can then look at transferring the object to a private individual outside of the public domain (Museums Association 2014). This can be done through free gifting of the object to an enthusiast or collector, or through a sale, although the museum should be wary when selling an object. Selling an object can be a difficult and risky process as the museum should never aim to make money from deaccessioning an object. A good example of the issues associated with selling objects was seen in 2009 when the New York National Academy Museum sold two of its paintings for $15 million. The museum claimed the money was needed due to financial difficulties; this did not stop the public, other museums, and the Association of Art Museum Directors (AAMD) taking various forms of punitive actions, including suspending any future loans or collaborations with the museum (Finkel 2009). If selling the object goes ahead, the Museums Association should be consulted first, and any money gained from the sale should go directly back into the museum's collections (Lewis 2004; Museums Association 2014). If no new home for the object can be found only two options remain. The first is to recycle the object as scrap (ICOM 2004; Museums Association 2014), or the object can be destroyed; however, this is only deemed appropriate when no other option exists, or the object in question poses a health hazard.

In the case of human remains, many of the methods of deaccessioning described above are inappropriate; the sale of human remains is illegal (unless skill has been applied), not ethical and issues of stewardship of the remains make transfers difficult (APABE 2017; DCMS 2005; Garratt-Frost 1992). However, museums do have another option with human remains, which is reburial. Reburial has many pros and cons, which again make the process of deaccessioning difficult. This will be discussed later in this chapter (Section 2.2.2 v).

2.1.2 Problems Facing Museums

Museums in England, as well as those throughout the United Kingdom, are currently facing a multitude of problems – from funding shortfalls to the ever-present threat of closure (Economist 2019). The many problems facing museums cannot adequately be discussed here. Instead, only the key problems that could potentially have an impact on, or influence, the preservation or protection of human remains curated by a museum are discussed. These include storage, staffing, and financial issues (which can impact on the museum staying open). Financial issues are divided into funding from the government or large historic bodies, and income from admissions, sales, or personal donations.

i. Storage Space

Storage space in a museum or museum storage facility is limited (Adams 2017; ICCROM 2017; Lambert and Mottus 2014). Each store can hold a certain volume of a museum's collections, and at some point this capacity will be reached. Storage is filled in several ways: through finds from commercial excavations; through donations and bequests; or through purchases of rare or unusual items from private collections or auctions (Ladkin 2004; Lewis 2004; Museums Association 2004; Roberts 2004). In recent years, museums have also been receiving collections from other museums that have, or will soon have, closed (Museums Association nd.). In response, some museum storage facilities have been amalgamated into a single unit; rather than each museum controlling one storage facility, several museums collaborate and give control over to a separate entity. Usually, each museum contributes to this; an example of this situation is the Tyne and Wear Archives and Museums (TWAM), which is made up of a collection of several north-eastern museums and galleries (TWAM 2019). TWAM is responsible for the collections and their storage, allowing the other museums to focus on welcoming visitors as well as presenting and disseminating information.

Museums and other bodies are attempting to manage storage capacity through numerous means, but it is clear that in the future, storage will become an even greater problem (Adams 2017; ICCROM 2017; ICCROM-UNESCO 2011; Sharp 2018). One interesting solution is that offered by DeepStore, a company that provides artefact and historical document preservation within the Winsford Rock Salt Mine in Cheshire. Storage is provided deep underground in the caverns excavated for the production of salt. Underground storage naturally protects against flooding, temperature fluctuations, and ultra-violet light exposure. Furthermore, air quality, temperature, and humidity controls are offered by the company as part of the long-term storage agreements (DeepStore 2019). Estimates for the cost of DeepStore are difficult as it often depends upon volume, number of boxes, and other negotiable factors (such as frequency of access). However, a basic estimate by Historic England found that one m^3 of storage would cost approximately £63.57 per year. Over a 10-year period, including VAT, the cost is approximately £762.80 per m^3 (Tsang 2017). Any collections transferred to DeepStore must be packed in boxes with lids that are in "good" condition (i.e., the sides cannot be crushed and the boxes must not be ripped); archival standard boxes are available from DeepStore (DeepStore 2021). Furthermore, the packing material inside the box must be sufficiently secure to be transported, and a detailed record of the contents of each box must be provided (Tsang 2017). Depending on the current state of a collection, adhering to these standards may involve a significant expense. Therefore, when calculating the cost of DeepStore it is not only about how much they charge per box or per m^3, the cost must also include the staff hours it takes to prepare the collections, as well as the resources that must be expended getting the boxes up to the required standard (Tsang 2017). Access to collections is obviously more complicated than in a traditional storage facility. Condition assessments (audit) can be conducted on site, at DeepStore; however, an appointment must be made in advance (DeepStore 2021). Similarly, while collections can be accessed by researchers or museum staff on site, this again requires making an appointment in advance (retrieval or return costs £1.10 per box – Tsang 2017). DeepStore does offer the option of transporting the boxes back to the museum (for a cost dependant on distance – DeepStore 2021; Tsang 2017); however, this is more complicated and expensive than accessing boxes held within the museum store.

When a storage facility becomes full, a museum has a few options, but none are ideal or without cost. The first is to relocate to a larger building (Wiltshire 2019). Two of the museums used in this study had relocated in the last ten years. However, relocation is not an easy task, and several steps must be taken to ensure the museum's collection is protected. Firstly, a suitable building must be found, along with the funding to acquire the building and fit it out with the necessary storage equipment, such as shelving. Next, the collection needs to be catalogued and packed in such a way that damage will not occur during loading, transportation, and unloading. Finally, once relocated, the collection needs to be unpacked and evaluated to make sure that the items are in the same condition on arrival at the new storage facility. This entire process can take months or even years to complete (Ashley 2011; Murphy 2018).

Another option is to open a second storage facility, as at the North Lincolnshire Museum (R. Nicholson pers. comm. 2019). The building will still need to be fitted out with shelving and other necessities, but cataloguing of the entire collection, as well as its packing and transport, can be avoided; the original collections could stay in place, and the newly acquired collections could be added to this second storage facility. However, in a time of financial insecurity for many museums, paying for and maintaining a second building is not an ideal solution. Furthermore, having more than one storage facility, especially if they are in different places, can also impact on curatorial staff's ability to support research visits, especially if the locations are miles apart.

The final option is controversial and contentious: deaccessioning collections or parts of collections (Baxter et al. 2018). Museum guidelines (APABE 2017; Collections Trust 2017b; DCMS 2005; ICOM 2004) suggest that deaccessioning is acceptable if: the "object" is duplicated within the collection, underused by the museum, or not in line with the museum's collection policy (Museums Association 2014). While human remains cannot be duplicated as each individual is unique, consideration might be given to whether existing collections are dominated by human remains from a particular period. However, the museum should still ensure it has the legal authority to deaccession any item from its collection before proceeding (Museums Association 2014). Deaccessioning can have many benefits for the museum, including increased availability of space and resources, which can then be otherwise utilised (Baxter et al. 2018). In Section 5.5.4, the possibility of deaccessioning human remains is considered and discussed, the benefits and problems of this idea are evaluated, and the feasibility of the use of technologies to limit the loss of information are explored.

a. Storage Problems - Commercial Archaeology Companies

As mentioned in Section 1.7, the filling up of museum storage is also having a knock-on effect on other organisations in the heritage industry, specifically commercial archaeology companies. Before beginning an excavation, commercial archaeology companies will arrange for a museum to store any excavated material; this includes human remains. However, as the time required for the post-excavation analysis increases, museums may utilise the allocated storage space for more urgent requirements, leaving the commercial archaeology company to hold the remains temporarily. This increase in post-excavation analysis is, in part, due to changes in the planning policies that govern archaeological excavations.

The original guidance, Planning Policy Guidance 16 (PPG 16 1990) implicitly aimed to make building on archaeological sites expensive for the construction companies, discouraging them from choosing sites of historic importance for development (Mckinley 2013 p.135; PPG 16 1990 p.5). If these sites were still chosen, the construction company would shoulder the cost of excavating and processing any archaeological materials found. In 2010, PPG 16 was updated and became Planning Policy Statement 5 (PPS 5). Whilst this was much the same as its predecessor, PPS 5 had a greater focus on investigation and publishing (PPS 5 2010). The publications produced by commercial archaeology companies detailing their excavations under PPS 5 provided valuable information. However, this increased the burden on commercial archaeology companies, with each site requiring considerably longer to excavate and process. Estimates have put the total time between excavation and the completion of the analysis at approximately ten years for the largest archaeological sites (McKinley 2013 p.141). In 2012, PPS 5 was cancelled and replaced by the National Planning Policy Framework (NPPF). This document set out all of the government planning policies in England. Following this, in 2015, "Historic Environment Good Practice Advice" was created with input from English Heritage (Historic England). The 2012 and 2015 documents contained similar information and purportedly did not increase or decrease protection for archaeological sites but condensed previous policies and guidance (IHBC 2016).

Museums, already struggling with a lack of storage space, cannot hold the storage space indefinitely. When site archives are deposited years after the initial request, museums may no longer have adequate space to accommodate the incoming archaeological materials. As mentioned above, this means commercial archaeology companies will need to retain archaeological material and store it themselves (Brown 2007; Edwards 2013 p.113; McKinley 2013 p.140; Ottaway 2010 pp.16-17; Southport Group 2011; Tsang 2017). The company will often resort to renting temporary storage for these archaeological materials, but designating this storage as "temporary" may be misleading. McKinley outlines this problem in her 2013 chapter "No Room at the Inn". She explained that 68% of the boxes held in temporary storage at Wessex Archaeology had been there for five years or less, 14% had been in Wessex Archaeology's store for more than 10 years, and some of the boxes dated back to 1986 (McKinley 2013 p.140). In 2009, prior to the implementation of PPS 5, a report investigated how much of this material was actually retained by companies (McKinley 2013). Wessex Archaeology reported that it held over 9000 boxes of archaeological material, including 803 boxes containing human remains. Oxford Archaeology reported they were storing 930 boxes containing human remains (McKinley 2013 p.140). This example demonstrates the scale of the problem faced by commercial archaeology companies. The problem has not been resolved in the intervening years since 2013; instead the problem continues to grow (J. McKinley pers. comm. 2019). Therefore, many of the issues investigated in this thesis and the potential solutions discussed for them could be applied to commercial archaeology companies holding human remains.

ii. The "Brain Drain"

The flight of human capital, or "brain drain", is another problem facing museums in England and the United Kingdom as a whole. Talented, skilled, and educated individuals are attracted to higher wages and better job prospects in other countries or other professions. In England salaries attached to many of the museum and gallery positions are well below salaries for jobs of a similar level in other countries, such as the United States of America (Steel 2017). For example, curatorial roles at museums in major cities in the UK provided an average salary of £29,000 (Glassdoor 2021a) whereas a comparable role in the USA provides an average salary of $92,000 or £66,000 (Glassdoor 2021b). This discrepancy in wages is repeated in several of the largest museums throughout the UK as well as throughout the lower-level roles (Adams 2019). For example, lower-level museum roles, such as front-of-house staff or curatorial assistants, in the UK have an average salary of approximately £21,500 (Prospects 2021), whereas similar roles in the USA have an average salary of $49,000 or £35,000 (Zippia 2021).

Low wages have always plagued the heritage industry. Traditionally, this industry attracted individuals who were not dependent on the heritage industry for their primary income (either due to independent wealth or private income); thus, wages were not competitive. This trend led to a heritage sector dominated by privileged individuals and a systemic lack of diversity. For those individuals without a privileged background the stagnant wages and inflation have resulted in many heritage sector workers being forced to take second jobs or forced out of the industry entirely (Adams 2019). These low wages also impact the morale and performance of the staff. Furthermore, as there is no real sense of progression, the turnover of the jobs is high, leading to a lack of continuity (Adams 2019). The vacant positions this "brain drain" leaves are unlikely to be filled by highly-skilled people as the jobs and salaries are not sufficiently attractive, even at an entry level. Individuals who step into these roles may not have the required skills or may not be looking for a permanent role, exacerbating the problem. This lack of highly-skilled workers is detrimental to the museum sector, and the heritage industry as a whole. While professional networks, such as the Subject Specialist Network, can provide training and guidance for unskilled workers, they are not a substitute for experience or education. Without these skilled workers, museums have to rely on volunteers or lower-skilled workers.

To bring this example back to the UK: UK national museums would struggle to compete on the world stage without the support of the international museum community and the UK would cease to be a world-leading country for historical excellence, a problem which was recognised over a decade ago

(Brinkley et al. 2010). This argument may seem absurd, but without greater funding and an increase in wages this outcome is entirely possible for museums in the UK. Innovation and creativity are needed to bolster the museum sector – to conceive solutions to the downturn in visitor footfall currently experienced in British museums (Association of Leading Visitor Attractions 2019), including organising displays and programmes that draw in high numbers of visitors and secure necessary funding. Museums need this world-leading excellence and experience if they are to make it through these trying times. The solution to the "brain drain" problem is relatively simple, although very difficult to implement. Museum salaries throughout the sector need to be increased to the point where they are internationally competitive. However, as the UK has fallen so far behind countries like the USA, this solution may be impossible to achieve.

iii. Financial Problems

As mentioned above, financial problems facing museums are twofold. The first is funding, which represents the money the museum receives from the government, local authorities, or other large organisations. The second is income, defined as money the museum has made through admissions, donations, sales etc.

a. Funding

The Mendoza review of 2017 highlighted that funding was a major issue for museums in England (Mendoza 2017). This was an independent review of museums in England that was commissioned by the government in the aftermath of the British membership of the European Union referendum. The dearth of funding was caused by government budget cuts and nearly a decade-long programme of austerity measures. Museums that are run and funded by local councils have seen a funding drop of up to 30% in real terms (Economist 2019). The total amount of money given to museums per year by local government has declined from approximately £829 million in 2007-2008 to £720 million in 2016-2017, a drop of £109 million (Mendoza 2017 p.23). Many museums have not been able to adjust to this smaller budget.

The reduction in budget primarily affects employment. Staff wages consume a significant proportion of a museum's operating costs (Kendall 2019a; The British Museum 2018). This has led to a reduction in staff (with some moving abroad – see "The Brain Drain" Section 2.1.2.ii) and, for those that remain, an amalgamation of roles. However, employing fewer staff has a knock-on effect, especially in smaller museums that had few staff before the reduction in funds. Without adequate staff, the museum is forced to reduce its opening hours, thus reducing income from visitors. To remain open, with fewer staff, the museum must cut services in some other way, and this also impacts the income of the museum. Furthermore, without qualified staff, the curation of the collection suffers. This is true for all types of archaeological material, including human remains. Additionally, the proper storage of human remains requires an investment from the museum. The storage facility, shelving, boxes, and packing materials all have associated costs. When museums are forced to reduce their budgets due to funding cuts, they are unable to provide the best storage conditions for the collections they curate.

Central and local government funding is not the only funding available to a museum. Museums may seek the sponsorship of private companies, individuals, or other non-government organisations (Pes 2017). One example of this is the British Museum working with BP – formerly British Petroleum (British Museum 2019). This type of funding is more common in the USA where both private individuals and corporations receive tax breaks from the federal government for monies donated to museums; some donations can be as high as $10 million (AAM - American Alliance of Museums 2018; Kahn 2006). However, some of these corporations have ethically "grey" reputations that may tarnish those who receive donations from them. The following example illustrates such a case.

In recent years, there has been greater interest from the general public about the types of corporations funding heritage organisations and cultural institutions. A recent high-profile example of this concerns the protest at the Guggenheim Museum in New York on the 9th of February 2019. This was in response to the news that the Guggenheim had accepted a large donation from the Sackler family, whose members own part of Purdue Pharma. This company is widely held responsible for America's opioid dependency epidemic (Economist 2019) and is currently at the centre of a $10 billion lawsuit regarding the claim (BBC 2019b; Kollewe 2019; Reuters 2019). The Guggenheim has since returned the money and has said it will no longer be accepting donations from the Sackler family. However, the Sackler family are among the world's most profuse cultural philanthropists and donate to institutions all over the world, including many in England (Economist 2019). Under threats of similar protests, the National Portrait Gallery London has also returned a one million pound donation. However, this has not ended the protests; purportedly another London museum has also been threatened – believed to be the Victoria & Albert Museum (Economist 2019). The outcome of this threat is currently unknown, and it is likely that the Victoria & Albert Museum will also respond to the demands of protesters and return donations from the Sackler family.

The public outcry about sources of funding could not have come at a worse time for museums, as it has compounded their funding problems. Not only has funding from governments been reduced, affecting many small museums, the American model, of soliciting donations from wealthy patrons (which could have alleviated the shortage) is becoming more controversial. Museums must be more selective in the solicitation of donors and consider the reputations of the corporations they work with or face public backlash.

b. Income

The second financial problem museums are facing relates to the income they are able to generate. Income, as briefly mentioned above, is described as the money the museum has made through entrance admissions, sales, visitor donations, gift aid donations, or membership charges (Crossley and Rowlands 2018; Gov.uk 2019; Museums Association 2019b). The key issue that has affected income is the reduction of footfall in museums, or the decline in visitors. Although many factors could have caused this reduction in visitor numbers, two stand out: the 2008/2009 recession and Brexit, the UK's exit from the European Union (although COVID-19 could be added to this list, at the time of writing, it is still too early to determine its long-term impact).

The aftermath of the 2008-2009 recession and the following decade of austerity have had an impact on visitor numbers. Over the last ten years people's spending habits in the UK have changed. Average incomes have declined, with the cost of goods and services increasing and spending power decreasing (Office of National Statistics 2019). This has led some families to decrease their spending, and museums and other cultural organisations have experienced this through their decline in visitor numbers. Museums that depend on admission fees have especially been affected. Museums with an admission charge have found visitors are either reluctant to pay or expect the museum to be free (Brown 2015a; Heywood 2009; Steel 2011). Thus, museums that operate in this way struggle to maintain themselves and, as Figure 2.1 above shows, many have not succeeded in doing so.

At the time of writing, the outcome of Brexit is still not fully understood, although the atmosphere created by the 2016 referendum has discouraged foreign visitors from holidaying in Britain. This has been particularly felt in London where the major museums had nearly two million fewer visitors in 2017 than in 2016 (Association of Leading Visitor Attractions 2019). No wide-ranging study has been conducted on the impact of Brexit on foreign visitors, but it is reasonable to assume that the confusion of Brexit and the perceived hostile sentiment towards foreign people visiting will have had an impact on visiting UK museums.

iv. Summary

Many museums show resilience against a decline in income or lower levels of funding because they are designed to be thrifty during fiscal downturns (Gosselin 2019; Kendall 2013). However, having income from visitors and government funding decline simultaneously, and for such an extended period, has overwhelmed many museums. Increased financial resources could alleviate most of the problems faced by museums, but finding the source of this funding remains a problem. One solution is to receive funding from investors, such as the Sackler family, despite their ethically grey reputation and the potential public backlash. This option requires the public to accept these donors who are culture-washing. Perhaps, if the general public knew the extent of the financial struggle facing museums in the UK, they might be more inclined to allow this sort of funding or, make a small donation themselves. However, it is not for the museums to decide, but for the "court of public opinion" to make the final decision.

2.2 Care of Human Remains in Museums

The skeleton is all that is left after a body undergoes decomposition after death, in both archaeological and forensic contexts. In archaeology a skeleton gives us a tangible link to individuals who lived in the past, allowing us to ascertain information about an individual's health, lifestyle, and even habits (for example: pipe-smoking facets in the Scottish soldiers at Durham who died in AD 1650 - Caffell 2014 pg.42; Millard et al. 2020). The amount of knowledge that can be obtained from a skeleton is huge, but this comes with ethical implications. We, as archaeologists, must always remember that we are dealing with the remains of a once-living person who had a life and a family. Studying human remains gives us so much more information beyond information from that one person. Whole population trends can be observed or inferred and parts of a culture previously unseen to archaeologists can emerge, such as the possible plight of the child match-makers in the North East of England and the condition of "phossy jaw", an ailment caused by phosphorus poisoning (Roberts et al. 2016). Once an individual has been studied the potential for knowledge still remains, as restudying of human remains often reveals more information because of advances in technologies and methodologies (Buikstra and Gordon 1981 pp.449-465; Mays 2017 pp.57-59; Roberts 2018 p.22; Roberts and Mays 2011 pp.626-630). Therefore, from a scientific point of view, reburial is not necessarily prudent. Yet, the storage of human remains is not simple. Similar to any object or artefact stored in a museum, human remains have special requirements; these are complicated by ethical considerations. Thus, caring for human remains properly requires the expertise of a human remains specialist. Estimating the number of specialist curators is difficult, as most of these specialists are often responsible for several types of artefacts or several time periods. The Human Remains Subject Specialist Network group reports that it has 38 members, many of whom are centred around London (J. Bekvalac pers. comm. 2021). Though this group does not account for all the human remains specialists in the country, it does give a good indication of how London-centric they are. Other human bioarchaeologists, although not necessarily curators, can be found throughout the country, but are usually clustered around universities or Historic England locations (J. Bekvalac pers. comm. 2021). White and colleagues (2011) suggest that there are approximately 262 institutions that curate human remains; although this paper is rather out of date and a number of these museums have since closed, some collections have been reburied, and new collections will have been excavated, showing that the number of museums with human remains collections far exceeds the number of human remains specialist curators. This issue is not limited to small regional museums. Larger museums, such as those run by National Museums Scotland, with substantial human remains collections do not have dedicated specialist curators. The lack of specialist curators could have an impact on the long term care of the collections of human remains in museums.

2.2.1 Guidelines for the Excavation, Curation, or Reburial of Archaeologically Derived Human Remains

Due to the ethical nature of human remains a number of guidelines have been produced (Antoine 2014; APABE 2017; Brickley and McKinley 2004; DCMS 2005; English Heritage 2005; Mays 1991; Mays et al. 2002; McKinley and Roberts 1993; Mitchell and Brickley 2017). In 2005 the Church of England (CoE) in partnership with English Heritage (EH, now Historic England, HE) created a document that covered the best practice for the treatment of any and all human remains excavated from a Christian burial ground (in England). In 2017 this document was updated by HE and the Advisory Panel on the Archaeology of Burials in England (APABE). The documents cover what should happen when human remains are disturbed, the process of archiving and storage of human remains, and then finally the potential for research including destructive analysis (APABE 2017; English Heritage 2005; Mays et al. 2013). Whilst these guidelines are not laws and therefore cannot be enforced through any legal channels, they still demonstrate standards and best practices that should be followed.

The primary law regarding the exhumation of human remains is the 1857 Burial Act. This Act made it an offence to disturb human remains, either by exposing or removing the remains, unless a licence has been obtained (Antoine 2014 p.10; APABE 2017 p.13; Burial Act 1857; Collections Trust 2020a; Gov.uk 2013). The licences were originally issued by the Home Office; this responsibility passed to the Department of Constitutional Affairs and then onto the Ministry of Justice. The burial licence is not only used for archaeological excavation; anyone can apply to have human remains exhumed and moved, if a good reason is found (Gov.uk 2013). The rest of this section, however, will discuss how burial licences are used by archaeologists in England. If human remains are expected during an excavation, then prior to the start of excavation a licence should be obtained. If, however, remains are found unexpectedly then an emergency licence should be obtained (APABE 2017 p.13). Whilst the 1857 Burial Act is the primary law determining what should happen to the remains, other laws and conventions can apply in certain circumstances. If the burial ground is no longer in use, then the Disused Burial Grounds (Amended) Act 1981 supersedes the Burial Act and should instead be followed (APABE 2017 p.12). Furthermore, if the remains are thought to be less than 100 years old the Human Tissue Act of 2004 should be followed (this is only applicable to England, Wales, and Northern Ireland), requiring special permission from the Human Tissue Authority (HTA) (Antoine 2014 pp.5-6; APABE 2017 p.3; HTAct 2004; Shelbourn 2015 p.1). If the remains are found on consecrated Church grounds, then a faculty (ecclesiastical) licence is needed; this can be obtained from the Church of England or other relevant ecclesiastical body (APABE 2017; Shelbourn 2015 p.2). Furthermore, for ancient burials, specific planning permissions may be required if these burials are associated with a scheduled monument (APABE 2017 p. 4). These licences (burial and faculty) also determine what happens to the remains after excavation. Faculty licences usually require that remains be reburied after a period of study (APABE 2017 p.9). Prior to 2008, the convention for burial licences was to take excavated remains that were not to be reburied and store them permanently in a museum or other institution (Antoine 2014). However, in 2007 the Ministry of Justice (MoJ) changed its stance on archaeological burials and declined to issue any new burial licences, stating that the burial laws did not apply to archaeology (Antoine 2014). In 2008 this convention changed again, and the Ministry of Justice instead decided to issue licences that required all excavated human remains to be reburied after a period of two years (Antoine 2014; Shelbourn 2015 p.20). This allowed some study of the remains but prevented them from being curated within a museum. Whilst the two years could be extended on a case-by-case basis, this new policy was not well received in the archaeological community (Shelbourn 2015 p.20). Many archaeological organisations and individuals spoke out about the loss of knowledge that would occur. In 2012 the Ministry of Justice changed their position once more and conceded that a wider range of disposal methods was needed, including the long-term retention of human remains (Shelbourn 2015 p.21). Burial licences are not just guidance on what should happen to the remains after excavation, they are statutory law. Therefore, the situation of the excavated remains cannot change unless permission from the Ministry of Justice is given (Loe and Clough 2020 p.161). A museum that has acquired human remains through the authority of a burial licence is legally required to retain the remains and would be unable to deaccession them without special approval. If the museum wishes to deaccession the remains, for whatever reason, they will have to apply for express permission to do so (DCMS 2005 p.18). This cannot be freely given and is instead decided on a case-by-case basis by the Ministry of Justice. The problems that this could potentially cause will be discussed further below.

In a country such as England (as well as the rest of the UK), which has been occupied for so long, disturbance of human remains is all but inevitable. It is important to know what to do when human remains are disturbed. If the disturbance of human remains is expected during proposed construction, then an application for authorisation to excavate should be made to the relevant authority prior to the work beginning (APABE 2017). The guidelines state that if all or even part of the burial ground is threatened by construction work, this can be classified as disturbance, and therefore, steps should be taken to excavate the remains for their protection (APABE 2017, English Heritage 2005). Government policy (1990 Planning Policy Guidance 16 [PPG 16]; 2010 Planning Policy Statement 5 [PPS 5]; 2012 National Planning Policy Framework [NPPF]; 2015 Historic Environment Good Practice Advice) says that human remains should not be needlessly removed or destroyed, and that a decision must be reached that balances the attraction of preserving archaeological sites with the benefits of the new construction. If the construction is deemed worthy, then the remains must be removed. Disturbance of human remains, or any other object, can also occur more deliberately in the form of a research excavation, such as the high-profile search for and eventual discovery of the remains of King Richard III (BBC 2013). In these cases, a decision needs to be made which compares the potential benefit of the accumulation of knowledge from the remains with the need to protect archaeological sites (APABE 2017; English Heritage 2005). Finally, as many churchyards have been in use for centuries, the likelihood of disturbing human remains from unmarked past burials is high. In these cases, however, as it is still part of the active churchyard, a faculty licence is required under ecclesiastical law (MoJ 2020 p.9).

In the application for a burial or faculty licence, those proposing to excavate human remains must include a plan for the deposition of these remains either in an institution, such as a museum, or in a burial ground following a period of analysis (APABE 2017 – "Authority to excavate human remains for archaeological purposes – question 37). Whilst it is technically possible to excavate without this being known (APABE 2017 – option C question 37), applicants must provide an estimated date at which a plan will be made for the remains, an authority that will make the decision, and provide the details of who will be responsible for the remains until a decision is made. In these cases, the licence will be issued with a reburial condition pending an alternative decision. If a different decision is made, an application to vary the licence will need to be made (APABE 2017 p.24).

When archiving human remains, a number of legal and technical aspects should be considered prior to storage (Garratt-Frost 1992; Museums Association 2018). Firstly, the retention of the actual remains should be legally authorised by the relevant authority; if the remains are Christian this would be the Christian Church (faculty licence), but if the remains are not Christian, then it would be the MoJ (burial licence) (APABE 2017; English Heritage 2005). The place of storage should be deemed suitable for the storage of human remains and meet all the relevant conditions to ensure that the physical integrity of the remains is preserved. Finally, the storage location should have the facilities to grant access to the remains to all legitimate researchers who seek access. This is because the primary reason for the retention is the propagation of knowledge (APABE 2017; English Heritage 2005).

As well as legal considerations, a number of ethical considerations need to be considered prior to archiving the remains. In Christian practice, no importance is placed specifically on physical human remains in relation to the resurrection of the individual after death; even so remains should still be treated with respect (APABE 2017; English Heritage 2005).

"So will it be with the resurrection of the dead. The body that is sown is perishable, it is raised imperishable; it is sown in dishonour, it is raised in glory; it is sown in weakness, it is raised in power; it is sown a natural body, it is raised a spiritual body." (1 Corinthians 15:42–44).

Even if the legislation, or lack thereof, says research is acceptable, relatives of known individuals or the local public may have their own views, which need to be strongly considered by the relevant bodies (APABE, religious groups, MoJ) prior to archiving. In relation to archaeology and education, human remains are invaluable and can arguably be described as one of the most important parts of archaeology. These are the remains of the people who created and shaped the past that archaeology endeavours to investigate. The remains of an individual can give us information pertaining to their environment, from the day they were born to the day they died (Roberts 2013). Furthermore, as scientific techniques improve, new methods can be applied to old collections, and consequently even old collections can still have significant scientific value (Buikstra and Gordon 1981). Displaying human remains, although sometimes problematic, which will be discussed later (Section 2.2.2 ii), can be extremely popular with the general public with several surveys supporting this claim; see Table 2.1 (Roberts 2018 p. 31).

Table 2.1: Survey responses

Survey	Question: Is it acceptable for human remains to be displayed in museums?	
	Yes	No (or Unsure)
Museum of London (National Archaeology Week) 2004 (B. White pers. comm. cited in Roberts 2018 p.31)	89%	11%
Museum of London 2008 (B. White pers. comm. cited in Roberts 2018 p.31)	92% (With 53% expecting to see them)	8%
Carroll 2005	79%	21%
Mills and Tranter 2009 For English Heritage	52% (79% if over 100 years old) (91% if over 1000 year old)	9%

It should be noted that the surveys in Table 2.1 collected their responses between 2004 and 2009. Since that time there has been a renewed drive within archaeology and the heritage sector to decolonise or decentre whiteness in their collections and displays and to encourage diversity of representation. Movements centred around decolonising museum displays, archaeological organisations, and academic curricula have grown in recent years (Lans 2020). The British Association for Biological Anthropology and Osteoarchaeology (BABAO), for instance, founded an Equality, Diversity, and Inclusion sub-group in 2018. This group produced an Equalities Monitoring Data Survey that ran from December 2019 through January 2020. There were 116 respondents (approximately 20% of the BABAO membership – BABAO 2018), of which only 5 (4.3%) identified as being from minority ethnic backgrounds (Arday and Craig-Atkins 2021). While 116 responses are not sufficient to fully represent BABAO, this survey does show that there is a lack of diversity within British bioarchaeological organisations and British archaeology as a whole. As members of a discipline that is overwhelmingly represented by white, middle-class individuals, archaeologists must make efforts to allow for other viewpoints to be heard; the cultural homogeneity of archaeologists, particularly in Britain, can too easily obscure valid opinions from minority groups (Arday and Craig-Atkins 2021; Jenkins 2012). As a consequence of these evolving attitudes many museums have begun to reassess their collections, to view their collections in a different light in an effort to redress the emphasis of a Western perspective and attempt to 'decolonise' the narratives that are found in museums (Lans 2020; Singer-Baefsky 2020). Any interpretations based on the surveys collected between 2004-2009 must be applied with caution as opinions may since have changed.

More recent feedback regarding the display of human remains was collected during the Bodies of Evidence Exhibit held in 2018 at Durham's Palace Green Library (Biddlecombe-Brown et al. 2019). The exhibit explored the human remains discovered during the building works conducted at Palace Green in 2013 (Biddlecombe-Brown et al. 2019). Analysis revealed that these remains belonged to soldiers that had fought at the Battle of Dunbar in 1650 who were captured and imprisoned in Durham Cathedral. Those who died were buried in two burial pits located near the cathedral (Millard et al. 2020; Quigley 2018). The exhibition covered the discovery and analysis of these remains, but also the techniques and ethical considerations involved in archaeology and the study of human remains more generally (Biddlecombe-Brown et al. 2019). The feedback collected through token voting on the question, "Is it ethically appropriate to excavate, study and display human remains for educational purposes?", showed that 3114 individuals voted "yes", while only 797 voted "no" (K. Braithwaite pers. comm. 2021).

Display of human remains is deemed acceptable by the CoE and Historic England (HE) provided that the remains serve a clear educational purpose and are accompanied by adequate explanations

(English Heritage 2005). Excavated remains can also be used to train human bioarchaeologists and this is deemed acceptable by the CoE provided that students are made aware of the ethical considerations and treat the remains respectfully. Handling sessions with the public are another excellent way to educate the public. However, whilst the CoE agree that this is an important way to teach the general public, they say that such contact may encourage greater risk of offending other religious groups (English Heritage 2005); a possible solution to this is to use replica skeletons and reserve the real skeletons for a more controlled setting with trained individuals.

If the remains are not to be curated long-term, reburial is required. To rebury remains properly, in accordance with scientific and religious best practice, the following guidance should be followed. It should be noted that this guidance is only applicable in England. Firstly, any remains that were excavated from a Christian burial ground should be reinterred in consecrated ground (as required by the faculty licence). Prior to reinterment the remains should be recorded to the current standards (English Heritage 2005). The guidance also states that any ancient remains, specifically ones not covered by the CoE, should not be cremated. This is unless there is a clear threat to health and safety, such as the presence of soft tissue, which would require special consideration (English Heritage 2005).

The 2017 CoE (APABE 2017) guidance offers best practices and guidelines of what to do in each situation, either reburial or retention. The Christian Church understands the need to retain skeletal collections for study, but appreciates the concerns some people may have with curation. There are thus no explicit rules set in place, with the CoE suggesting that decisions for human remains should be decided on a case-by-case basis (English Heritage 2005). If there is a difference of opinion, a third party should be consulted to help mediate the problem such as APABE, but the final decision should be given by the MoJ or the Christian Church, depending on the context of the remains.

2.2.2 Archaeological Human Remains in English Museums

In 2004/2005, around the same time as the CoE and HE were developing the "Guidance for best practice for treatment of human remains excavated from Christian burial grounds in England", the Department for Culture, Media, and Sport (DCMS), the governmental department that oversees the working of museums in the UK, created a similar set of guidelines that covered the care of human remains within museums (2005). The DCMS document contained all of the factors for museums to consider. It should be noted that the guidance refers to a museum as any institution permanently holding human remains as collections (DCMS 2005 p.10). The document was the end result of a near five-year process which started in 2001 when the Working Group on Human Remains in Museum Collections (WGHR) was created, with the aim of advising on human remains in English Museums, and with a particular interest in the repatriation of Indigenous remains (DCMS 2003; Jenkins 2008; Jenkins

2012 p.466; White, B. 2011 pp.481-482). In 2003, after publishing their report the Working Group was disbanded, but agreement on the outcomes of the report was not unanimous (DCMS 2003; Jenkins 2011; White, B. 2011 pp.481-482). In 2004 a document was created summarising the process and findings of the WGHR project; this summary also included a number of responses from different organisations, including: International Council of Museums (ICOM), United Nations Educational, Scientific and Cultural Organisation (UNESCO), Honouring the Ancient Dead (HAD) a neopagan advocacy group, the Australian government and several non-UK museums. From this summary document and the responses from the groups, the 2005 "Guidance" document was published (Jenkins 2011; White, B. 2011 pp. 479-492; White, L. 2011).

The guidance document was created knowing that the subjects and advice contained within would not become statutory law and would instead be used as a "code of practice" for museums. It is clear that the guidance has not been fully utilised (Jenkins 2011; White, B. 2011 pp. 479-492; White, L. 2011). As the DCMS 2005 document provides the basis for museum guidelines, each section will be discussed in relation to other documentation, creating a summary of best practice for museums. It should be emphasised that this guidance is only really applicable to English museums.

i. Acquisition of Archaeological Human Remains

Although the guidelines for the acquisition of archaeological human remains are more ethically demanding, the actual process museums go through to acquire and then accession human remains is not significantly different to the process that happens with any other archaeological object. Similarly to artefacts, the museum may wish to check the human remains have been packed and processed properly (in accordance with SMA 2020); a condition report including the physical condition, completeness and the provenance of the remains should also be included. Further information should be recorded for the human remains, including estimated age at death, biological sex, any evidence of pathologies, and a record of associated artefacts; obtaining this information requires consultation with a human remains specialist (DCMS 2005). Once acquired, the museum will have to deal with the problem of ownership as no ownership can be given to human remains, unless skill has been applied to the remains (Collection Trust 2020a p.15; Museums Association 2004). An example of applied skill would be a carved skull cup; as agency had been applied to the skull it can have an owner (Bello et al. 2011).

Like other objects, human remains can be transferred and loaned between accredited museums and institutions without a problem, provided the general guidelines for transfer and loans are followed. This is usually conducted if the holding museum no longer has the space or resources to house the remains; in these cases, the remains can easily be transferred, but the process should be well documented to avoid any ethical issues (DCMS 2003; DCMS 2004; DCMS 2005). Donation of human remains is acceptable, but care must be taken based on the issues around ownership of the remains (Collections Trust 2020a p.15). As mentioned above the museum should only accept donations that are in line with its collecting or acquisition policy and that they are equipped to deal with. If they are accepting donations of human remains, they must fully understand the correct procedure for acquiring them (discussed below). Additionally, the museum should understand the differences between human remains and other artefacts, particularly surrounding the ethical treatment and storage of human remains. Their treatment must reflect the fact that these are the remains of a once-living person.

Before accepting human remains, it is beneficial if the museum has a human remains policy in place. This policy should include a determination of the scope of the intended collection that will influence which remains the museum will acquire. This would help to guide the care and management of the remains by controlling who can access the remains, for what purpose, and whether the remains can be used for destructive analyses. These policies should cover how the remains will be stored, whether they can be loaned to other institutions or put on display, the situations in which images of the remains can be produced, and how the copyright of those images are managed. The Collections Trust has a guide to help museums write their own human remains policy (Collections Trust 2020a p.28).

In Britain the law does not recognise human remains as property and therefore no ownership can be held over them. This presents a challenge with regards to the donation of human remains. Human remains can be donated by a private individual through the Portable Antiquities Scheme, provided the individual holds the legal title to the land on which the remains were found, or has express permission from the landowner. Once the human remains are confirmed as being of archaeological rather than forensic interest, and have been validated by the Portable Antiquities Scheme, the remains can then be donated to a museum. With this process the museum can be confident that the remains have been dealt with legally and their provenance has been established (Portable Antiquities Scheme 2006).

Human remains can be donated by the police once the remains have been proven to be over 100 years old (to avoid falling under the Human Tissue Act – DCMS 2005; Human Tissue Authority 2020). Usually once the remains have been shown not to be from a forensic context they would be passed to a relevant local archaeological body. This archaeological body is then free to donate the remains to the museum.

If provenance and authority can be proven then the museum can accession the remains. If the context or date of the remains is unknown and cannot be discovered, then the ability of the museum to accept the donation is influenced by them having a Human Tissue Licence (Human Tissue Authority 2020).

Museums without a Human Tissue License can accept human remains of unknown date; however, these remains cannot be used for a scheduled purpose, such as display.

When considering the acceptance of a donation of human remains the museum must be satisfied that the remains have an established provenance, are currently being held in accordance with the law and will have a clear relation to the museum's current collections and provide the potential for scientific research. Therefore, for human remains whose provenance is unknown or whose scientific value is limited, accepting these remains may not be the best option for the museum. Regardless of the form and source of the donation, the process should be well documented to avoid any legal or ethical problems for the museum in the future (Clegg 2020 p. 70; DCMS 2003; DCMS 2004; DCMS 2005).

Human remains can be acquired through excavations, which is the most common method of acquisition of human remains for museums. To be acquired they must comply with the relevant laws and guidelines, such as the Human Burial Act (Burial Act 1857; Gov.uk 2013), which made it a criminal offence to exhume or disturb human remains without lawful authority, established by the Department of Constitutional Affairs (2003-2007) and currently the Ministry of Justice. In addition, if the human remains are Christian or from a Christian burial ground, a faculty (ecclesiastical) licence should be obtained (Church of England 2015), and the guidance from the CoE and EH, outlined previously in Section 2.2.1, should be followed (APABE 2017; English Heritage 2005). If the remains are thought to be non-Christian or found in unconsecrated ground, then only the burial licence will be necessary. Whilst other historical objects can be bought and sold, this is deemed inappropriate for human remains for a number of reasons. First and foremost, the sale of human remains is extremely unethical and entirely immoral (BABAO 2017). Secondly, as no true ownership can be held over human remains, this makes sales almost impossible as no owner can give permission (Collections Trust 2020a p.15; Garratt-Frost 1992). Thirdly, as human remains cannot be owned under English Common law (unless skill has been applied), they also cannot legally be sold. They can, however, legally be held within a private collection, if they meet the requirements of the 2004 Human Tissue Act (this act does not include Scotland), which prohibits holding human remains less than 100 years old (BABAO 2017). BABAO has reported that several skeletons classified and advertised as "antique" were in fact much more recent and would be subject to the Human Tissue Act (BABAO 2017; 2021a). Many of these more recent skeletons originate from China or India, as the practice of exporting human remains was not banned until 1985 in India and 2008 in China. There is some evidence that, even with these recent bans, the export of human remains from these countries continues (BABAO 2021a). Despite these reasons, large quantities of human skeletal remains can still be found for sale online, on sites such as eBay, Instagram, and Amazon (Graham and Huffer 2017; Huffer and Chappell 2014; Huffer and Charlton 2020; Hugo 2016; Huxley and Finnegan 2003). Professional bodies, such as BABAO, are attempting to curb the sale of human remains online, by tracking how human remains are sold, monitoring the use of human remains in social media, and raising public awareness about the ethical and legal ramifications of the sale of human remains (BABAO 2021a). Unfortunately, the sale of these remains has moved from moderated e-commerce sites to social media platforms (such as Facebook or Instagram), where transactions can take place with negligible intervention from moderators (BABAO 2021a).

Once the acquisition has been completed by the museum, regardless of the method of acquisition, the human remains can be accessioned (if it is intended to become part of the permanent collections). If this is the course the museum wishes to take, then a formal and permanent record should be created in line with the Collections Trust (2017d) guidelines.

ii. Storage

The basic guidance on storage facilities, discussed above, should always be followed. Some guidance, such as avoiding direct sunlight and keeping the storage facility pest free, are universal and can be implemented for any material in a museum. However, for the long-term storage of human remains, other conditions are needed. The specific conditions required for the storage of human skeletal remains have been set out by Bonney and colleagues (2020), Cassman and colleagues (2006), Clegg (2020 pp.72-76), DCMS (2005), Garland and colleagues (1988), Janaway and colleagues (2001) and the Society for Museum Archaeology (2020), and are outlined below.

The temperature of the storage facility should be kept between 16–20°C, whilst trying to avoid fluctuations. The humidity of the facility should be kept at 45% ±5%; lower humidity can cause the bone to crack, whilst higher can cause mould growth. Due to the ethical considerations inherent to human remains, they should be stored in a separate dedicated area where access can be controlled and restricted if necessary. Durable and strong shelving (preferably metal) should be used and should not be overloaded. The boxes themselves should be kept at least 10cm off the floor. Where possible, boxes should not be stacked on each other, and the collection should be labelled and ordered appropriately. The boxes should be made of an inert material and should be large enough to accommodate the largest bones. Acid-free packing material (not newspaper) and strong clear plastic bags should be used to protect the elements and prevent them from moving around within the box – bubble wrap can be used but should be seen as a temporary measure. Boxes should be packed so that the larger heavy elements are on the bottom and the more fragile elements are on top. Finally, regular inspections should be conducted to ensure all needs are being met and that no problems have arisen.

The conservation of human remains should only occur when absolutely necessary and a principle of minimum intervention and reversibility should be adhered to (DCMS 2005). Preventive conservation work includes keeping the bones clean, dry, and free from dirt. If needed, remedial conservation work should only be conducted by a trained conservator who has experience in dealing with biological material, and the work should be overseen by an osteologist (DCMS 2005).

iii. Display

Displaying human remains is quite different from displaying other objects due to the emotive nature of the remains and, as such, museums that do so have a number of ethical challenges to overcome (Biers 2020 p.239). Surveys show that even with associated ethical issues, museum visitors enjoy and actively want to see human remains in museums (Barbian and Berndt 2001; Barham and Lang 2001; Biers 2020 p.241; Gazi 2014; Kilmister 2003; Rumsey 2001; Sledzik and Barbian 2001). As shown in Table 2.1, surveys undertaken by the Museum of London (2004, 2008) found that between 89% and 92% of the participants felt that display of human remains was acceptable (B. White pers. comm. cited in Roberts 2018 p.31). However, as discussed above in Section 2.2.1, these surveys do not take into account the recent changes in public opinion driven by movements like Black Lives Matter and efforts to decolonise museum collections. Any new survey should endeavour to include and quantify if and how these changes have affected opinions regarding the display of human remains in museums.

Human remains can be invaluable in educating visitors (Alberti et al.2009; Biers 2020 p.241; Gazi 2014). However, many challenges can arise from the display of human remains. The incident of "covering the mummies" at the Manchester Museum is a good example of these challenges (Exell 2016; Giles 2009). Three mummies in the Egyptology galleries were covered, after the museum received feedback from visitors who felt that the display of unwrapped mummies was disrespectful (Brown 2011). The feedback was collected during a series of consultations regarding the ethics of displaying human remains in preparation for the future year-long temporary exhibition of Lindow Man, a 2000-year-old bog body discovered near Manchester, on loan from the British Museum (Brown 2011; Exell 2016; Giles 2009). The Human Remains Panel at the Manchester Museum covered the unwrapped mummies not as a permanent solution, but rather to ascertain visitor reactions (Brown 2011; Exell 2016). However, the reaction of the visitors was one of outrage and disappointment on a scale that attracted worldwide media coverage and widespread condemnation (Brown 2011). As a result of this backlash, within a few weeks, one of the bodies was fully uncovered, one was partially uncovered, and the third was taken off display and returned to its previous home (Stonyhurst College in Lancashire, UK) (Exell 2016). The Human Remains Panel at Manchester Museum was also disbanded and many of those involved in the incident left the museum (Exell 2016).

Seeing human remains in a gallery is not for everyone; people may have personal, moral, or religious objections to seeing them, and therefore, the museum must put systems in place to avoid surprising visitors (Alberti et al. 2009 p.137; Biers 2020 p.251). Manchester Museum now has in place panels near the entrance of the museum warning people about the display of human remains, and offering routes that circumvent these displays (Brown 2011). Other options include signs warning visitors, or deliberately placed curtains so the remains cannot be seen accidentally (Gazi 2014). Increasingly, museums have begun conducting front-end evaluations to gauge public opinion before committing resources to creating a new exhibition (Natural History Museum 2021a). These evaluations include determining who currently visits the museum, whether they are representative of the local population, their opinions regarding what would be displayed and the interpretations that would accompany the display (Foster 2008 pp. 7-12). This would allow the museum to determine how suitable the proposed exhibition would be to the visitors and non-visitors alike, and whether or not the museum should proceed with the proposed exhibition. Human remains should not be shown just because they are popular and will attract visitors; they should be used to educate (Biers 2020 p.251; Gazi 2014). They should not become collectors' objects, fit for cabinets of curiosities, as was the case during the colonial period (17th to 19th Century) with the collection and display of Indigenous remains (DCMS 2005). Whether museums decide to display human remains or not may have an impact on the preservation of these remains. Display conditions are not necessarily equivalent to storage conditions, though several of the same guidelines are followed, such as not exposing remains to direct sunlight. In some regards the display of human remains may be beneficial to their preservation. Human remains on display are monitored more closely than those held in storage, they are securely mounted or supported, and the display cases are typically climate controlled. If any problems are discovered, they can be quickly resolved. Therefore, whether a collection was displayed was recorded in the Museum information recording sheet (Appendix 12), used in this research.

iv. Research

When we look at human remains used for research, it is not dissimilar to that of any other part of a museum's collection, with the only significant difference being that of the ethical nature of the human remains (Fossheim 2020). Museums should always encourage research of their collections when space and resources allow. Due to the ethical considerations associated with human remains it may be beneficial to restrict access to remains, only allowing trained individuals access for defined research projects. The impact this restriction has on preservation needs to be known, and therefore this information is included in the Museum Information Recording Sheet (Appendix 12).

As mentioned earlier (Section 1.1), human remains are a vitally important source of evidence when looking into our history. They give us a tangible link to our past through the people that lived through it, giving us unique and significant information (Roberts 2018 pp. 21-22). However, research has shown that handling remains, particularly in a teaching context, does lead to deterioration and sometimes loss of bones and teeth (Caffell et al. 2001). Furthermore, in some research projects it is necessary to conduct destructive analyses (such as isotopic analysis), and whilst this research can give us important information, such as on diet or migration patterns, it is done to the detriment of the remains (Machicek 2012). As destructive analyses directly involve damaging human remains, this will be a factor in the preservation of human remains. The samples taken for analyses are consumed, but also the removal of a sample of bone or tooth may weaken the surrounding bone leading to further deterioration of the remains (Mays 2013). Whether these types of analyses are permitted on a collection is an important factor in evaluating the change in preservation and therefore were recorded on the Museum Information Recording Sheet (Appendix 12). The museum must decide whether or not they want to allow this type of research; although part of the remains will be lost, important knowledge could be gained. If the museum does decide that destructive analyses are useful, then it should be undertaken by a qualified individual and be conducted to the highest standards with only the smallest necessary sample taken (DCMS 2005; English Heritage 2005; Mays et al. 2013). The justification (purpose of the research) for this decision should be added to the collection records, along with a record of the samples taken, the location from which they were taken, photographs taken before and after sampling, and finally the location of the resulting publication or data (Clegg 2020 p. 71; DCMS 2005). Museums need to make the decision whether the benefits of such research and potential for knowledge outweigh the probable and often certain damage to remains. Whilst it is important for a museum to encourage research, the primary role for a museum is to protect the objects they curate for future generations (Museums Association 1998; Redfern and Bekvalac 2017 p.378).

v. Deaccessioning

Unlike other objects in a museum's collection, the deaccessioning of skeletal human remains is not as straightforward. No ownership can be applied to human remains, which make sales and transfers to private individuals neither ethical nor legal (Collections Trust 2020a p.15; Garratt-Frost 1992).

The deaccessioning of human remains can take place for a number of reasons. As this thesis focuses on English skeletal remains from English museums, repatriation will not be discussed, but the following sources provide further information on this (Clegg 2020, p.73; Jenkins 2012, p.466). One reason for deaccessioning human skeletal remains is to rationalise the museum collection; this was the case with the disarticulated and un-stratified skeletal remains at the Museum of London (J. Bekvalac pers. comm. 2021). This process of de-selecting specific parts of a museum collection and creating storage space (Baxter et al. 2018) is increasingly being suggested as a way to help alleviate the storage problem that is occurring in English museums (McKinley 2013).

A related, but separate, process is required for remains retained for a temporary period of study. When human remains are excavated under burial or faculty licences that require reburial, there is an interim period allowed between excavation and reburial for analysis of the remains (APABE 2017). During this period the remains must be stored in a suitable location such as a museum or other institution and this must be stated in the application for the burial or faculty licence (APABE 2017). These remains would not be formally accessioned, nor would they be considered part of the museum's permanent collection; however, they would still take up space in the museum's storage facility. The time allowed for study must be stated in the application for the burial or faculty licence (APABE 2017). Whilst this period can be extended if needed, it would require an application to vary the original burial licence. As these remains are not accessioned by the museum, they need not be deaccessioned before reburial. However, the reburial process will be similar to deaccessioned human remains.

Burial licences can preclude deaccessioning of human remains (DCMS 2005 p.18; Shelbourn 2015). This can cause problems if the museum wishes to rationalise their collections for the purposes of creating space. The museum can apply for permission to rebury the remains from the Ministry of Justice; however, this decision is made on a case-by-case basis and can take time.

Once it has been established that the museum wishes to deaccession the human remains they curate and has the legal authority to do so, the process can begin. Spectrum outlines the process for deaccessioning and disposal, including what steps should be taken, who should be contacted and what should be recorded prior to reburial (Collections Trust 2017c). During the process of deaccessioning there should be an opportunity for any other parties, including the scientific community, to appeal (DCMS 2003; DCMS 2004; DCMS 2005). It should be noted by the museum that the deaccessioning and reburial of human remains will inevitably lead to their destruction over time due to environmental factors (Dent et al. 2004; Gordon and Buikstra 1981; Nord et al. 2005; Surabian 2012), along with the loss of potential information. However, even with this unwanted outcome from a scientific perspective, museums should not shy away from deaccessioning if it is necessary and they have the ability to do so and are prepared to face the reputational damage that could result from that decision.

2.2.3 Ethics of Human Remains

Dealing with human remains in any capacity has ethical challenges, and this should be the case as we are dealing with the remains of once living people. However, human remains in archaeology are vitally important in helping to construct the lives of individuals in the past, without which we can never fully understand how they lived and how they died.

Despite the ethical issues, having to deal with human remains is unavoidable, as skeletons are often excavated as part of pre-construction processes rather than as a research project. All we can do is treat the human remains in an ethical and responsible manner whilst they are being curated and being used for research and teaching. The truth of the situation is that archaeologists can never really know what an individual would have wanted after they had been buried, or what the family of the individuals would have wanted, with the exception of a few individuals who made their wishes clear. William Shakespeare shared his thoughts:

"Good frend for Jesvs sake forbeare to dig the dvst encloased heare. Blese be ey man ty spares thes stones and cvrst be he ty moves my bones" Engraved on William Shakespeare's headstone.

Yet, when remains are excavated due to building work, it could be considered a lost opportunity if we do not study these people.

Christian remains are often recovered through archaeological excavations; research suggests that 75% of human remains recovered through excavation in the UK are from Christian burials (APABE 2017). When these remains are found on consecrated ground they are protected under Ecclesiastical law. However, human remains found in non-Christian burial grounds, outside of designated burial grounds, in disused monastic burial grounds, or in disused or lost churchyards, are not subject to Ecclesiastical law and are instead covered by MoJ burial licences (APABE 2017). Ancient burials can also be protected by Scheduled Monument status and specific planning considerations may be required under the Ancient Monuments Protection Act (1882 and subsequent amendments) or the Ancient Monuments and Archaeological Areas Act 1979 (APABE 2017). Faculty licences allow for the disturbance of Christian remains but typically require that the remains be reburied on consecrated ground after a period of study (APABE 2017 p.9). As mentioned in Section 2.2.1, burial licences offer three options for excavated human remains: retention in an institution, reburial, or a decision to be made at a later date (however, as discussed above this third option has ramifications). The most common option applied to these remains is retention in a museum or other institution (APABE 2017 p.9). These differences in the laws regarding non-Christian remains has worried some groups that refer to themselves as pagans, or neopagans. However, neopagans are not a single unified religion, nor do they have a single unified belief system (Wallis and Blain 2007). Instead, the term "neopagan" can be seen as an umbrella term for a number of different but similar ideologies, each with different beliefs or motivations (Wallis and Blain 2007). Contemporary pagan groups include, but are not limited to, Wicca, Druidry, Heathenry, and various "shamanistic" paths. Neopaganism can be described as one of the fastest growing spiritual identities in the West (BBC 2014; BBC 2019a). Many archaeologists describe themselves as neopagans, and as such it is becoming difficult to not include them in the discussion about the past. Neopagans are united in their concerns over ancestor welfare, and this has led to a number of calls for the reburial of human remains (Wallis and Blain 2007).

Honouring the Ancient Dead (HAD), established by Restall Orr in 2004 after the Stonehenge public enquiry regarding the proposed moving of the A303 road, aimed to bridge the gap between pagan groups and professionals in the field. HAD aims to ensure continued respect for ancient human remains, with clearer interactions between archaeologists, historians, landowners, and the pagan community (HAD 2018). Despite this, they do not advocate for the mandatory reburial of all human remains. HAD understands the valuable information that can be gained from the study of human remains; they only wish that this is conducted in a respectful manner (HAD 2018; Wallis and Blain 2007).

HAD's opinion, however, does not represent the whole pagan community. Some groups, such as Council of British Druids Orders (CoBDO), do not agree with the study of ancient human remains and instead would like to see them reburied with their grave-goods (Bristol Evening Post 2008; CoBDO 2017; Wallis and Blain 2007). An example occurred in 2006 when English Heritage and the National Trust received a request to rebury the prehistoric remains held at Avebury Museum from Paul Davies, a member of CoBDO. As the request had come after the DCMS 2005 guidance document, which gave museums guidance on how to deal with claims for repatriation (albeit from other countries), English Heritage and the National Trust believed that the basic principles of that guidance could be applied to the request (this was agreed to by Paul Davies and CoBDO – Thackray and Payne 2009; 2010), despite the claim not meeting the conditions of a repatriation request set out in DCMS. From the DCMS guidelines, 12 criteria were used to determine the validity of the claim. These criteria included whether the claimant had a genetic, cultural, or spiritual relationship with the remains. This information was compiled in a report (Thackray and Payne 2008), which was then sent for public consultation in 2008 to ensure the public regarded the report and decisions as fair. The public consultation findings were that the majority of the public agreed the report and decision were fair and that the criteria had been applied correctly. Concerns have been raised by Wallis and Blain (2011; Wallis 2015) that the questions for this consultation were posed in a leading manner, biasing the responses in favour of retention (Wallis 2015). The decision of the report stated that the request to rebury the Avebury remains would be rejected by English Heritage and the National Trust. The main reason for the decision was the determination that no "direct and close" (Thackray and Payne 2010 pg. 3) genetic relationship could be established between CoBDO members and the Avebury remains, a situation that has been verified by recent publications (Brace et al. 2019). Furthermore, while the remains are culturally and spiritually important to CoBDO and other neopagan groups, they also have great cultural significance to many others including the scientific community; therefore, no preferential status should be given to CoBDO's request. Finally, retaining the remains was considered the more reversable option. Despite this attempt by CoBDO to rebury the Avebury remains, it should be noted that this desire to see the remains reburied was not shared by other Druid groups – many were concerned that they had not been consulted by CoBDO first (Wallis and Blain 2007).

Pagan groups should be considered to some degree when dealing with the past, because they feel a strong connection to the ancient site, artefacts, and people; however, this is a complicated situation as no unified position exists. Yet, when dealing with requests for reburial we should remember that neopagan groups are not official claimants under the DCMS official guidelines (2005). Furthermore, ancient DNA studies have shown that the majority of these claimants have little to no genetic relationship with pre-Iron age remains (Brace et al. 2019). Instead, the studies show that during the Neolithic transition circa 4000 B.C. there was significant migration and replacement from Iberia and the Mediterranean, leading to population displacement in Britain (Brace et al. 2019). Thus, individuals that predate this Neolithic transition are unlikely to share a genetic relationship with modern inhabitants of Britain.

There are ethical implications to the interpretations that are applied to human remains. Archaeological evidence and its interpretations can have repercussions relating to identity (Hingley et al. 2018). Cultural identities are adapted and drawn from a shared understanding of a collective past; thus, changing interpretations of that past can dramatically influence these identities (Lucy 2005). These identities can also be used for political and nationalist purposes (Hingley et al. 2018). Researchers must be cautious in their interpretations and consider how they may be used or misused. Interpretations naturally evolve over time as new techniques are developed and new data become available. One example is the use of isotopic analyses in the assessment of the Roman diaspora by the University of Reading. The project involved studies at multiple sites across England using isotope analyses, skeletal research, material culture and epigraphic analysis to explore evidence of diaspora communities in Roman Britain (Chenery et al. 2010; Chenery et al. 2011; Eckardt et al. 2009; Müldner et al. 2011). Investigations at Gloucester, Winchester, and York found several individuals of non-local origin through evaluations of carbon, nitrogen, oxygen, and strontium isotopes (Chenery et al. 2010; Eckardt et al. 2009; Müldner et al. 2011). However, investigations at Catterick did not show definitive evidence of non-local individuals (Chenery et al. 2011). Taken together, these studies suggest that diaspora communities were focused around larger urban centres, particularly in the later Roman period (Chenery et al. 2010; Chenery et al. 2011; Eckardt et al. 2009; Müldner et al. 2009). However, there are limitations to isotope research. Human oxygen isotope ratios are dependent on the drinking water that an individual consumes and vary according to factors such as altitude and climate. As such, oxygen isotope ratios that are consistent with groundwaters in Britain are also consistent with groundwaters in a variety of Continental regions (Chenery et al. 2011). Similarly, human strontium isotope ratios are dependent on the strontium ratios and content of local bedrock or oceanic values.

Thus, strontium values that are consistent with local origins, such as those sampled at Catterick, may also be consistent with large areas of Central and Eastern England or with Continental areas (Chenery et al. 2011). Understanding the limitations of the data evaluated in these studies is as important as understanding the interpretations presented by the authors. While the original publications will address the biases and limitations of the studies, when the conclusions are cited by other parties these nuances may be lost (Frieman and Hofmann 2019). Furthermore, scientific techniques such as isotope analyses appear to be objective, potentially imparting undue significance to the conclusions of studies using these methods. However, due to the selection of samples, small sample sizes, and the interpretations drawn from the data the conclusions are, in fact, subjective. This appearance of objectivity leads to misunderstandings in the interpretations and an overemphasis on the conclusions by others (Frieman and Hofmann 2019).

History helps people to form their identities and shared identities, but their understanding of history is based on how they were raised and educated. There are biases in education regarding which subjects are emphasised, how these topics are explained, and what areas are overlooked (Bonacchi et al. 2016; Hingley et al. 2018). Until recent reforms in 2013, history education in England began with Roman history, neglecting prehistory entirely. The prominence of the Roman period in English education has led to interpretations of this era being manipulated for political purposes (Hingley et al. 2018). This can be seen in arguments from both sides of the Brexit debate. The “Leave” side of the debate focused on imperialist invaders from Europe, drawing an analogy from the Roman invasion (Hingley et al. 2018). Further arguments purported that it was Rome’s multiculturalism that led to the downfall of the Roman empire and that the same would happen with the European Union (Hingley et al. 2018). The “Remain” side focused on the civilising influence the Romans had over the “barbaric” Iron Age inhabitants of Britain, citing television shows and phrases such as “What have the Romans ever done for us?”. Both sides of the debate selectively used history for their own purposes (Hingley et al. 2018). Examples such as this show that archaeologists must be cautious in their interpretations. While it is not possible to entirely prevent the misappropriation of archaeological evidence, ethically archaeologists have a responsibility to ensure that evidence is presented in a clear and objective manner.

The ethics pertaining to human remains is not, and will never be, a simple debate. The need to be respectful to the remains, as well as to any living relatives or associated religious groups, needs to be carefully balanced with the potential gain or loss of scientific information. There is no simple way to resolve this issue. Therefore, each set of remains must be examined for their potential research value and the ethical nature of studying the remains by the curating institutions. If the potential for research outweighs the ethical cost (such as the potential loss of bone elements) of handling the remains, then the remains should be retained and studied, but if not then they should be reburied. However, even this will not keep everyone happy. The truth is that hundreds of thousands of remains are stored in museums across England and many collections of skeletons are not generally known about, so they go unstudied and take up space in museums (as was the case for some of the collections used in this research). Therefore, something needs to change. Although this section has focused on how the guidance pertains to English museums and collections of archaeologically derived human remains in line with the scope of this research, the guidance is also applicable to archaeological human remains from the rest of the UK.

2.3 Preservation Scales for Human Bioarchaeology

The state of preservation of excavated human remains is an important area for study. Preservation in this case is the condition of the remains; that is, an analysis of the level of damage that has occurred through taphonomic processes both in the ground and after excavation. Human skeletal remains are a finite resource and the factors influencing their preservation must be understood if we are to protect them. Researchers need to know the preservation state of collections of interest before visiting repositories in order to be certain that the remains are sufficiently preserved to answer the research question. Museums and other storage facilities need to understand the state of preservation of their curated collections to aid in conservation work and ensure the long-term survival of their collections. These condition reports can be conducted at any point, but many museums require them as part of the acquisition process to help the museum understand the state of preservation of the collection on arrival. These reports are typically produced by a specialist with training in human remains, using a preservation scale; the scale may be one of the scales listed below, or a simple coding system of: good, fair, or poor. Despite the important role of preservation and preservation scales, there is a lack of wider research on the subject of preservation of the contents of depositories. This is clear in the field of human bioarchaeology, where throughout the history of the discipline only two scales for recording preservation and one scale for recording completeness have addressed the subject, including one scale that was not designed for human remains. In this section past preservation scales will be outlined and critically evaluated, and a summary of what a new preservation scale should ideally contain will be presented. It should, however, be noted that some institutions and contractors, such as Oxford Archaeology (Loe 2017 p.6), are moving away from the traditional scales to digital imaging (photogrammetry). These digital records allow more complete documentation of the excavated skeletal remains (Loe 2017 p.6). This accurate documentation allows, amongst other things, much greater detail of post-excavation damage to be tracked (Valente 2019). The use of technology in recording human remains is discussed in more detail in Chapter 5.

2.3.1 Preservation Scales

i. Behrensmeyer (1978)

The first scale used by human bioarchaeologists to evaluate the preservation of human bone was created by Behrensmeyer (1978). The original project grew out of a larger taphonomic sampling initiative in the Amboseli Basin during 1975. The Basin lies along the northern edge of Mt. Kilimanjaro located in the southern region of Kenya, Africa, and it covers an area of approximately 600km^2 (Behrensmeyer 1978 p.150). The region contains a medley of different environments and vegetation, making the area opportune for a study of the taphonomic changes of bone in relation to weathering (Potts 1986). Six descriptive categories were created at the launch of the study and were designed to be easy to use in the field; see Figure 2.2 (Behrensmeyer 1978 p.151; Cook 1995; Lyman and Fox 1989). This study focused on 35 animal carcasses from large herbivores such as zebra and wildebeest, with known dates of death one to two years apart, from six different locales throughout the Basin. During 1975 and 1976 the 35 carcasses were split into groups based on years since death, and then evaluated based on the initial scale. The results showed that, predictably, the longer the period since death the greater the amount of weathering was found on the bones, and therefore the further along the scale it was placed (Behrensmeyer 1978 p.157). The scale was designed to work for the bones of any animal, but the research showed that smaller animals less than 100kg in weight weather more rapidly; the same outcome was noted for juvenile remains (Behrensmeyer 1978 p.160). The primary aim of the scale was to evaluate the period of time between death and burial, during which the fossil bone was exposed to post-mortem "events" (natural or otherwise), allowing archaeologists and other scientists to look at the pre-burial history of an assemblage (Fiorillo 1988). The scale does have other practical applications for archaeology and may be applied to other subject

Stage 0.-Bone surface shows no sign of cracking or flaking due to weathering. Usually bone is still greasy, marrow cavities contain tissue, skin and muscle/ligament may cover part or all of the bone surface.

Stage 1.-Bone shows cracking, normally parallel to the fiber structure (e.g., longitudinal long bones). Articular surfaces may show mosaic cracking of covering tissue as well as in the bone itself. Fat, skin and other tissue may or may not be present

Stage 2.-Outermost concentric thin layers of bone show flaking, usually associated with cracks, in that the bone edges along the cracks tend to separate and flake first. Long thin flakes, with one or more sides still attached to the bone, are common in the initial part of Stage 2. Deeper and more extensive flaking follows, until most of the outermost bone is gone. Crack edges are usually angular in cross-section. Remnants of ligaments, cartilage, and skin may be present

Stage 3.-Bone surface is characterized by patches of rough, homogeneously weathered compact bone, resulting in a fibrous texture. In these patches, all the external, concentrically layered bone has been removed. Gradually the patches extend to cover the entire bone surface. Weathering does not penetrate deeper than 1.0-1.5 mm at this stage, and bone fibers are still firmly attached to each other. Crack edges usually are rounded in cross-section. Tissue rarely present at this stage

Stage 4.-The bone surface is coarsely fibrous and rough in texture; large and small splinters occur and may be loose enough to fall away from the bone when it is moved. Weathering penetrates into inner cavities. Cracks are open and have splintered or rounded edge

Stage 5.-Bone is falling apart in situ, with large splinters lying around what remains of the whole, which is fragile and easily broken by moving. Original bone shape may be difficult to determine. Cancellous bone usually ex- posed, when present, and may outlast all traces of the former more compact, outer parts of the bones.

Figure 2.2. Descriptive categories taken from Behrensmeyer's 1978 preservation scale (Behrensmeyer 1978 p. 151)

areas, including providing evidence for the relative duration of occupation at a site and recurring occupations (Behrensmeyer et al. 2000; Cook 1995; Fiorillo 1988; Potts 1986).

Although Behrensmeyer's scale was used for nearly 30 years by human bioarchaeologists looking at human remains, it had many significant issues. The primary and most significant problem is the fact that the preservation scale was never specifically designed for human bones; it was designed for animal bones, which weather differently compared to human bones, due to the differing structure of the bone, most notably the thicker cortex found on animal bone. This means that the categories described are not entirely applicable to human remains (Behrensmeyer 1978; Behrensmeyer et al. 2000; McKinley 2004). Moreover, there are many factors that can influence how a human body decays and loses its integrity, particularly in an archaeological context, many of which are not applicable to animal remains. For example, many intrinsic features of the bones, such as size, age, biological sex, or density can have a major impact on the taphonomic process (Waldron 1987). Secondly, the taphonomic processes described in the article are from an African context, which would differ significantly from taphonomic processes elsewhere in the world with different environmental conditions, such as climate and weather patterns. Furthermore, the remains used in this study were "subaerial" - in the open air or on the earth's surface - rather than being buried as with archaeological human remains, meaning the deterioration observed would be completely different; being buried can have a significant impact upon taphonomy (Behrensmeyer 1978; Forbes 2014). The scale was designed for larger mammals, weighing over 100kg when fleshed (Behrensmeyer 1978 p.160), which makes the scale inapplicable to human bones. Most humans, particularly those found in archaeological contexts, did not weigh more than 100kg when alive (Hughes 2014[3]), implying the weathering pattern of the bone would be different. The length of the study can also be seen as a problem, especially when the scale is applied to archaeological remains. In the study the oldest remains were approximately 15 years old (Behrensmeyer 1978 p.157), whereas archaeological remains are significantly older and spend longer in the ground. Finally, the scale itself was designed to be, in Behrensmeyer's own words "a hypothesis which needs testing" (Behrensmeyer 1978 p.162) and was designed to be a starting point for such a scale rather than the "standard method" it eventually became (Lyman and Fox 1989).

ii. Buikstra and Ubelaker (1994 p.7)

Buikstra and Ubelaker (1994) set out to create guidelines for recording bone preservation that could be applied to archaeological human remains. During the course of this work they broached the subject of preservation and how to compile an inventory of a skeleton (Glassman 1996). The preservation scale they suggested using was the original Behrensmeyer (1978) scale which, at the time of writing,

[3] Following the method proposed by Auerbach and Ruff 2004 of estimating body mass from the femoral head on two English populations from different historical periods.

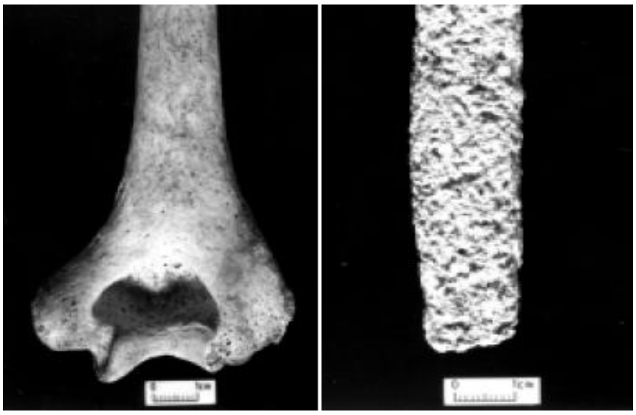
was the only extant guideline (Buikstra and Ubelaker 1994 p.98). To create an inventory of a skeleton, they suggested a specific coding system to show which bones were present, and to what extent they were "complete". Complete bones were classified as one (>75%), partial bones as two (75%-25%), and the most incomplete remains were classified as three (<25%) (Buikstra and Ubelaker 1994 p.7). This scale differed from Behrensmeyer's (1978) work as Buikstra and Ubelaker intended this scale to be used on whole skeletons rather than individual bones, to give an overview of the completeness of the entire skeleton. The code was designed to indicate how much bone was preserved for study.

A useful aspect of the Buikstra and Ubelaker system is that it incorporates the completeness of the bones, which no other scale considers. This is valuable because no matter the state of preservation, if most of the bone is absent then the amount of information which can be obtained is obviously reduced (Buikstra and Ubelaker 1994 pp.6-7). Another useful aspect of the scale is the quantitative categories (>75%, 75%-25%, <25%), reducing the subjectivity associated with the scale. Any new scale should consider the completeness of the remains alongside preservation, to allow researchers to fully understand the overall preservation status of a collection before actually visiting it.

Although useful, it is important to remember that the Buikstra and Ubelaker (1994) scale was not designed to record preservation; instead it was designed to complement the Behrensmeyer (1978) preservation scale. While completeness is significant, on its own it does not necessarily give an indication as to how useful the remains are for the purposes of specific research projects, as completeness only shows how much of the bone remains, not how well the bone is preserved, or how much of the surface is left. Bone surface preservation is key to many research projects. Several methods of adult age and sex estimation depend on observations of the surface morphology of bone: pubic symphysis scoring system for age (Brooks and Suchey 1990), auricular surface changes related to age (Lovejoy et al. 1985), sternal rib end changes related to age (İşcan and Loth 1986), and the composite arch morphology related to sex estimation (Bruzek 2002). Observations of many non-metric traits and pathological conditions found in skeletal remains require good preservation of the bone, as the changes are often present on the surface of the bone. Metric analyses can be affected as well by poor surface preservation if anatomical landmarks are obscured. Without an accurate recording of surface preservation, researchers can spend unnecessary time travelling to and accessing a collection that may not be applicable to, or usable in their research, wasting both their time and the museum's. For these reasons it is important that the surface preservation of skeletal human remains is recorded. In addition, the Buikstra and Ubelaker (1994) scale assumes a certain level of knowledge of human bone, so an understanding of what a complete bone looks like is necessary; without this knowledge the scale is difficult to implement and use. If completeness of a bone is to be used in a new preservation scale, it should be accompanied by a number of documents to help untrained individuals to use it. In this case (as well as throughout this thesis) an untrained individual is someone who has had no formal training in human bioarchaeology or archaeology. It is important that any future scale is usable by untrained individuals, as archaeologists are not the only group that could potentially implement this scale. Museums could use the scale for condition assessments, and the museum staff and volunteers may not have a background in archaeology or human bioarchaeology; in these cases, a scale that can be used by untrained individuals, or individuals whose training lies elsewhere, would be invaluable.

iii. McKinley (2004)

McKinley's (2004) preservation scale was created primarily as a tool to help create skeletal inventories and assessments of disarticulated and sometimes comingled remains. This was because disarticulated remains, or more specifically, the condition of disarticulated remains could be the key to understanding the formation processes of how the assemblage was created and therefore indirectly an indicator of ritual or mortuary rites (McKinley 2004 p.15). McKinley (2004) noted that human bone weathers differently to animal bone and that, therefore, Behrensmeyer's scale was not applicable to human remains; this is because of the difference in characteristics of the bone structure, with animal bone tending to have a much denser and thicker cortex that aids preservation (McKinley 2004 p.6). She also noted the difference in erosion seen in human remains commonly found in burials from the UK and how this erosion was different to that described in Behrensmeyer's scale (McKinley 2004 p.6). Behrensmeyer's (1978) scale covered cracking and flaking of bone, both of which are strongly associated with weathering, but are not wholly applicable to preservation seen in UK remains, in which bones are rarely exposed for an extended period of time, apart from in forensic contexts. The characteristics of erosion in the UK often include damage (usually to the surface of the bone) from excessively acidic or alkaline soil conditions, root or fungal damage, abrasion caused by repeated exposure to the surface, as well as disturbances from the surface, such as from animals or ploughing (McKinley 2004 p.15). McKinley's scale consists of seven categories (0-5+), from the absence of any change on the bone to



Grade 0: Surface morphology clearly visible with fresh appearance to bone and no modification

Grade 5+: As grade 5 but with extensive penetrating erosion resulting in modification of profile

Figure 2.3: Grade 0 and Grade 5+ from Jacqueline McKinley's preservation scale, both picture and description given (adapted from McKinley 2004 p. 16)

complete obliteration or destruction of the cortical surface (Figure 2.3) and it was designed to explain the position and extent of the erosion/abrasion (McKinley 2004 p.16). This scale has now become the standard method for UK human bioarchaeologists (Gamble and Fowler 2012; Leivers et al. 2008) and is part of the standard guidance for BABAO (2020) and the Chartered Institute for Archaeologists (CIfA 2020a), because of its simplicity, clear photographs, and explanations. The scale was first presented in BABAO's guidelines on recording human remains (Brickley and McKinley 2004) which was jointly published with the Institute of Field Archaeologists (IFA, now CIfA), and remains in the 2017 updated addition to this document produced by Mitchell and Brickley (2017). The McKinley scale is an extremely useful tool in a human bioarchaeologist's repertoire; not only is it the sole preservation scale that is specifically designed for application to human skeletons, but it is relatively straightforward to use and the categories are easy to understand, with the help of the detailed photographs.

Despite the use of McKinley's scale in human bioarchaeology, there are some challenges with its use. First and most importantly, there is no full guidance given on how to implement or use the scale. Although some suggestions are given, it is the opinion of this author that this is not sufficient as without detailed guidance there may be variability in the way individuals interpret and apply the scale. Secondly, information on how it was created and tested was not detailed in the chapter; when looking at how a scale works it is useful to look at what processes led to its implementation. In this case this information was not available until McKinley was contacted directly in 2016. In the 2004 chapter that introduced the scale there was no indication of error testing. Due to her commercial archaeology work, McKinley had had time constraints, and therefore no inter or intra observer error testing took place. Whilst it is understandable that human osteologists working in commercial archaeology have limited time for research, observer error testing is an important part of assessing the effectiveness of any scale/grading system that has been created. This is to ensure consistency in recording for observers themselves but also between observers. In addition, the scale is around 16 years old, meaning that the photographs used, although suitable at the time, are starting to become somewhat dated, due to the improvements in photographic equipment and techniques over the past decade. It is the opinion of this author that the photographs of the bone preservation categories should be updated every few years, allowing more detail to be shown through better resolution, therefore better representing the categories they show.

iv. Creating a New Preservation Scale for Human Skeletal Remains

In reviewing and evaluating past preservation scales, as well as related published papers, the requirements for a new or improved scale were clear. If a new scale was to be as widely used as that of McKinley (2004) three primary aspects needed to be considered, as well as a number of secondary aspects. Firstly, the new scale should use descriptive categories for each of the bone preservation groups that accurately describe the condition of the bone, as illustrated in Behrensmeyer (1978). These should be clear and simple so that even those who are not familiar with human remains can understand and assign bones to a category relatively simply. Secondly, the new scale needs supporting photographs with good resolution for each of the specific bone preservation categories, as used by McKinley (2004). In addition, the scale should strongly consider the content of the previous preservation scales; this would allow for some comparability with, at the very least, the McKinley (2004) scale.

When creating a new scale, a number of additional aspects should be considered to make the scale as useful and precise as possible. Firstly, the scale should look at both the preservation of the bone, as per the other scales, but also look at bone completeness (Buikstra and Ubelaker 1994). Currently, condition assessments of human remains are often done on a "traffic light" style system, recording only whether the remains are considered to be in good, fair, or poor condition. These assessments are highly subjective and not very descriptive. However, as they are quick to determine and easy to record, they persist. By combining completeness and preservation into a simple rating scale, this scale balances ease of use with detailed recording. Individuals can compare human skeletal remains against the descriptions and photographs provided to determine the appropriate preservation and completeness rating. Although it is understood that this would take more time than the current "traffic light" system, it would take less time than recording both features separately. For this reason, in theory, the proposed scale would be more applicable in situations where time limitations are a factor, but detailed records are desirable. The new scale should also consider the makeup of each bone, how it develops, and more importantly how it decays (Cassman et al. 2006 pp. 29-34; Curry 2002 pp. 27-37; O'Conner 1987). This would aim to gauge how bone decays and is commonly damaged both in the ground and, more importantly, once it has been excavated and is curated in a museum. Finally, the scale should consider how the previous scales were created to allow comparison; while this is possible for Behrensmeyer (1978), it proves a challenge for the McKinley (2004) scale as no information was published on its creation.

If all of the above needs are met, the scale could be used to create a baseline condition of human remains being curated at accession as recommended by Janaway and colleagues (2001), and facilitate changes in their preservation state to be recorded whilst they are curated (Cassman et al. 2006 pp. 34-48). The scale should also provide the means for comparing bones from different funerary contexts or periods, allowing comparative preservation research to take place across these different boundaries, which in turn allows wider preservation questions to be asked and answered. Finally, the scale should provide a basis for comparison of collections between different institutions or researchers, by minimising associated intra and inter observer error (Perez-Perez et al. 1990). If all of these aspirations were realised, the new scale would be considered successful.

However, even with a successful test of the scale, no scale will be perfect, and bias can always be found. In the scale developed in the current research, bias might come from the actual human bones used to demonstrate each category. This will relate to the soil conditions in which the body, and subsequent skeleton, was buried and how they differ not only globally, but even within a country such as the UK.

2.3.2 Research on the Preservation of Human Remains Curated in Museums

The majority of human remains that are available to human bioarchaeologists in the UK are curated in museums. Larger museums with more well-known collections facilitate most of this research, with smaller museums and their collections being less, or rarely, used (Roberts and Mays 2011). As well as museums, universities and commercial archaeology companies curate a large number of collections and, in the former, most are referred to as teaching/research collections and are used by archaeology and anthropology students for their courses, including dissertations (Durham University 2018; University of Bradford 2018; University of Sheffield 2018). However, universities rarely keep track of the preservation of these collections over time, despite the increase in students using them (best demonstrated in Caffell et al. 2001).

Very little work has been conducted on changes in preservation of human remains in institutions (i.e., museums, universities and other repositories, such as commercial archaeology companies). It is not known why there is a lack of studies in this area, although the most likely possibilities include:

1. The time-consuming nature of developing an initial baseline set of data for human remains, specifically the state of preservation of each skeleton at accession (Janaway et al. 2001), and the lack of resources to conduct such a study.

2. A lack of understanding that there could be a serious problem with preservation, so there is no impetus for it to be investigated.

Despite this, the preservation of human remains is an important area of research. If research on human skeletal collections continues in the future, then we must understand the impact this has on the integrity of skeletal collections (as discovered for teaching by Caffell et al. 2001). Furthermore, this type of research is not just relevant to human remains, but is relevant to all curated archaeological evidence.

Although little work has been done on the preservation of human remains curated in institutions, one key study looked at the impact of "use wear" on skeletal collections curated by the University of

Bradford over a number of years (Caffell et al. 2001). Caffell and colleagues selected 40 adult individuals from two different sites (Caffell et al. 2001 p.190). The first, from Chichester, Sussex, concerned skeletons from the late-medieval leprosy hospital of St James and St Mary Magdalene; the skeletons were divided into "old" Chichester and "new" Chichester, with the old Chichester remains having been excavated in 1986 and curated in 1988, and the new Chichester remains having been only curated at the university for a year (Caffell et al. 2001 p.189). The second site of Raunds Furnells, an Anglo-Saxon church and churchyard in Northamptonshire, was excavated between 1977 and 1984, with curation starting in 1982 (Boddington et al. 1996). However, the skeletal remains themselves were stored in several locations over the period, and moved at various times to suit what storage the University had available, likely having a detrimental effect on the preservation. For example, one location, the original location of the Department of Archaeological Sciences at 21 Claremont, was damaged by an explosion from a nearby building in 1983 causing the loss of part of the collection which was stored in the basement of the Department (Caffell et al. 2001 p.190). Caffell and colleagues reconstructed the "storage and use history" of the human remains by looking at the amount of pressure on the skeletons through the amount of use the remains had had through laboratory teaching. The "pressures" included: dissertation/thesis work (undergraduate, Masters and PhD students), laboratory classes, researchers visiting from other institutions, summer schools, and other general teaching (Caffell et al. 2001). An estimation of use was then established, but exact use was impossible to determine due to the lack of full documentation.

The skeletons studied were split into two categories: light or no use and heavy use. Once the two groups had been established, the skeletons were evaluated for damage using two primary indicators. The first indicator was a loss of bone elements from the individual skeletons since accession; to evaluate this the number of elements in the skeleton box was compared to the elements that were present when the skeleton was first curated at the University of Bradford. Where the element was present it was given a score of one, if the element was missing it was given a score of zero, and if fragments remained then the element was given a fractional score (Caffell et al. 2001). In addition, the skeletal elements were divided into large elements, such as the long bones, and small elements such as teeth, the expectation being that small elements would be lost more frequently than the larger ones (Caffell et al. 2001 p.190). The second indicator used was an evaluation of the condition, or preservation, of the elements. This was conducted by comparing the descriptions and photographs of the elements from the original recording forms to their present state, enabling damage sustained over time to be estimated (Caffell et al. 2001 p.191). An assumption was made that the photographs would have been taken when the skeletal report had been done; however, this could not be verified as no accompanying dates were found. Post-mortem damage was also recorded for each skeleton and damage during curation at the University of Bradford was distinguished from burial environmental damage using specific criteria, namely staining on the bone, angularity of any breaks, the presence of soil in the break, and the presence of soil within the bone (Caffell et al. 2001; White and Folkens 2005 pp.50-51). The results of this study showed that the more a skeleton is handled the greater the chance a bone or tooth will be lost, as might be expected. The old Chichester skeletons, which were mostly heavily used, suffered the most damage with around 91% of them having lost one or more bones or teeth. In comparison, only 30% of the new Chichester group had lost a bone. The smaller elements such as the hand or foot bones were most commonly lost, followed by the teeth (Caffell et al. 2001 p.192). A similar result was seen for the second indicator of damage, the condition of the bone, with the higher use groups being more damaged. Unexpectedly, 62% of the skeletons had in fact gained bones or teeth in their boxes: most commonly the bones from the hands and feet, with the Raunds skeletons being most affected. This may possibly be attributed to the Claremont explosion and the disruption it caused for that collection (Caffell et al. 2001 p.195). The study showed the need for detailed recording of remains when they are first accessioned by an institution ("condition assessment" – see Janaway et al. 2001). This would then allow comparative periodic preservation and completeness checks to be carried out to evaluate the integrity of skeletal collections as they are used over the years. This study also showed how important it is to label each skeletal element (and loose teeth) with the skeleton number to avoid mixing of remains and to enable the ability to rectify this when it happens. The final important part of this study showed that handling, although a major issue, was not the only factor that affected preservation; packaging and storage conditions of remains also had a significant effect on their preservation, with the "order" of packaging also being of vital importance (Caffell et al. 2001 p.194). When packing human remains, best practice is to ensure heavier bones (femora, humeri, tibiae, et cetera) are placed on the bottom, while more delicate bones (skulls, scapulae, ribs, et cetera) are packed near the top to avoid the heavier bones crushing the delicate ones (Roberts 2013).

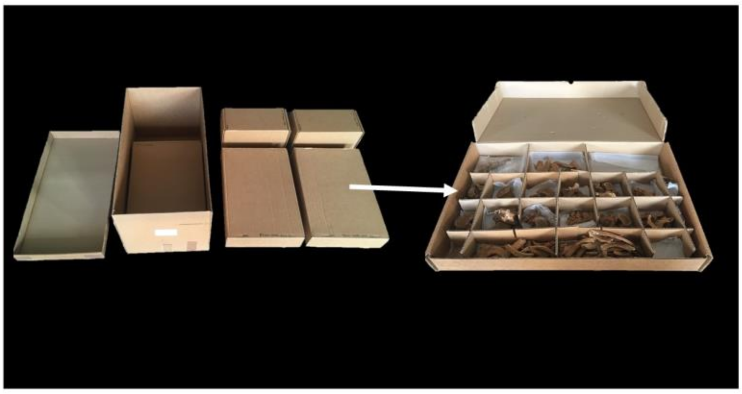


Figure 2.4: A Bowron Box, image taken in the Durham University Archaeology Department.

Caffell and colleagues' (2001) study prompted other research into the (in)adequacy of storage conditions for human remains used by most institutions, and a reassessment of packaging and storage procedures (Cassman et al. 2006 pp. 103-105; Roberts 2013 pp. 125-131). One such study was conducted by Bowron (2003) as a Masters dissertation (MA Conservation, Durham University), and led to the creation of "Bowron boxes" and their use for skeletons curated at Durham University's Archaeology Department from the late-medieval site of Fishergate House, York. Bowron's (2003) research considered storage conditions and curation policies of seven different institutions around the world. The study evaluated the number of skeletons curated, how the skeletons were packaged, as well as any guidelines or policies the institutions had implemented. This was then used to assess the current quality of storage. Bowron (2003), like Caffell and colleagues (2001), found that in most cases the storage conditions were somewhat inadequate, with the primary reason for this being attributed to an insufficient budget, and a lack of time, planning and organisation by the archaeologists who originally excavated the remains and the museums which curate them. The primary aim of the Bowron study was to evaluate the common types of damage seen in human remains curated in institutions, and to create a suitable cost effective, "fit for purpose", box for human remains (Figure 2.4).

Firstly, common damage was evaluated using the York Fishergate collection from the York Archaeological Trust (YAT), and three distinct categories of damage were identified (Bowron 2003 p.99) as follows:

1. **Environmental damage** (delamination, cracking of bone, and mould growth associated with high humidity).

2. **Storage and handling damage**, which was characterised as "scuff" marks (caused by two bone surfaces rubbing against each other) and fresh breaks.

3. **Reconstruction damage**, categorised as failure of adhesives, masking tape marks, and "left over" sticky residues.

Of all these forms of damage the most commonly seen on the bones were scuff marks, followed by fresh breaks, both of which are associated with storage and handling damage. Bowron (2003) suggested a number of ideas that could help reduce this type of damage, including creating handling guidelines, implementing environmental monitoring systems, and finally designing a new system of storage (Bowron 2003 p.100). The primary concept for a new box was to offer protection for the bones and to enable ease of access for the researcher. The design of the box was a large box within which six smaller separate boxes fitted that could each be labelled individually, removing the need to open all boxes unnecessarily if a "user" was just using one specific bone (Bowron 2003). The size of the boxes was determined by taking a measurement from the largest bone in the body (the femur). The first impressions of the box were not entirely positive; the box was described as "too large for its function" (Bowron 2003 p.102) as it was approximately three times the volume (163,842 cm^3 compared to 45,000cm^3) of a standard box found in museums, meaning most museum and storage shelving could not accommodate the box without incurring great expense. However, after consideration, it was decided that the remains were being held in a space to protect them effectively, and that this was as small as possible. As well as the size and design of the box, the material used in its construction was also carefully considered by balancing cost with function. Ultimately, "non-archival corrugated board" was selected, as the cost was significantly cheaper than "active archival storage board", and it fitted the specifications required. It should be noted, however, that most museums will not accept material held in boxes that are made from non-archival cardboard; if this box design is going to be used in the future the material would have to be adapted to archival grade cardboard. The aim of the research was successfully achieved to some degree as the estimated cost was £10.83 per unit (Bowron 2003 p.103) which, although more expensive than a "normal" box (approx. £4), has more functionality and protection. It was acknowledged that these boxes may not be suitable everywhere; for example, places with large collections, locations that are struggling for space (and money), or places where the shelving could not accommodate the size may find them impractical (Bowron 2003; Roberts 2018 pp.92-93). Furthermore, due to the large size, handling and manoeuvring the boxes can be difficult, especially for smaller individuals who are unable to lift or carry them without assistance. Despite this, Bowron (2003) concluded that the boxes were useful but could not develop their work further due to the time constraints of the Masters course. At the time of writing this thesis, the boxes are still in use in the Durham University Archaeology Department and have suffered only minor superficial surface damage on the boxes after a period of approximately 18 years. The remains inside have not yet been evaluated for preservation, but are still used regularly during the teaching of the MSc in Human Bioarchaeology and Palaeopathology (formerly MSc in Palaeopathology).

2.4 Summary

Museum curators and staff have a plethora of guidelines to abide by in curating their collections, and many are important for the protection of the "objects" themselves. These guidelines have been summarised above, with a particular focus on issues that could potentially impact human remains curated in museums. To contextualise this research, challenges faced by museums were summarised to give a clear picture of the status of the museum and heritage sector. Alongside the museum guidelines and challenges facing museums, guidelines that focus on the care and curation of human remains specifically were summarised. These documents show the best practice, with regard to human remains, that museums should follow. This included general ethics of curating, storing, and researching human remains. Finally, this chapter looked at previous preservation scales and outlined the positive and negative aspects of each scale; it then put forward a plan for a new preservation scale and what that scale should contain.

In the next chapter the process of creating, testing, and evaluating the new preservation scale developed is described, followed by an explanation of the methods that were used to collect and evaluate skeletons curated in the museums selected for study. Finally, the background information for the museums and sites are documented.

Chapter 3: Methods and Materials

As presented in Chapter 1, the aim of this research has been to evaluate the relationship between change in preservation of a skeletal collection in a museum and the amount of access it has received. The objective of this chapter is to describe the methods that were used in this research to achieve this aim.

The research conducted for this thesis can be divided into two main parts. Part One (Section 3.1.1) included creating, testing, and evaluating a new preservation scale that met the requirements set out in the previous chapter. When the scale passed this test, it would then be used in the next part of the research. Part Two of the research involved visiting museum skeletal collections, evaluating the preservation of the skeletal remains (both current and estimations of preservation when the remains were added to the museum) and comparing this to the amount of access, as well as other factors that could affect preservation. Section 3.1.2 outlines the framework and methodology used to complete this part of the research.

This chapter concludes with Section 3.2 which outlines the materials (skeletal collections) that were used in this study. Background information about the history of each of the museums and the demographic breakdown of the collections is included.

Contrary to convention, the materials section of this chapter has been placed after the methods section. This was primarily because the creation of a new preservation scale was significant for the rest of the study. Therefore, the creation, testing and evaluation of the results of the newly created scale appear first in this chapter.

3.1 Methods

The first part of this research, as outlined above, was the creation and testing of a new preservation scale, which considers previous scales and all of the factors defined and discussed in Chapter 2.

3.1.1 A New Preservation Scale

Following the review of the preservation scales that are currently, and have been, used, it became apparent that these scales – due to their scope and limitations – would not be applicable to the aim of the current research. A new scale that looked at completeness as well as preservation was needed to give a fuller picture of the state of preservation of adult human remains in the museums selected. Behrensmeyer's (1978) scale could not be used as, amongst other things, it was based on animal bone, and this would deteriorate differently to human bone (Aerssens et al. 1998). Buikstra and Ubelaker's (1994) scale could not be used as it merely covered completeness and advocated the use of

Behrensmeyer's scale, which at the time was the only one available. Finally, while McKinley's (2004) scale could be used, it was decided that due to its age (16 years old), a more modern preservation scale would be better. This new scale needed to be designed to incorporate all of the positive features presented and discussed in Chapter 2 (Section 2.3.1 iv) into one scale, and yet still be simple enough to be used by untrained individuals.

After outlining what the new preservation scale should contain, a draft version (1) was created (Appendix 1). The categories of preservation were based on a 0-5+ scale, similar to that used in McKinley (2004). This was implemented for two reasons. Firstly, the 0-5+ scale is an extremely useful and efficient way of marking out the preservation categories as it shows that deterioration does not stop after "5"; it continues until there is no bone left. Secondly, using the same scale allows some retrospective compatibility with McKinley (2004), allowing data from older research to be compared to the new data created from the new preservation scale.

Each category was then assigned a completeness percentage, similar to that in Buikstra and Ubelaker (1994). Category 0 was given a completeness of 100%, as bone that falls into this category should be complete. Category 1 was given a completeness of above 75%, as bones that fall into this category should be close to complete but could have some damage to their epiphyses. Categories 2, 3, and 4 could have any level of completeness and therefore the preservation category should be based on the actual characteristics of the bone surface. Categories 5 and 5+ represented the most poorly-preserved remains and therefore were not expected to be complete, so a completeness level of less than 25% was chosen to represent this category. An example of this table can be found in Appendix 1.

Characteristics of the bone surface were then defined. This was achieved by considering the categories McKinley (2004) described and by comparing them to the degradation pattern of the bone. The categories describe the observed changes the bone goes through as it slowly deteriorates and how extensive this deterioration is. The changes start at category 0, which is almost unaffected and has a complete morphological profile, and goes through to category 5+, where all the surface of the bone has been lost and the profile is lost. Bone, however, does not deteriorate in punctuated categories. Instead, deterioration is a continuous process that depends on many factors (Karr and Outram 2012). In the ground, factors such as microbes, the pH of the soil, as well as burial conditions can impact the way the bone decays and deteriorates (Child 1995; Gordon and Buikstra 1981; Jans et al. 2004). Once excavated, the deterioration does not stop, but is instead impacted by a new set of factors. These factors, many of which were observed in this study, impact the preservation and deterioration of the bone; they include factors that are related to the storage conditions of the facility where the remains are held (Bonney et al. 2020 p.227; Cassman and Odegaard 2006 pp.49-75; Garland et al. 1988;

Janaway et al. 2001; Watkinson and Neal 1998). Preservation scales cannot fully capture this process; instead best fit preservation categories must be used (Johnson and Creech 1983; Sullivan and Artino 2013; Zumbo and Zimmerman 1993).

Accompanying the seven newly-created bone preservation categories was an image of an adult long bone that visually represented that category. Whilst all the categories do have associated photographs, finding bones to represent categories 5 and 5+ was difficult, as the collections curated in the Durham University, Department of Archaeology Fenwick Human Osteology Laboratory are all used for teaching and are mostly well-preserved.

Table 3.1 Observer error testing results (for preservation scale version 1b)

Total (n.)	Difference in agreement (0 = agree)			
	0	+/-1	+/-2	+/-3
37	16	18	3	0

Version 1a: The first set of small-scale testing was conducted by the author, using adult long bones from the Durham University Fenwick Human Osteology Laboratory. The bones were examined against the scale and the state of their preservation was estimated. One week later, the bones were examined again by the author and the preservation state was once again estimated. The data showed some variation between the two sets of data, and it was decided that some of the preservation categories, most notably 2-5, needed better descriptions. Once these improvements had been made (Version 1b), a second small-scale test was undertaken with a colleague from the Durham Archaeology Department (a fellow human bioarchaeology PhD student, with a Masters degree in Palaeopathology and an undergraduate degree in Anthropology. The colleague also has experience volunteering in a museum: five years part-time, working both in a front-of-house role as well as in collections management). The test aimed to look at the long bones (humerus, ulna, radius, femur, tibia, and fibula) of four adult skeletons that were in the Human Osteology Laboratory. The test showed that out of the 37 bones analysed (some did not have all of the long bones preserved), 16 were given the same preservation score. Twenty-one of the bones, however, were assigned a different preservation score, with 18 being assigned within plus or minus one of each other and the remaining three being assigned within plus or minus two (Table 3.1). After discussions with the colleague, it became apparent that there was some ambiguity with how to deal with cracks and flaking on the bone surface, which can be associated with weathering/erosion. It was then deemed necessary to add another evaluation category onto the scale to deal with this possibility (“possible characteristics”).

Version 2: The second iteration of the scale (Figure 3.1) attempted to resolve the issues discussed above. A new preservation aspect was added to the scale which considered "possible characteristics" of the bone which could be present, but did not necessarily have to be present. Categories of 0 and 5+ were not considered for these characteristics; this was because category 0 represented a complete well-preserved bone and therefore cracks and flakes should not be seen. Similarly, category 5+ describes a bone surface that is too badly damaged or is missing altogether, so this type of damage will not be seen. Categories 1 to 5 were enhanced to describe the increasing amount of weathering/erosion damage that can be seen on human remains, starting with small cracks along the surface, all the way to a coarse fibrous surface with a rough texture which is seen in extreme weathering conditions.

Preservation Scale

Category	0	1	2	3	4	5	5+
Approximate Completeness	100%	>75%	Any	Any	Any	<25%	<25%
Characteristics of the bone surface	• Bone appears untouched and fresh • No sign of cracking or flaking • Complete profile	• Light and patchy surface erosion covering less than 25% of bone surface • General profile maintained	• More extensive surface erosion than category 1, with deeper penetration • General profile maintained	• Moderate erosion covering more than 50% of bone surface • General profile maintained	• More extensive erosion than category 3, covering all of bone surface • Some modification to bone profile	• Heavy erosion covering all of bone surface • Modification to bone profile	• Extensive penetration and complete destruction of the bone surface • Extreme modification to bone profile
Possible Characteristics of bone		May have: - *Small cracks along shaft* - *Small chips on surface*	May have: - *Larger chips* - *Small amount of flaking* - *Damage to joints* - *Deeper, longer cracks than category 1*	May have: - *Large chips* - *Some flaking of bone surface* - *Joints damaged, or missing completely*	May have: -*Missing joints* - *External layer of bone removed* - *Patches of rough bone*	May have: - *Coarse fibrous surface* - *Rough texture*	

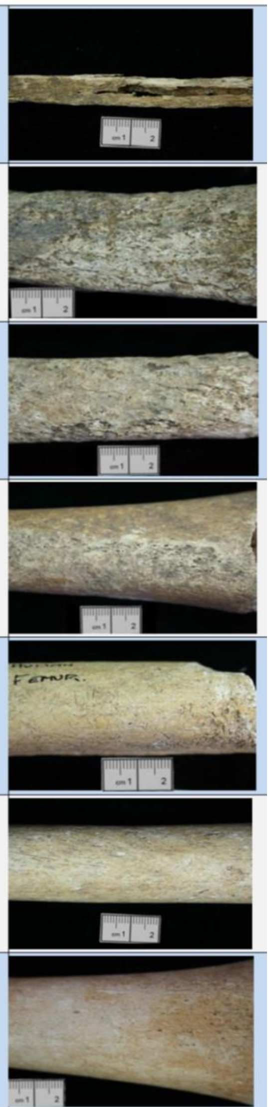


Figure 3.1: Version 2 (final version) of the created preservation scale. This is the version used throughout the remainder of the research.

It was deemed necessary to include new characteristics such as chips to the bone surface and fresh breaks, which, although not considered to be related to weathering, can be attributed to mishandling or improper storage. Boxes that are too small to accommodate the bones will cause friction that leads to abrasions, whilst large boxes with insufficient packing material will lead to increased impact between the bones causing chips or breaks. Furthermore, it was thought appropriate to include damage to joint surfaces as another characteristic. Whilst again this can happen in the ground, damage to the joints can also be seen as post-excavation damage resulting from improper handling and/or unsuitable storage. The scale itself was redesigned to accommodate the extra information for each preservation category. This revised scale was then deemed fit for purpose and was taken forward into full-scale inter-observer testing.

Additional resources were created to aid in the application of the preservation scale. The first was a set of specific guidelines (Appendix 2) designed to help people understand how the scale relates to the bones and in what order recording should take place. The guidance also includes a section which looks at exceptions to the rules; this was to avoid conflicting answers when using the scale. The main exception applied to any bones that were over 75% complete yet had a preservation rating worse than category four (i.e., 5 or 5+). Although these situations may be extremely rare, statistically a number of remains will have these characteristics. The guidelines suggest that in these rare cases the bone completeness should be ignored and instead the preservation of 5 or 5+ take precedence. The reason for this is that bones that have a preservation of 5 or 5+ are the most badly preserved and therefore usually the most fragile, except for pathological bones, and should be treated as such. By applying a 5 or 5+ to a bone we are acknowledging that it is poorly-preserved and research should only be attempted when deemed absolutely necessary.

It is acknowledged that individuals who are not familiar with human remains may have a problem evaluating some of the categories, most notably the completeness and whether the profile of the bone is normal. To attempt to solve this problem, “figure 1” was created to be used with the preservation scale (Appendix 3). This figure contains profile images, cross-sectional diagrams, and approximate lengths of all six of the main adult long bones. The profile of each bone was hand drawn by the author based on other similar profile drawings found in Buikstra and Ubelaker (1994 pp. 80-84). Similarly, the cross-sectional areas were hand drawn from photographs taken by the author. The estimations of the length of the bones were taken from the mean lengths as observed by Trotter and Gleser (1952 p.478; 1958 pp.84-85) and White and Folkens (2005). These averages were taken from deceased American soldiers from both World War 2 (Trotter and Gleser 1952) and the Korean War (Trotter and Gleser 1958). Whilst the World War 2 data only included Black and White Americans, the Korean War data included Black, White, Mexican, Asian, and Puerto Rican Americans. Trotter and

Gleser also used the Terry Collection (a cadaver collection) to measure the length of bones for both Black and White women (Trotter and Gleser 1952 p. 468). To create the estimated range of lengths for each of the long bones used in Appendix 3 (Figure 1), the mean lengths from the White complete military male data (n=545) and the mean lengths from the White female data (n=3) from Trotter and Gleser (1952 p. 478) were used.

Whilst Trotter and Gleser (1952; 1958) represent the most commonly used stature estimation and average bone length data we have, we must understand and recognise the ethical and moral issues with the data (White and Folkens 2005). For example, the Terry collection includes 1728 individuals born between 1822 and 1943 (Hunt and Albanese 2005). This collection originated during a period when permissions were not required for the acquisition of skeletal remains. During the 20th century several American states had passed legislation allowing the scientific use of the remains of unclaimed poor individuals; this was a significant factor in the accumulation of individuals included in the Terry collection (de la Cova 2019; Hunt and Albanese 2005). Several of the other documented collections used in the development of bioarchaeological methods and other research suffer from similar ethical issues (de la Cova 2019). In current times we must recognise how marginalised people were exploited, often without consent, to create these collections and data.

i. Inter- and Intra-Observer Testing of Version 2 (final version)

The parameters for inter- and intra-observer testing of the preservation scale were as follows. Ten adult long bones were selected from the collections housed in the Durham University Fenwick Human Osteology Laboratory that best represented a range of different levels of preservation (images are included in Appendix 4). Examples of category 5+ were not included, as skeletons that are quite badly preserved or have significant research value (rare pathological skeletons) are not suitable for being handled by large numbers of people, some of whom were untrained or unfamiliar with the proper handling of human remains. The number of bones for testing was set at ten; this was due to space requirements in the laboratory, and the fact that the skeletal remains would need to be left out over a period of time. In addition, it was assumed by the author that the shorter the time required for testing, the more individuals would be willing to participate. The aim was that this test would take less than ten minutes to complete and would allow multiple people to take part at the same time. The ten bones that were selected were then laid out in a random order in the Durham University Fenwick Human Osteology Laboratory and left there for three weeks, so that individuals could participate when they were free to do so. For the intra-observer error test, a baseline assessment of the ten long bones was recorded when the test was first set out. The first observation was conducted one week after the bones had been set out (Test 1), the second conducted at the end of the three-week period (Test 2), and the third test was conducted 4 months later (Test 3).

One of the original aims for this preservation scale, set out during the early stages of research, was ease of use that would make it usable by a wide range of individuals in the heritage sector, covering applications in museums and the wider archaeological community. As such, it was deemed appropriate to test the scale using participants that represented a cross-section of disciplines that are commonly associated with this sector. Consequently, individuals from both the Archaeology and History departments were invited to take part. Individuals from all levels of studies, from undergraduate to post-doctoral levels took part, and particular interest was paid to those students within the Archaeology department who had experience working with human remains, i.e., the MSc in Palaeopathology as well as Bioarchaeology PhD students. From these cohorts, three distinct categories were created, which are discussed below. Participants were solicited on a voluntary basis, through a general email to the heads of the relevant departments; in total 51 people participated in the testing.

The inter-observer error data were collected using an observer recording form that was specifically created for this study (Appendix 6). As well as recording "preservation" for the 10 bones, the form also attempted to gauge information regarding the level of knowledge and experience of the participants in different areas. The first question ascertained the individual's experience level in the field of human remains (PhD, Master's, Undergraduate, and None). It was predicted that the level of experience with human remains would have some impact on the results. The next question asked if the individual had any experience or training in archaeology (yes/no). The final question asked if the individual had experience in a museum and in what capacity. This was set out as an open answer question as there are many roles that can be found in a museum. This information was used when interpreting the data to evaluate the usefulness of this preservation scale and to see how well the scale performed when used by individuals who had little or no experience with human remains. The second part of the recording form asked for feedback and comments on the scale. No scale is perfect, and it was hoped that the feedback received could help to further improve the scale. The feedback asked for a number of different pieces of information. The first asked which was the clearest category to identify, followed by which was the least. This was to gauge if any category was consistently found to be difficult to understand and therefore needed to be reworded. The second question asked about the general difficulty the participants found using the scale, to again see if anything needed to be reworded or improved. The third question asked for additional notes from the participants on their thoughts and comments on the scale. The information gathered from these questions will be summarised later in this chapter.

When the participants had completed the exercise, the data from the forms were evaluated. This was done by considering each of the ten bones individually and comparing the highest and lowest preservation scores for the bones in order, to find the range. Once the data had been collated it was then evaluated based on the background of the participant. Firstly, the individuals who were familiar with human remains were compared to those who were not, to see if there was a significant difference between the two. Then the individuals who came from an archaeological background were compared to those who did not.

a. Criteria for Success

The first criterion for success was that the scale should be highly consistent - consistency being the number of people that agree on the same category, to be given as a percentage. For example, if half of the participants chose category 0 for a particular bone then this would be 50% consistency. For the purpose of this test a level above 50% was expected. The second criterion was that the scale should have a high level of agreement both for inter (from the 51 participants) and intra (from the three studies conducted by the author at the beginning, middle, and end of the study) observer error. To establish this, statistical tests were used; these are discussed later in this chapter. Values above 0.6 (60%), which is considered to represent strong agreement, were expected.

The third criterion was that the scale should be easy to use and understand, and therefore be suitable for professionals, untrained individuals and those in-between. To evaluate whether this criterion had been met, the statistical agreement was evaluated; a value above 0.6 was required. The test also evaluated the differences in the answers given by those that were familiar with archaeology and those that were not. If the scale was to be effective as a recording tool, and widely usable, it should not matter if the person using it had archaeological training or not. Similar to archaeological experience, the answers given by those who had museum experience and those who did not, were evaluated. If the majority of the criteria described above were met, then the scale was deemed successful and fit for purpose. It was acknowledged that any scale is subjective to some degree, but it was hoped that even with this subjectivity some consistency could be observed (Annett 2002).

b. Statistical Testing

To analyse the data collected from the inter- and intra-observer error testing described above, two primary statistical tests were implemented.

To analyse intra-observer error, Cohen's Kappa (κ) Coefficient was implemented. The first mention of a kappa value was by Galton (1892), but this was later formalised by Jacob Cohen (Cohen 1960; Smeaton 1985). Cohen's κ measures the agreement in the answers of two raters (observers), or the same rater (observer) twice, but is a more useful statistical approach than a simple percentage of agreement, as Cohen's κ also considers the possibility of the agreement occurring by chance or randomly (Caro et al. 1979). Cohen's κ can be calculated using the following formula:

$$\kappa = \frac{Po - Pe}{1 - Pe} = 1 - \frac{1 - Po}{1 - Pe}$$

Where Po = (a+d) / (a+b+c+d) and Pe = (marginal a+ marginal b)

Figure 3.2: The equation that expresses the formula for calculating Cohen's Kappa (Cohen 1960 p. 40)

For the purposes of this test, a κ value that tends towards 1 (100% agreement) was considered excellent and a κ value that approaches 0 (0% agreement) was considered unsatisfactory (Viera and Garrett 2005). As this statistical test was to be used for intra-observer error, a higher κ value was expected. Some limitations have been expressed by some researchers in relation to the underestimation of certain factors, i.e. "rare categories", and as such, Cohen's Kappa should be considered a very conservative measure of agreement (Agresti 1988).

To analyse inter-observer error, Cohen's kappa coefficient is not sufficient in cases where the number of observers/raters exceeds two (Landis and Koch 1977). A different test that can accommodate these differences therefore needed to be applied. Krippendorff's alpha (Kα) was selected, due to its versatility and ability to deal with: any number of observers, any number of values, several different levels of measurements, and missing or incomplete data (De Swert 2012; Hayes and Krippendorff 2007; Krippendorff 2011). While not all of these abilities were required for this study, it was still useful to have them available.

If the alpha value is above 0.800 then there is a strong correlation in inter-rater agreement. If the alpha value falls between 0.800 and 0.667 then there is a moderate correlation in agreement, and below 0.667 there is little to no agreement (Krippendorff 2004). For the purposes of this test a value above 0.800 showing a strong correlation was desired.

Table 3.2 – Kα bootstrapping example

alphamin	q
0.9000	1.000
0.8000	0.402
0.7000	0.000
0.6700	0.000
0.6000	0.000
0.5000	0.000

c. Bootstrapping

The second benefit to using the Kα statistical test is its ability to generalise a larger data set by treating the sample as a population through the process of bootstrapping (Field 2013). Bootstrapping is the statistical method that uses random sampling and replacements to create estimates of the sampling distribution (Efron & Tibshirani 1993; Wright et al. 2011). The process can be run any number of times. The standard number for a representative sample is greater than 2,000; however, any unit of 1,000 runs can be used. The higher the number of runs used, the longer the bootstrapping process takes to complete (1,000 – 1 minute, 10,000 – 10 minutes, 100,000 – 100 minutes). Furthermore, there is a diminishing return in the detail of the data; thus, the difference in the detail returned between 10,000 and 100,000 runs would be minimal. Therefore, a process of

10,000 runs was chosen as a compromise between the time required and the detail of the information received. While the test does not give an actual alpha value, it does give the percentage (probability) that the dataset will not achieve an alpha value of at least the alphamin, which is set at various confidence intervals. Table 3.2 shows an example of the data received from the bootstrapping test. It shows that there is a 100% chance that the alpha value for the whole population will be below .9000, but there is only a 40% chance that the alpha value will be below .8000, and finally a 0% chance that the alpha value will be below .7000. Therefore, there is a 100% chance alpha is between .7000 and .9000. While this is a useful process, and was used in this study, it is a generalisation of the data and gives us a picture of what the data could show, rather than an actual definitive answer.

As well as the two statistical tests discussed above, the data collected from the observers were also presented in a number of bar charts to allow a visual comparison of the data. It was predicted that, due to the large number of comparisons to be made between the different experiences of the observers, a great number of graphs would be needed. Only the first four graphs are presented here, and the rest are presented in the Appendices 7-10.

ii. Results

Fifty-one participants (Table 3.3, Table 3.4, and Table 3.5) analysed ten selected adult long bones in the Durham University Fenwick Human Osteology Laboratory over a number of weeks, as outlined above (Section 3.1.1 i), and their data (Appendix 5) were collected on the observer recording forms reproduced in Appendix 6.

Table 3.3 Breakdown of participants by human remains experience

Human Remains Experience	*N*
PhD	7
Master's	13
Undergraduate	12
None	19
Total	51

Table 3.4 – Breakdown of participants by archaeological experience

Archaeological Experience	Yes	No	*N*
PhD	7	0	7
Master's	11	2	13
Undergraduate	9	3	12
None	0	19	19
Total	27	24	51

Table 3.5 – Breakdown of participants by museum experience

Museum Experience	Yes	No	*N*
PhD	6	1	7
Master's	4	9	13
Undergraduate	3	9	12
None	1	18	19
Total	14	37	51

Table 3.3 shows the breakdown of their experience with human remains. Graphs were created for each bone, as well as by the different experience levels of the participants; these graphs can be found on the following pages.

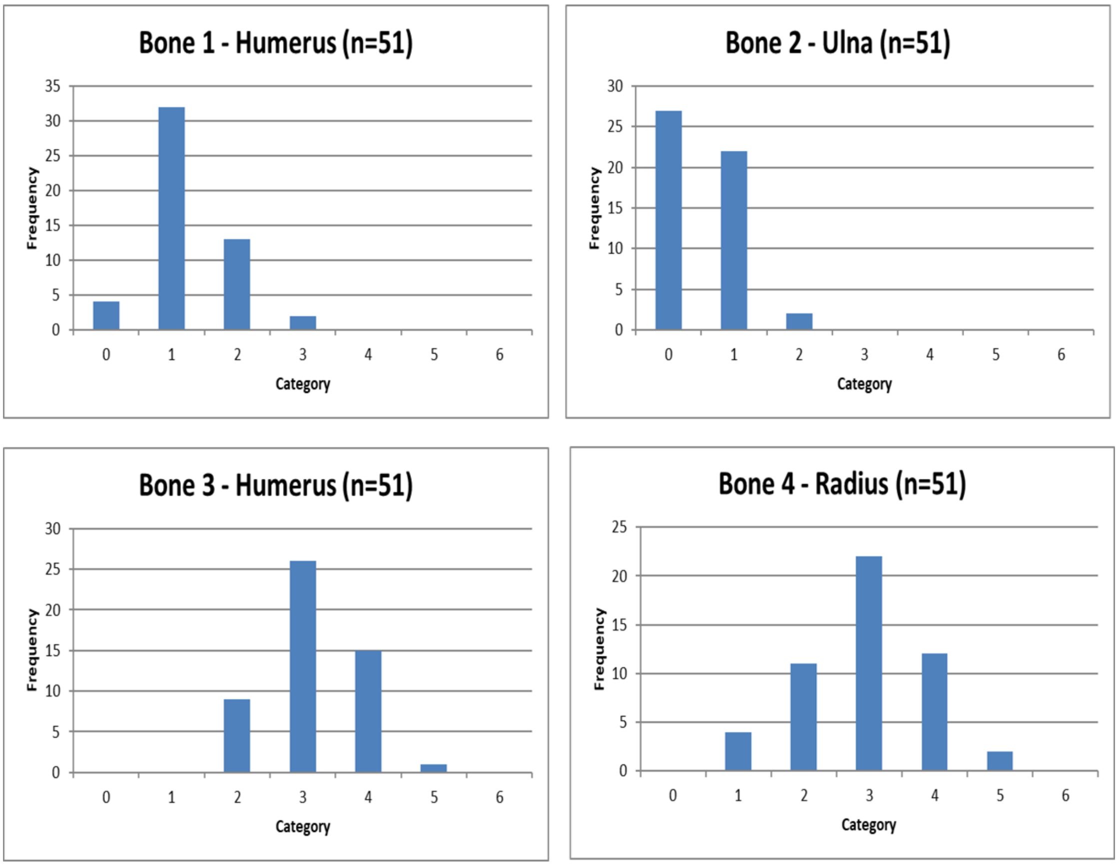


Figure 3.3: (Set 1) Frequency of categories assigned for bones 1 to 4

The first sets of graphs (Figure 3.3) compare all of the people who participated in this study, regardless of their experience. Above are the graphs for bones 1-4; those for bones 5-10 can be found in Appendix 7. The second set of graphs (Figure 3.4) show the results of the inter-observer error broken down by the participants' level of human remains experience from PhD to no experience at all. Below are the graphs for bones 1-4. The remaining six graphs (bones 5-10) can be found in Appendix 8. The third set of graphs (Figure 3.5) show the answers given by the volunteers split by those who had archaeological experience and those who did not. Once again, the graphs for the first four bones (1-4) can be found below; the rest can be found in Appendix 9. The final set of graphs (Figure 3.6) show the responses divided between those who had experience working in a museum and those who did not. As the museums group was somewhat underrepresented, the percentages were used to allow clear comparisons. As in the previous sets of graphs, only the first four bones (1-4) are presented, the remaining six (5-10) can be found in Appendix 10.

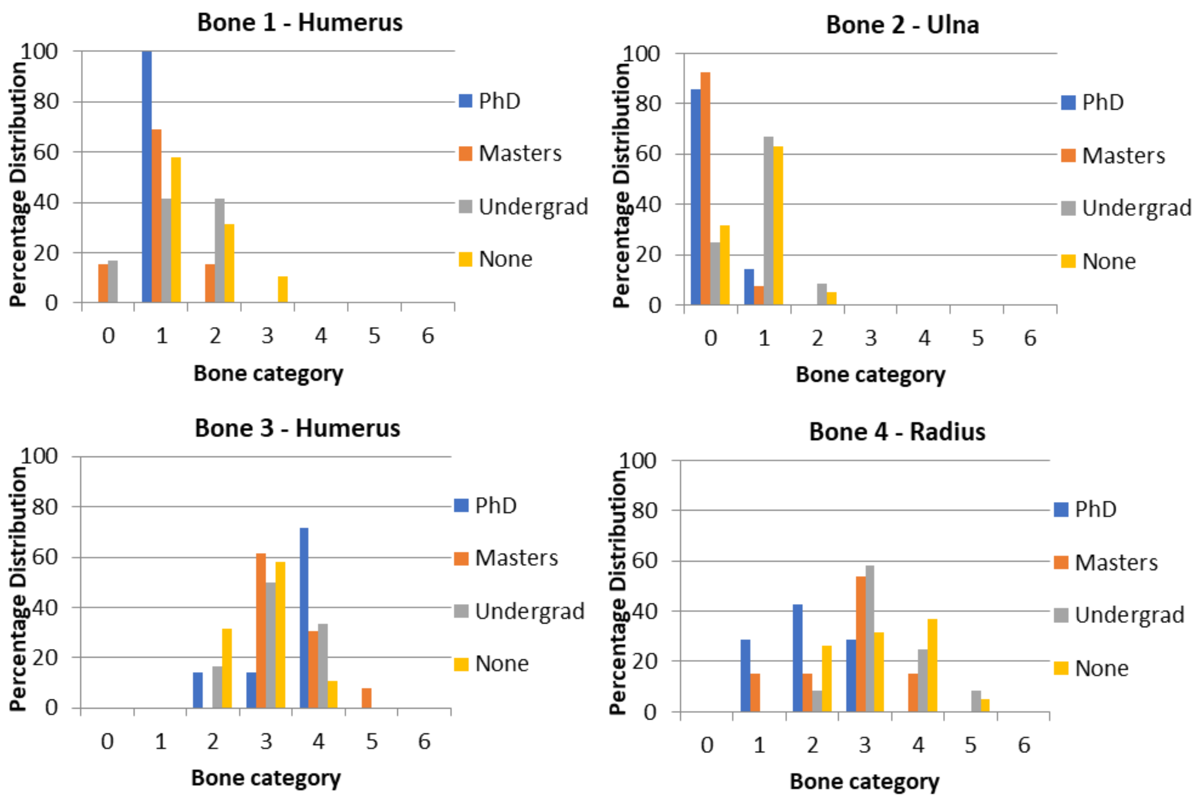


Figure 3.4: (Set 2) Percentage distribution of the categories assigned for bones 1-4, divided by the individuals' experience with human remains.

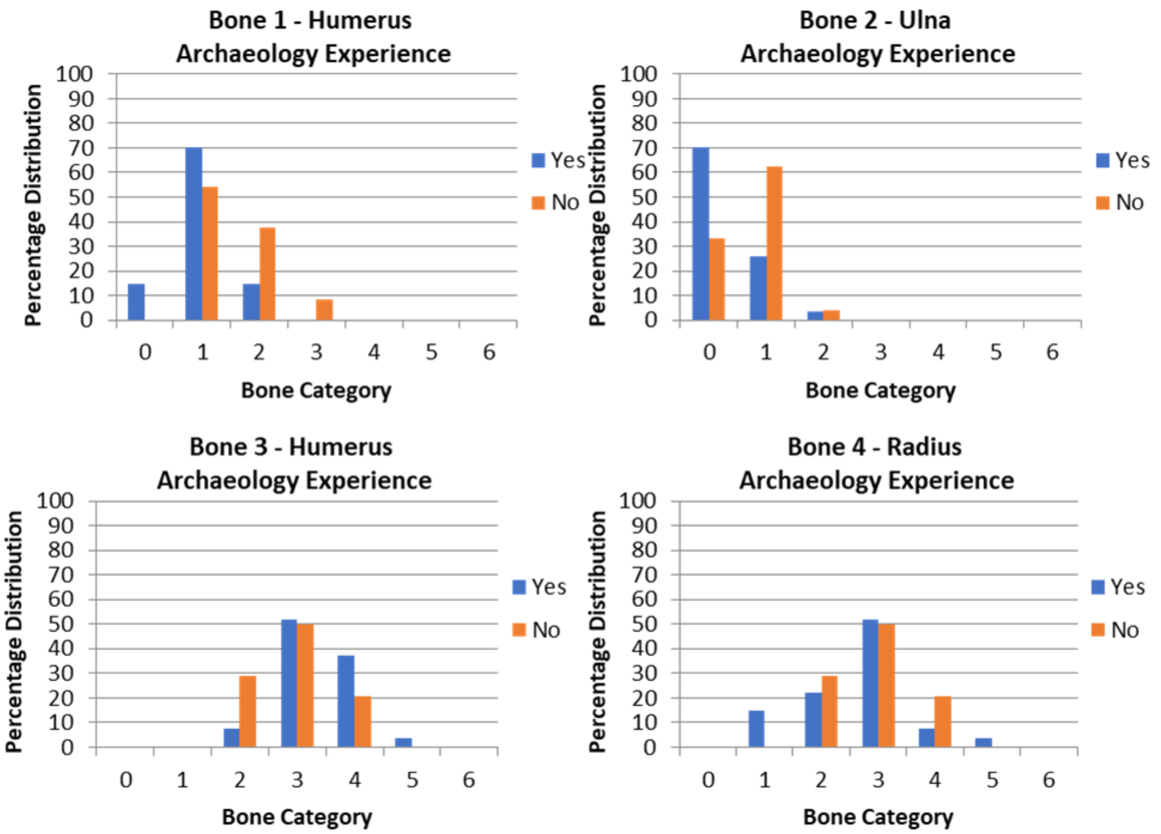


Figure 3.5: (set 3) Percentage distribution of the categories assigned to bones 1-4, divided by the individuals' experience in archaeology

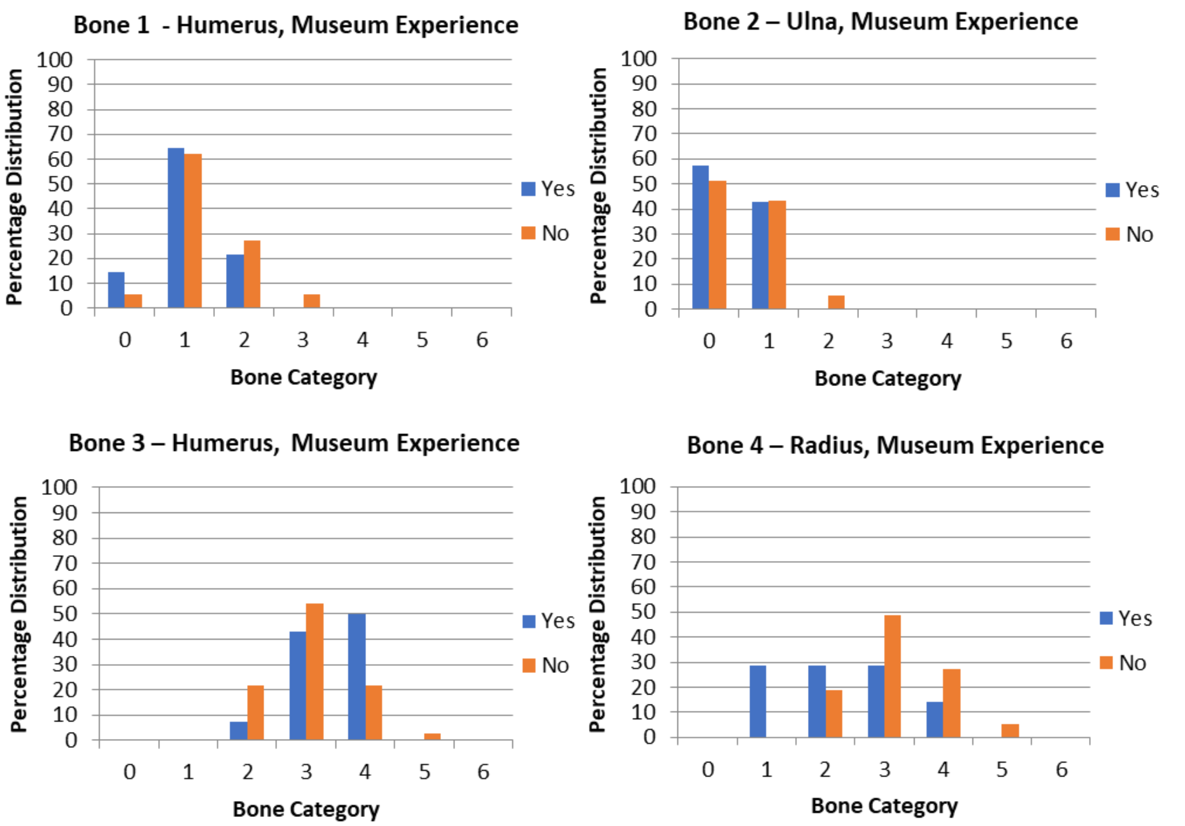


Figure 3.6: (Set 4) Percentage distribution of the categories assigned to bones 1-4, divided by the individuals' experience of working in a museum

iii. Statistical Analysis

Two statistical tests were chosen to evaluate the level of inter- and intra-observer agreement.

For the intra-observer error test, Cohen's kappa was run three times to cover each set of results. Each of the three observations were tested against the recorded baseline, as the test can only compare two sets of data at a time. Cohen's Kappa was run using the crosstab feature of SPSS (Statistical Package for the Social Sciences). After conducting the statistical test, the following Kappa values were obtained.

Table 3.6 – Cohen's Kappa results

Test 1	Test 2	Test 3	Average
κ = 1.00 (100%)	κ = 1.00 (100%)	κ = 0.90 (90%)	0.96 (96%)

Table 3.6 shows an average κ value of 0.96 was produced meaning a 96% agreement between each of the observer reports, showing that intra-observer error for this preservation scale is low. Any value above 60% (0.6) shows strong levels of agreement, and above 0.8 is seen as almost perfect agreement (Rafieyan 2016).

For the inter-observer error test, Krippendorff's alpha was implemented. The test was run using a macro (a computer shortcut that can perform multiple instructions in one step) created by Andrew Hayes from Ohio State University, written for SPSS (Hayes and Krippendorff 2007). Once the macro was loaded and the data had been input, a simple program was written allowing the test to be run. The program used was as follows "*KALPHA Judges = V1-V51/level = 2/detail = 0/boot = 10,000*". This simple program runs the macro to calculate Kα where "V1-V51" are the individual results for the participants, and "level" is the tested variable. In this test the data were ordinal, so level had to be set to 2. "Detail" sets the level of information given in the output. As only a Kα value was wanted, "detail" was set to 0. Finally, "boot" is the number of bootstrapping processes that were run (as discussed earlier in Section 3.1.1 (i. c.) this was set to 10,000 times) (De Swert 2012; Krippendorff 2011).

When Krippendorff's alpha was run to measure inter-observer agreement among all of the participants, it was found that the Kα value was 0.8114, with an 11% (0.1064) chance that when looking at a larger population (through the process of bootstrapping) the actual Kα value would fall below 0.8000. This shows that there is a strong correlation among the results recorded by the 51 participants, because anything above 0.8000 has a strong correlation (De Swert 2012; Krippendorff 2004). As the process for running the Krippendorff's alpha statistical test had already been set up, other inter-observer agreement tests were conducted. These were done by simply changing the V1-

V51 values found in the KALPHA program. Three comparisons were run to look at how level of experience affected the amount of agreement among the observers. Then three more Krippendorff's alpha tests were run to evaluate change within a high human remains knowledge group, a medium knowledge group and finally a low knowledge group. For this research, PhD and Master's volunteers were put into one group due to the low number of PhD participants; this group represented a high level of knowledge. Undergraduates represented the middle group, with some knowledge. The third group was made up of the volunteers who had no experience in working with human remains.

When Kα was run for the PhD and Master's level individuals, the statistical test returned an alpha value of 0.8578 with a 0% (0.0000) chance that the alpha value would fall below 0.8000 when the whole population was estimated (through the process of bootstrapping). This represents an extremely strong level of agreement for the answers among the participants.

The next Kα test considered the inter-observer agreement of the middle knowledge group, made up of undergraduate volunteers. Krippendorff's test returned a Kα value of 0.7977, with a 55% (0.5567) chance the value would be below 0.8000 if the whole population was evaluated. This represents a moderate to strong correlation in the agreement for the answers given by the undergraduate participants.

The final test considered the individuals that had no experience with human remains. Using Krippendorff's test the Kα value returned was 0.8462, with a 0% (0.0000) chance that the Kα value would fall below 0.8000 if the whole population was represented. This signifies a very strong correlation in the agreement among these observers.

iv. Discussion

In this section the results produced from the inter- and intra-observer error testing presented in the previous section are discussed alongside an evaluation of the performance and usefulness of the preservation scale, in order to see whether it met the "success" discussed in the Background chapter (Section 2.3.1).

When studying the graphs presented in the previous section it can be quite difficult to evaluate how accurate the observations actually were. However, when the graphs based on the specific experience groupings are considered, some patterns become clear.

Based on experience of working with human remains, the different groups produced clear patterns in their data. The PhD group gave relatively consistent answers with all of the answers for the 10 bones being above 70% agreement (>70% assigned the same category). The preservation categories with the least variation were the better-preserved bones; i.e., 0, 1 and 2. These were closely followed by the extremely poorly-preserved categories (5 and 5+). The highest variation in the preservation categories was found in the middle categories of 3 and 4; this pattern is echoed throughout the other groups.

Less agreement is found in the Master's group, with only six of the bones having more than a 60% agreement (60% assigned to the same category). Similar to the PhD group, the most consistently reported categories were 0, 1 and 2. However, unlike the PhD group the next most consistent categories were 3 and 4, and then the poorly-preserved categories of 5 and 5+. It is thought, by the author, that this is due to the personal experience of the group, being fairly new to the field of bioarchaeology and therefore not having as wide a knowledge base as the PhD group, leading to less appreciation of the characteristics of damage to the bones. The Master's group also had the highest number of erroneous or incorrect data observations; erroneous or incorrect data being described as data that were either significantly different from the average, or categories that simply could not have been assigned due to the constraints set out by the completeness of the bone. For example, a well-preserved bone that was less than 75% complete could not be assigned higher than a 2.

The undergraduate group had a similar level of consistency in the answers they gave as the Master's group, with most of the bones being placed in a preservation category within plus or minus two categories of each other. This was with the exception of bone 8, which seems to have caused some confusion within this group in particular, with a maximum agreement of only 30% for this bone. It is thought that this was because of the particular bone, rather than problems using the scale. Unlike the PhD and Master's groups, all the categories had approximately the same amount of variation, with no one category having significantly less variation than another. One pattern that was clear was overestimation of the damage to bone by this group, and the consistent assignment of a higher category of preservation (worse) than the Master's and PhD groups. It is hypothesised that this could be because of lack of experience that may be associated with the undergraduate group, who would have less depth of knowledge of human remains than the Master's and PhD groups.

The group with no experience with human remains were less consistent than those in two of the previous three groups. This was expected, as in addition to having no experience with human remains, they had vastly different educational backgrounds, which would likely have influenced how they assigned the categories. Surprisingly, the "no experience" group were more consistent with their answers than the undergraduate group (who had some experience), with the majority of the agreement for the assessments of the bones being above 50%. Similar to the undergraduate group, the results for the no experience group showed significantly less variation in the answers given for each bone. Again, we see a general overestimation of the bone damage categories, when compared to the Master's and PhD groups. Similarity with the undergraduate group was attributed to lack of experience found in this group and the limited knowledge of human remains that the group had.

When looking at all the data from the groups with different levels of human remains experience, it is clear that the more experience an individual had with human remains, the more consistently similar were the preservation categories assigned. This difference in experience is best seen with bone 2 (Figure 3.4), where the "experienced" groups (PhD and Master's) rated the bone 0, while the "non-experienced" group (undergraduate and none) rated the bone 1. As a group, the PhD students were reluctant to assign the most poorly-preserved category to any of the ten bones, possibly because of their wide range of knowledge and experience; they were also the most consistent in their answers, and had the highest percentage of inter-observer agreement. The undergraduate and no experience groups consistently overestimated the damage to the bones, but also assigned the same categories as the other members of the groups. Despite the difference in the patterns of answers given by the separate groups, normal distribution curves were found for all ten of the bones used in this test; this becomes particularly pronounced when the outlying or erroneous data are discounted. This suggests that the majority of the answers given were relatively similar and were within a small range.

a. Archaeological Experience:

The next category that was used to group the participants was whether they had any experience within archaeology. The expectation was that those who have had general experience in archaeology may have a better understanding of the potential of deterioration and damage to bone as well as other archaeological material, and therefore be more consistent when assigning preservation categories. Archaeologists are trained to recognise minute differences in the materials they study and are familiar with the range of damage expected, giving them a better understanding of the difference between well-preserved and poorly-preserved archaeological material. This experience is expected to translate to observations of human remains, whether or not the archaeologist has specific experience in this sub-specialty. Archaeological experience was described as any experience working in, teaching, or studying archaeology. The number of archaeologists and those with no experience was relatively even, with 27 of the participants having archaeology experience compared to 24 who did not; see Table 3.4 for the educational breakdown of these participants.

In the archaeologist group, for seven out of the ten bones, the participants showed more agreement in their answers than the group that had no experience. It is hypothesised that this is because of their common educational background in archaeology. The bone preservation categories where there was most agreement in the archaeology group were 0 and 1 (with a maximum agreement of 85% in category 0 and 70% in category 1), which was the same for all the other groups. Unusually, however, this was followed by category 3 with an agreement of 50+%, while finally the higher preservation categories (poorer preservation) had the least agreement. This differs from the trends seen earlier in the "human remains experience" groups, where categories 3 and 4 had the least agreement and the higher categories (5 and 5+) had the second most agreement. Furthermore, most of the recorded outliers were found in the archaeologist group. This correlates to the fact that the Master's students, who had the most outliers in the previous comparison, were also in this group.

The group that did not have any archaeological experience gave fairly consistent answers, with most being within plus or minus one preservation category for each bone. It is clear that, barring bone 3, the "no archaeology" experience group rated the bones generally higher on the scale than the archaeologist group, meaning they observed worse preservation. This was somewhat expected, as this group had not worked in or studied archaeology and are unlikely to have a trained understanding of how objects, and bones, deteriorate.

Comparing the data from the two groups shows negligible differences. Although the no experience group overestimated the damage to certain bones, this was expected. The hypothesis that was presented at the start of this section, that archaeologists would have a better understanding of deterioration of archaeological material and therefore have more consistent answers, was supported, helping to show the usefulness of this comparison. The graphs from the results section, in conjunction with the comparisons discussed above, also suggest that there were no significant differences between the answers given by those who had experience in archaeology and those that did not. This implies that the individuals' level of experience in archaeology had a minimum effect on how the scale was interpreted and used.

b. Museum Experience:

As the purpose of this research was to develop a preservation scale that could be used by anyone who works with human remains, it was considered that museum staff would make up a key demographic of the group. This is because museums are one of the key locations where human remains are stored. For the purposes of this research, museum staff were characterised as anyone who had worked in a museum who held a curatorial, conservation, or collection care position. This information was obtained via the questionnaire completed by each of the participants. Out of the 51 participants, 14 had museum experience, which ranged from a curatorial role to volunteering; see Table 3.5 for educational breakdown of the participants. This represented a good cross-section of the museum community.

As observed in the other comparisons, the "museum experience" group had the most agreement in the preservation categories of 0 and 1. The least agreement was found in bones 4 and 8 which covered the preservation categories of 2, 3, and 4, which is comparable with the other groups in this study. This group also appeared to be reluctant to assign the preservation category 5+ to the bones; this is possibly because of their background knowledge and their understanding of deterioration in artefacts in general. In eight out of the ten bones a minimum level of 50% agreement was achieved and in three a value of 60% agreement was achieved, meaning this group gave relatively consistent responses.

Participants who did not have museum experience managed to achieve an agreement of >50% in six out of the ten bones recorded, which is very similar to the experienced group, with three of these bones having >60% agreement. Like the other groups, the preservation categories of 0 and 1 had the highest level of agreement, and assigning preservation categories 2, 3, and 4 had the least amount of agreement. This pattern is mirrored throughout the groups.

Despite some differences being observed between the experienced museum group and the "no museum experience" group, in most cases this was minimal, best reflected in the graphs for bones 1 and 2 (Figure 3.6), where the maximum difference between the two groups was around 5%, which is very low. Furthermore, out of the ten bones, all but two of the bones (4 and 8) had low variation in the answers recorded, suggesting high levels of agreement. The data presented above imply that there are no significant differences in the answers about preservation categories between those with museum experience and those without. This suggests that this preservation scale could be implemented in practice by museums across the country with minimal levels of disagreement.

As discussed above (Section 3.1.1 iv), depending on which groups are compared, different patterns emerge from the data. They show the strengths and weaknesses of the scale, with the strengths primarily being its ease of use and its high level of agreement. As ease of use relates to the observer experience, this will be discussed in the free text feedback section below. Agreement within observers (intra-observer) was demonstrated by Cohen's Kappa showing an average of 96%, and between observers (inter-observer) by Krippendorf's alpha showing a value of Kα = 0.8114. The weakness of the scale was the general subjectivity, relying on the user's personal experience. It is clear from the data that an individual's experience with human remains is most relevant when implementing the preservation scale, which is to be expected. In general, the differences found between the "archaeological experience" group and the "no archaeological experience" group were minimal, with the largest difference being the overestimation of damage to the bones by the latter group. This pattern is mirrored in the "museum experience" group, with the inexperienced group again over-estimating the amount of damage of the bones. Whilst the PhD group were the most consistent in agreeing on preservation categories for the bones, the "no experience group" were not the least consistent. This was instead the undergraduate group, but even for this group it was a very slight difference. It should be remembered that the phrases "least agreement" and "most difference" used, are all relative. Although the "lowest levels of agreement" were the lowest out of the groups evaluated, they were still comparatively high, with all preservation categories having greater than 50% agreement. This strongly suggests the preservation scale is well suited to being used by both experienced individuals and inexperienced individuals, which was one of the original aims of developing the scale. The next section considers the feedback of the participants.

c. Free Text Feedback:

A free text feedback section was added to the end of the inter-observer test to gather the personal thoughts of the participants.

The first question asked which category was the easiest to assign and which was the most difficult. Some individuals named more than one category for their answer, and both their responses were included. Table 3.7 shows the percentage of people who found the categories easy or hard to assign. The easiest preservation category to assign by a large margin was category 0 - the no damage or perfectly preserved category. This was followed by the preservation categories 1 and 5+. These data are reflected in the data presented earlier, with categories 0 and 1 being those with the most agreement by the participants. The most difficult category to assign was category 3 closely followed by category 4. Once again, these responses are reflected in the data presented earlier, with the preservation categories of 3 and 4 having the lowest percentage of agreement.

Table 3.7: Easiest and hardest categories to assign.

Cat	Easiest %	Hardest %
0	58.8	4.5
1	17.6	4.5
2	5.9	10.6
3	0.0	37.9
4	3.9	25.8
5	2.0	13.6
5+	11.8	3.0

Comments from the participants were encouraged regarding any specific difficulties as well as thoughts or improvements for the scale. To contextualise their response, the difficulties are discussed below alongside levels of experience. The most common difficulty, in particular in the no experience group, was their personal lack of knowledge and experience with human remains. This was expected to be a problem with this scale, as it is extremely difficult to adapt a scale such as this and account for all levels of knowledge.

The next most common difficulty experienced by the participants was the problem that occurs when the preservation of a bone falls between two preservation categories, usually - in the case of this exercise - the middle categories (2, 3, and 4). This is a common problem with any subjective scale as personal experience is always going to be a factor (Annett 2002). Although guidance was provided on what should be done in these instances, it appears that this still led to some difficulty when using the scale. The guidance stated that if the bone fell between two preservation categories the worst preservation category should be selected. This, however, is an issue with bone preservation and its analysis, as bone does not decay at specific and obvious intervals that can easily be categorised. Instead, it decays in a much more gradual and continuous process. Due to this, when the preservation state of bones is evaluated, they will often fall between the two preservation categories, leaving the observer to make the final decision.

Other difficulties were found when assigning how complete the bone was, particularly by those with no or very little experience of working with human remains, who would not necessarily have a good understanding of the normal size, shape, and profile of adult bones. To enable untrained individuals to use the scale, line drawings of bone profiles (named Figure 1) were attached alongside the guidance and the preservation scale (a copy can be found in Appendix 3). It is the suggestion of this author that if a person is undertaking a study of preservation of human bone using this scale, and is unfamiliar with working with human remains, that an investment is made in a relevant text, such as White and Folkens (2005) "*The Human Bone Manual*". This book gives full images of all the (well-preserved) bones of the body, from multiple angles. A 3D model skeleton could also be used and would be invaluable for inexperienced individuals; however, skeletal models can cost in excess of £250 (Anatomy Stuff 2021).

The final set of challenges that were presented by the participants were difficulties in understanding the terms and descriptions used, specifically: what characterised the differences between large and small chips; the difference between light, moderate, and heavy damage; and finally what characterised "destroyed". All these comments were supplied by individuals from the "no" or "undergraduate" experience groups, suggesting these problems are related to prior experience and knowledge. To resolve this issue a glossary of terms was developed to help untrained individuals understand the terminology used in both the preservation scale and the linked guidance. To create the glossary, the definitions for the words were taken from books and sources generally used by human bioarchaeologists. This would ensure those who were already familiar with the terms and had a previous understanding of their meanings would not be confused by the creation of new definitions.

Other individual difficulties were presented, but these were specifically about the individual bones used in the inter-observer test rather than the difficulties using or understanding the scale itself. These are not discussed here as they are not relevant to the function or assessment of the scale.

The second part of the feedback asked the participants for general free text feedback and if they had any suggestions for improvements to the documentation or scale. Some left this section blank whilst others suggested the scale was fit for purpose. The two most common or useful pieces of feedback are described below.

1. To add a caption to Table 1 in the guidance to better explain what it shows and what its purpose is.
2. To better explain the difference between the terms used; for example, describe the difference between "modification" and "erosion". This was consequently added to the list of terms in the guidance glossary.

v. Scale Success Conditions

In the light of the feedback summarised and discussed above, it is important to determine whether the preservation scale met the criteria set out at the beginning of this chapter. The criteria were: high level of consistency, high level of statistical agreement, and ease of use.

a. Consistency in Recording

Consistency was described as the number of people that agree on the same category. Two levels of consistency were evaluated in this study: the overall consistency, and the consistency within the groups. When the groups taking part were evaluated individually, the PhD group assigned preservation categories at a consistency above 70% for all of the ten bones. The Master's group had a general consistency above 60% with a number of erroneous data points. The undergraduate group had a similar consistency to that of the Master's group, except for bone 8, which, as mentioned in the results section (Section 3.1.1 ii), caused some challenges. Finally, the "no experience" group had an agreement of above 50%. The high level of consistency in the PhD group and Master's group shows how experience does have an effect on how the scale was implemented. Clearly, the greater the experience with human remains, the more consistent the answers given.

When the overall consistency of all groups is evaluated, a value of approximately 52% is found. The results show that, although the minimum value of 50% was reached, the low consistency in the "no experience" group did impact the overall consistency; however, this was expected even with all the resources provided. A similar pattern has been shown in other bioarchaeological studies; for instance Davis and colleagues (2013) found that observers with a higher level of experience showed greater consistency than those with less experience (two years of bioarchaeological training) – although the difference was small in that case. A larger study (38 participants) conducted at a paleopathology conference, with observers divided into "beginner" and "expert" categories of experience, also found that increased experience led to greater consistency among observers when rating indicators of osteoarthritis (Waldron and Rogers 1991). Miller and colleagues (1996) similarly showed that experience was a key factor in recognising and diagnosing skeletal pathologies in dry bone, with more common pathologies identified more consistently than unusual pathologies or presentations. Yet, few studies include individuals without any experience at all. If this study did not include the "no experience" group, the overall average consistency would be above 60%, with the consistency for some of the individual bones being as high as 85%. It should also be noted that many inter-observer studies did not use as many participants as this study did. Many of the papers found in the *International Journal of Osteoarchaeology* used 2-3, often with one of the observers having proposed the method under evaluation (Davis et al. 2013).

These data show that regardless of the quality or design of the scale, it is not a sufficient substitute for a background or experience in human bioarchaeology. If this scale is to be used in a museum it is suggested that the museum endeavours to find someone with experience in human bioarchaeology, as it is clear it makes a difference in the consistency of evaluations. Despite this lower overall consistency, as a value of >50% consistency was required for the first condition to be met, it can be said this condition has been met.

b. High Level of Statistical Agreement

When statistical agreement of use of the scale was analysed, using Krippendorff's Alpha, it was found that the overall level was 0.8114 Alpha. The PhD and Master's group had an agreement of 0.8578. The undergraduate group had an agreement of 0.7977 and the "no experience" group had an agreement of 0.8462. As an overall value of 0.6 was required for the inter-observer agreement and a value of 0.8114 was received, the condition was met. The intra-observer error testing needed to return a value greater than 0.8 Kappa to be considered valid; this was achieved. This condition was therefore also met.

c. Ease of Use

Evaluating the ease of use of the scale was a more challenging condition to assess because ease of use is quite a subjective concept. A number of factors were chosen to represent ease of use, including: statistical agreement, consistency, and general feedback. As discussed above, the first two criteria (statistical agreement and consistency) have been met. Participants were asked for comments on the difficulties they found when using this scale. Whilst some difficulties were presented about its nuances, namely terms used, overall the feedback was positive. Some issues were found by the participants who lacked experience with human remains, but these difficulties related to not being familiar with human remains rather than specific problems with the scale. Furthermore, in the general feedback some participants suggested the scale was useful and fit for purpose. If this scale is to be tested further the time taken to evaluate each bone should also be considered, as it is clear that this will be a factor in how widely the scale will be used. Time taken can indicate how easy the scale is to use. This aspect was not included here as this was the first large-scale testing of the preservation scale, but if it is to be used more widely, further testing is needed. For the purposes of this research, it was decided the scale had met this condition.

The final criterion to show whether the scale is fit for purpose, was that the differences between those with museum and archaeological experience and those without this experience should be minimal, proving that the scale could, in theory, be used by anyone. To evaluate these differences, or lack thereof, the data presented earlier are reconsidered.

The data showed that the answers given by the “archaeological experience” group and the “no archaeological experience” groups were relatively similar, with many of the preservation categories assigned to the bones being the same. Although a general overestimation of the damage in the “no experience” groups was noted, this was expected. Both groups exceeded 50% consistency for recording many of the bones; furthermore, for five of the bones, both groups had the same high level of consistency for the same categories, implying more than half of the participants from both groups agreed in their assessment. Thus, the differences between those with archaeological experience and those without were minimal.

The “museums experience” group and the “no museum experience” group had more than 50% consistency in their assignments of the preservation categories in six out of the 10 bones; four of these bones produced a high level of agreement. Unlike the other groups, overestimation of bone damage for either group was not seen. All of this information suggests that the difference between the two groups was once again minimal. As shown above, the final criterion that the difference between the “experienced” and “no experience” individuals from both the “museum” and “archaeology” groups should be minimal, is supported.

vi. Summary

When the test was developed, several criteria were set to evaluate the usefulness of the scale and how successfully it performed. As all of the aforementioned criteria were met, and the inter- and intra-observer error testing were completed successfully, it was concluded that the preservation scale had passed the testing and was fit for purpose, and it was used in the next part of the research. Fifty-one participants are a relatively small sample size by statistical standards, but this is an improvement, as the previous scale (McKinley 2004) was produced without any inter-observer testing due to time constraints (McKinley pers. comm). This study was also subject to time constraints, and future testing could involve larger sample sizes.

3.1.2 Museum Data Collection

In the previous sections, the creation, testing, and analysis of a preservation scale are described. The analysis showed the scale met the criteria for acceptance and was therefore declared fit for purpose. Knowing this, the methods of this research are discussed below. The creation of a baseline condition assessment of human remains was deemed vital for the aim of this research, but many museums had not conducted these assessments. This was discovered when contacting museums to take part in this research. Below, a method for creating a retrospective baseline condition assessment is presented, along with an evaluation of its potential benefits and limitations.

The primary aim of this project is to assess the deterioration of bone in museums and compare this to the amount of research access, to establish if the benefits of the research outweigh the deterioration of the remains. The study should show whether it is the research that causes the maximum deterioration, the storage conditions, or something entirely different.

Data collection for this research entailed visiting regional museums, analysing and recording the skeletal collections they curate using the new preservation scale, creating a retrospective baseline preservation assessment from available documentation, and then collating access which has been provided to the collections. Data analysis is discussed below, including what factors were compared and what they showed.

i. Data Collection Part 1 (Museum Data)

The primary aim of this part of the data collection was to observe and record the preservation of human skeletal remains in a range of museums (Section 3.2).

The first part of this data collection involved the primary collection of the skeletal preservation data from adult skeletons in the museum collections, using the preservation scale developed. This involved assessing the long bones (humeri, radii, ulnae, femora, tibiae, and fibulae) from each individual in the selected curated sites; note that not all long bones were present for all skeletons. For a number of reasons only the long bones were used in this research. Firstly, long bones are generally more robust and therefore tend to survive better during burial excavation and analysis, and ultimately have a better chance of being present, which was important for this research. Another key factor was the time constraints set by many of the museums and the need to evaluate several collections during each visit. As discussed in Chapter 2 of this research, museums are underfunded and understaffed; therefore, concessions must be made, particularly in relation to access and time given to visiting researchers. Evaluating every bone of every skeleton in a collection would have taken too much time and not been practical for a PhD project. Care had to be taken to ascertain the form of previous research, to ensure that it could have impacted the preservation of the long bones, and to discount any research that could potentially have taken place without disturbing the long bones. Furthermore, only adult skeletons were evaluated in this research, as non-adult skeletons are more fragile than adult skeletons; therefore, the preservation categories created earlier would not necessarily be applicable (Bello et al. 2006; Lewis 2017b pp.4-8; Mays 2010b p.28).

Depending on the space restrictions of the specific museum, the long bones were either all laid out and evaluated, or the bones were taken out one at a time. Once the bones were set out, they were examined carefully and ascribed a category number from the scale created earlier. Once a category was decided it was recorded in a specifically designed spreadsheet (Appendix 11).

The spreadsheet included the skeleton number as well as the site code and museum name. This allowed each collection to be easily recorded and sorted. The preservation category for each of the surviving long bones of each individual was recorded. Finally, an average preservation for the whole skeleton could be calculated (by totalling all of the preservation categories and dividing by the number of long bones present). The mean was considered to be the most appropriate statistical average to use (discussed in greater detail below).

It was predicted that some of the museum collections could hold hundreds of individual skeletons, and that it would not be practical to evaluate the whole collection. In those cases only a sample of the individuals were evaluated. This sample was decided on a case-by-case basis depending on the size of the collection. Ultimately this was only necessary for one collection, Wicken Bonhunt, where individuals with complete osteobiographical information were selected for evaluation.

The primary aim of this data collection was to evaluate change in preservation of the 12 bones of each adult skeleton studied, by comparing its current preservation to its preservation at accession (start preservation). The method outlined above shows how the current preservation was established. However, determining the start preservation presented much more of a challenge and could only be estimated through creating a retrospective baseline preservation assessment. The retrospective baseline preservation assessment reflects the preservation of the bones when the earliest available documentation of the skeletal remains was produced, which ranged from post-excavation recording to accessioning.

Several sources of information can be used to establish a retrospective baseline preservation assessment; however, since challenges can be associated with all of them, the ones deemed most applicable to this study are discussed below. It should be noted that the methods are not all independent and can be used in conjunction with one another. The first method is the personal knowledge of the curator. In some older museums that are not, or have only recently become, accredited, the documentation of the objects can be limited. Information is instead held in the memory of the curator or a long-term staff member. Although this is becoming less common, smaller museums and heritage centres sometimes have no choice, as they do not have the money or time to record all of the objects they curate (see Chapter 5). This method was not used in this study as it would not have been possible to create a reliable retrospective baseline assessment.

The second source of information is the basic written description of the object that is required for Spectrum, a digital collections management system (Clegg 2020 p.68; Collections Trust 2017c) which is useful for museums trying to gain accreditation (Poole and Dawson 2013). These descriptions can be extremely valuable if they are detailed and well written, enabling a detailed retrospective baseline assessment to be easily created. However, the detail in the description is based upon the person's experience; if the person does not have a background in archaeology or human remains, the descriptions may not be sufficiently detailed to be useful. This is becoming more of an issue as museums turn to volunteers to save costs (Museums Association 2019c). Although most individuals are given suitable training (Museums Association 2019c), long-term commitments and extensive training requirements can be barriers to volunteer recruitment, especially when attempting to recruit younger and more diverse volunteers (Museums Association 2019c).

The third approach is to use photographs. These photographs could be taken during excavation (*in situ),* during post-excavation analysis, during accession, or during later documentation conducted by the museum. This information source, if completed correctly, can be the most useful. If a photograph of the remains exists, this can be used alongside any written descriptions to help create a relatively accurate retrospective baseline assessment of the material. The problems associated with this method are based upon the quality of the photographs created. Photographs taken at low resolution may fail to capture details of damage to the bone. Similarly, if only a single view is captured then damage on the opposite surface of the bone may not be visible; bones are three dimensional and photographs can fail to capture significant details. With *in situ* photographs some bones may be obscured by soil, other bones, or artefacts in the grave. If the *in situ* photograph is the only documentation available for the obscured bones, their preservation cannot be recorded, and they were not be included in this study. Additionally, the soil matrix present in the burial may hold fragmentary bones together; in these cases the *in situ* photograph may be misleading as to the preservation of the bone. However, breaks that occur in the burial environment will be stained by the soil to a similar degree as the bone surface; this staining will not be present on fresh breaks that have occurred during or since excavation. Where *in situ* photographs were used during the course of this research, bones that appeared whole in photographs but were discovered to be fragmentary in practice were examined for soil staining. If the broken surfaces were consistent in colour with the bone surface, these breaks were understood to have occurred prior to accession. Therefore, the original retrospective baseline preservation assessment based on the photograph was updated with this information. For this research, photographs were the preferred method of creating a retrospective baseline preservation assessment, as was the case with Caffell and colleagues (2001).

The fourth approach is the original skeletal or excavation report created after the skeletons were excavated. If a skeletal report was created for the collection, this should provide enough information to create an accurate retrospective baseline preservation assessment. However, if an excavation report was produced, depending on the detail, the information about the skeleton may not be sufficient. Furthermore, the date of the report could have an impact, as until professional standards were established information about preservation may not have been included as this was dependent on the individual author. For this research, if the museum did not have sufficient photographic documentation the skeletal report was used instead.

Regardless of the source or format of the data, the method for recording the data and calculating the start preservation remained the same. The documentation and photographs were used with the newly created preservation scale, to give an estimation of the preservation. The retrospective baseline preservation assessment, referred to as the start preservation, is an assessment created from the earliest available documentation. None of the skeletal collections used in this thesis had a baseline preservation assessment conducted at the time of accession or excavation; thus, it was necessary to use whatever documentation was available to estimate the condition of these skeletal remains retrospectively. Only the skeletal collections held at the Newark Museum had baseline condition reports available, although these assessments were not conducted at accession but in 2008 as part of the relocation of the collections. These condition assessments were adapted to fit the preservation scale created for this study. The data collected for the retrospective baseline preservation assessment were recorded on the same spreadsheet as the skeletal observations, allowing the change in the preservation to be easily calculated (Appendix 11).

Little prior research has been conducted on how to retrospectively create a baseline assessment. Several possible ways to retrospectively calculate a baseline condition assessment have been presented above, along with a simple evaluation of how effective they would be. While all the methods could theoretically be used to create a retrospective baseline, not all were appropriate for use in this study. Detailed description and photographs used together were the preferred source of information for this research, but where this was not available, the skeletal or excavation reports were used. If none of these were available or applicable, then the collection was not used.

One complication found was that some of the available documentation was created significantly later than the date of accession (Table 3.10). This impacted correlations between change in preservation (start preservation and current preservation) and the time the collection had spent out of the ground. This is discussed in more detail in the Materials Section 3.2.

Figure 3.7 shows an example of the method used and how the retrospective preservation baseline was created, using a photograph and written description. The photographs (or detailed documentation) were compared to the preservation scale and assigned a preservation category.

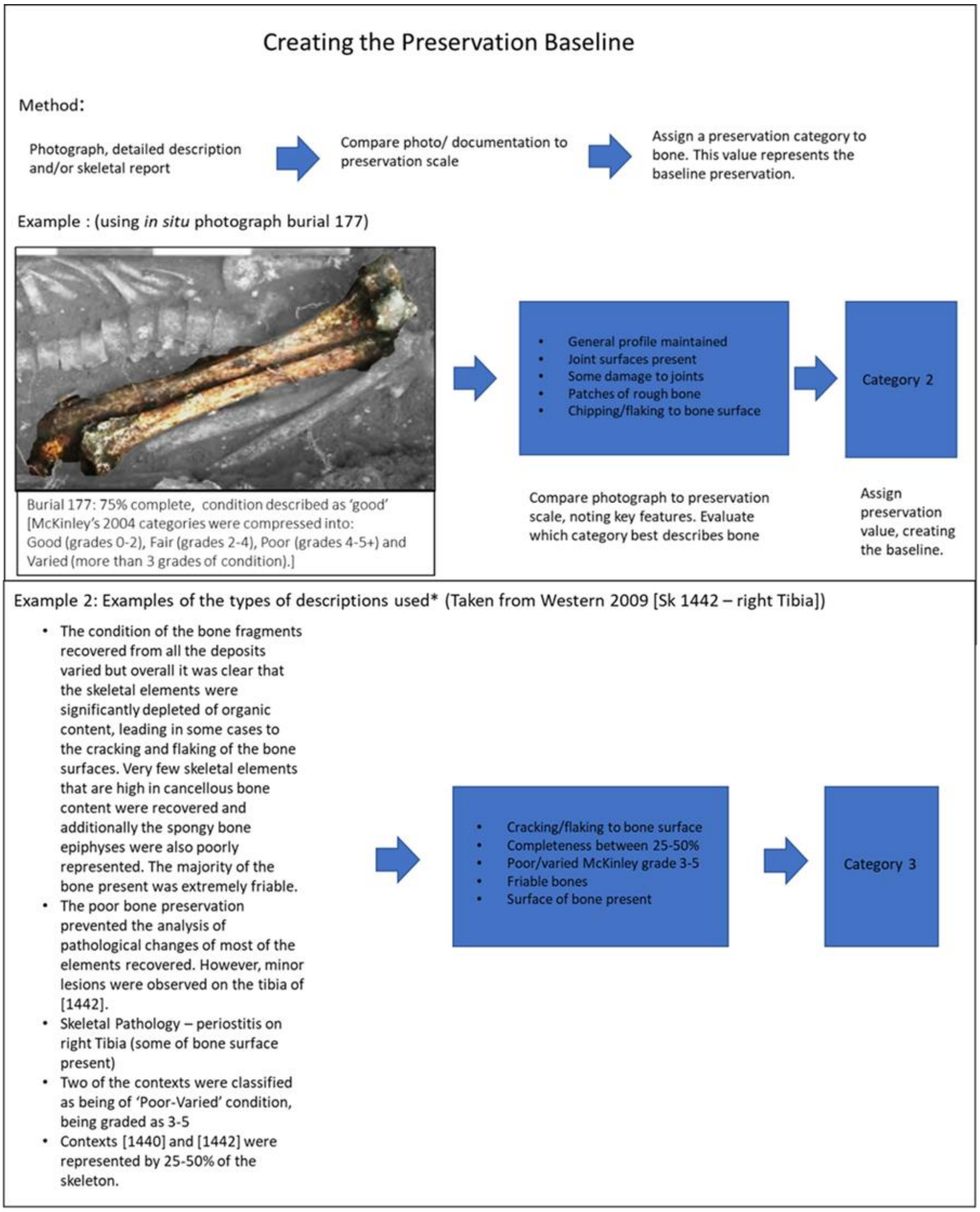


*Figure 3.7: The methodology used in this thesis and an example showing the process of creating a retrospective baseline preservation assessment. The photograph is of Burial 177 at the Worcester Technical College site (All Saints building); the background has been shifted to greyscale to highlight relevant bones (Sworn et al. 2010). The description is from Sainsbury's St Johns site, Sk. 1442 (Western 2009). *This is an example of a set of descriptions used to establish a baseline; other types of description were used in some cases.*

While at the museums, several other pieces of information were collected. Any background information about the specific collections the museum curates was collected to aid in understanding the history of the skeletal collection. Information about the excavation was gathered, including the location and format of the excavation or skeletal reports. Any prior research conducted on the remains was also recorded, as this was the key comparison for this research.

As well as information about the collections, details about the museum were obtained to aid in analyses and comparisons of the data (Appendix 12). The size of the museum was noted, and the museum was placed into one of three categories (small, medium, or large). This was achieved by evaluating the physical size of the museum (approx. m^2), the number of full-time staff they employ, and the average number of visitors they receive per day. Whether the museum is independently run, government funded, or run by a university was noted, as how a museum is run can affect the amount of funding the museum receives. Other questions included:

1. Does the museum have a dedicated specialist to take care of the human remains?
2. Are there any guidelines in place to limit access to the remains?
3. Are the remains regularly inspected for damage, pests, or mould?
4. Is the store temperature and humidity monitored?
5. Does the store have up-to-date security?
6. Does the museum have a policy on using consolidants?

Other information that would be needed for the secondary comparisons could be observed during the collection of the skeletal data. This included: box size, packaging material, packing order (how the bones were packed in bags, and how the remains were packed in the box), quality of shelving, dedicated storage, sunlight, and whether the boxes were stacked.

All of the above information was recorded on the Museum Information Recording Sheet (Appendix 12). Some of the questions were given as multiple choice as the answers could only be one of a number of options. For each of these multiple-choice answers further details were recorded as free text in the notes section of the form included in Appendix 12. The first question, whether the museum had dedicated storage for human remains, was accompanied by a description of storage conditions. Details included whether the storage area was protected from sunlight, what type of shelving was used, and whether the boxes were stored at least 10 cm above the ground (Cassman and Odegaard 2006). Details recorded included the answers to questions one to six listed above. Other information collected included whether the museum maintained a full inventory of their skeletal remains that listed all of the individuals in each skeletal collection as well as any osteobiographical information. However, as extensive documentation was required in order to create the retrospective baseline preservation assessment, all of the museums chosen for this study had complete inventories of their skeletal remains. The second question, whether the museum had considered displaying human remains, was accompanied by a record of any remains that were or had been on display. The third question, whether the museum implemented guidelines for staff, was accompanied by a list of policies that applied to human remains. This included whether the museum had a Human Tissue Licence, a dedicated human remains policy, and whether their general museum guidelines for ethics and practice included a specific section regarding human remains. The fourth question, whether the museum allowed destructive analysis, was accompanied by a list of any restrictions the museum placed on this type of access. The fifth question, regarding who the museum allowed to have access to the human remains in their collections, was accompanied by any further details regarding such access.

The free text notes format of this recording sheet allowed any other pertinent information to be recorded. This included information about the boxes and packing material used to protect the human remains in each collection. These data was recorded in free text as there were multiple options for each component and determining whether these options were suitable (or not) was not straightforward. There are many strategies for protecting human remains that could be considered suitable, and infinitely more that would be considered unsuitable. This free text description was collated and simplified into a table, presented in Appendix 13 (along with what was defined as suitable and what was not). The table in Appendix 13 recorded individual basic components that described the suitability of boxes and packaging, as well as whether the boxes of remains were stacked and the order in which the remains were packed. For example, whether boxes were suitable was determined by evaluating both the size and state of repair of the boxes. However, despite archival grade cardboard being recognised as the best material, whether boxes were constructed of archival grade cardboard or not was not recorded. Packing material consisted of the type of bags used, whether they were of an appropriate size, whether the bags were sealed, the state of repair of the bags, how the bags were labelled, whether further packing material was used appropriately, and, if so, what type of packing material was used. The thickness gauge of the bags was not determined, instead 'type' of bag refers to material, whether bags were plastic or paper. The order in which the bones were packed within the box was evaluated using the standards set out in Roberts (2018 p. 91). From these components it was determined whether or not the collection/museum had met the basic criteria for suitable boxes or packaging. If a collection, or parts of a collection, failed to meet a criterion then there was further consideration to determine whether the failure was mitigated. For instance, some of the individuals in the Newark Castle collection were in boxes that were larger than necessary for the remains; however, these individuals were carefully packaged to prevent movement of the remains within the boxes that could lead to damage. This was considered suitable. However, if there was no indication of mitigation, then the collection/museum would be considered to have unsuitable boxes or packaging. The factors were then rated as either suitable (1) or unsuitable (0). The data collated in Appendix 13 was recorded for each individual collection. Individual skeletons were not recorded separately in this research, as each collection recorded was well standardised and had the same boxes and type of packaging. If a situation occurred where individual skeletons had different types of packaging or boxes, then the skeletons would have to be recorded separately. These individuals could then be organised into sub-sets within a collection that could be rated separately. In this research, if the majority of the collections held by each museum had boxes and packaging that were rated as suitable, then the museum collection as a whole was said to have boxes and packaging that was suitable. This was done so that if the museum had a single collection that was poorly packaged, for whatever reason, it would not affect the overall average rating of the museum. This evaluation was included in Table 4.5 as part of the calculation of the storage quality value. It should be noted that this process was somewhat subjective due to the number of options that could be recorded, for both suitable and unsuitable boxes and packing material. Of the factors evaluated, only whether the boxes were stacked or not could be evaluated objectively. In comparison, whether additional packing material was used appropriately was difficult to quantify. Referring to the published guidance on the order and appropriate packaging of human remains helped to limit this subjectivity (Roberts 2018 p. 90-92; SMA 2020); however, subjectivity cannot be entirely eliminated from these considerations. Once all the data were collected, the preservation of each collection was compared to these factors and any patterns that emerged were evaluated and discussed.

ii. Data Collection Part 2 (Research Data)

Once the skeletal collection details and museum information were collected, the second part of this research could proceed. Part 2 involved evaluating the amount of access that had been granted to the skeletal remains in the museums, to create a “use history” of the remains. This was achieved by reviewing the collection information to ascertain how many researchers had accessed the collection and what form (the skeletal elements used) the research took (“use history”). Curators were asked about this whilst at the museum and their responses were recorded alongside the skeletal data. It is likely for some of the larger collections that not all the skeletons from that specific collection will have been used in the research. Therefore, it was important to find out exactly which individual skeletons were used by each researcher, and if the access would not have impacted the long bones, then that skeleton was not included. For the smaller collections this is less important as it is likely that any research would cover all of the individuals. The museums contacted at the beginning of this research were selected on the basis that they had the best documentation, and therefore it was expected that most, if not all, of this information would be available.

iii. Data Analysis:

Once the data from parts “i” and “ii” had been collected and collated, analysis of the results ensued. The first stage of the analysis was to calculate the average value of change in preservation (*Dv or* *deterioration value*). This was achieved by evaluating the difference in the means for each data set of all the long bones. The retrospective baseline, or start preservation (Figure 3.7 shows the method for creating this), was compared to the current preservation for each of the individual skeletons in the collections. The equation that was used to calculate *Dv (change in preservation),* created specifically for this research, is provided in Figure 3.8.

$$Dv = \frac{\sum x}{n_x} - \frac{\sum y}{n_y}$$

Where x is the observed preservation values, y is the retrospective baseline preservation values, n_x is the number of x values and n_y is the number of y values. Σ (sigma) is the sum of.

Figure 3.8: Equation to calculate change in preservation (Dv)

Worked Example – calculating the change in preservation

1. Make observation of the long bones recording the current preservation

Humerus (R/L)		Ulna (R/L)		Radius (R/L)		Femur (R/L)		Tibia (R/L)		Fibula (R/L)		Sum (Σx)
1	1	1	2	2	2	2	2	2	2	2	2	21

Determine the mean of these values. Calculate the total of these values ($\sum x$): 21. Divide this number by the total number of values (n_x): 12. Mean = 1.75

2. Establish a retrospective baseline condition assessment using detailed description and photographs

Humerus (R/L)		Ulna (R/L)		Radius (R/L)		Femur (R/L)		Tibia (R/L)		Fibula (R/L)		Sum (Σy)
0	0	1	0	1	0	1	1	0	1	1	2	8

Determine the mean of these values. Calculate the total of these values ($\sum y$): 8. Divide this number by the total number of values (n_y): 12. Mean = 0.666667

3. Using the formula from Fig 3.8 and the values calculated above, calculate the change in preservation (Dv).

$$Dv = \frac{\sum x}{n_x} - \frac{\sum y}{n_y} \qquad \frac{21}{12} - \frac{8}{12} = 1.75 - 0.666667 = 1.08333$$

Humerus (R/L)		Ulna (R/L)		Radius (R/L)		Femur (R/L)		Tibia (R/L)		Fibula (R/L)		Mean	Dv
0	0	1	0	1	0	1	1	0	1	1	2	0.666667	1.083333
1	1	1	2	2	2	2	2	2	2	2	2	1.75	

4. Once the Dv has been calculated it can be compared to other factors (Collected in Part ii)

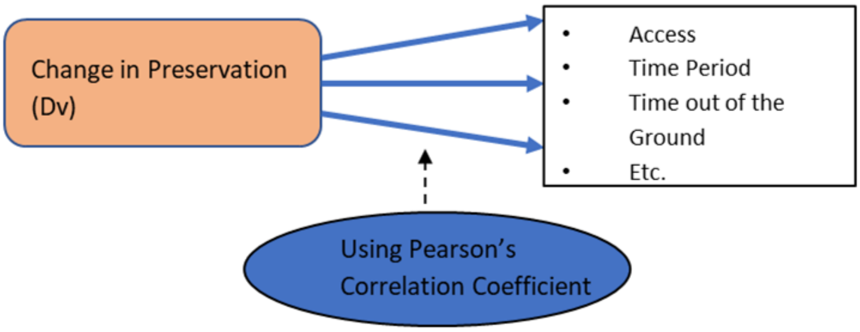


Figure 3.9: Worked example showing the method used to calculate the change in preservation.

A worked example of this calculation can be found in Figure 3.9. If Dv or the average value of change in preservation is zero, then no change has occurred; as Dv increases it shows that more change has occurred. The average value of change in preservation can then be compared directly to the potential preservation factors (listed in Section 3.1.2 iv) using Pearson's correlation coefficient. The average value of change in preservation is a statistical value that shows the average preservation of all the long bones of the skeleton. As each skeleton has up to 12 long bones[4], and therefore up to 12 values of change, it was necessary to average these values to find a single value for each skeleton. Although values for the individual bones could have been used, due to the difference in the structure, size, and shape of the different bones, they would not have been as comparable. It was decided that a single value to represent the whole skeleton was more appropriate.

a. Unconventional Mean:

The analysis of the change in preservation value for these data relies heavily on the use of the average (mean) preservation of all the long bones for each skeleton. This is not a typical average to use with ordinal data collected on an ordinal scale. However, in recent years a strong argument has been put forward for using ordinal data with parametric tests and comparisons (Norman 2010). Examples of this are the Likert scale in psychology (Likert 1932) and grade point averages in a number of educational systems. There are many situations where parametric comparisons created from ordinal scales are robust to their assumptions being violated, and act like any other quantitative data (Norman 2010). Therefore, for this set of data the mean and other parametric analyses were used.

To ensure the data were as robust as predicted and the assumptions made were accurate, the data were tested. This was achieved by collapsing the seven categories used in the preservation scale to five – categories 1/2 and 4/5 were combined (see Figure 3.10). This process, as outlined in Norman (2010), skews the data accentuating any issues or problems. If the data gave similar results, allowing the same conclusions to be drawn, it was accepted that the data set was robust, the parametric analyses would work, and any conclusions drawn from the analysis would be accurate. The results from the robustness test are presented at the start of Chapter 4.

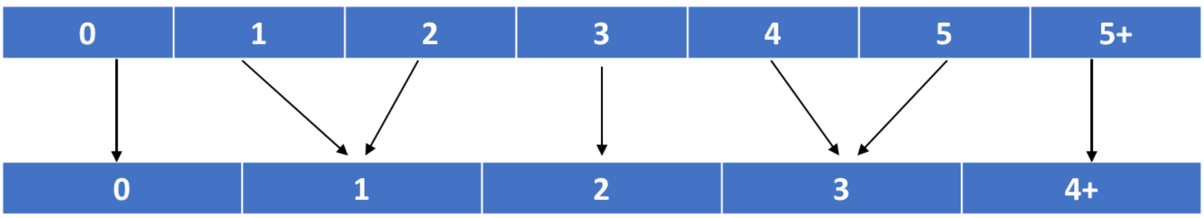


Figure 3.10: Demonstration of how the 7 preservation categories were reduced to 5.

[4] For the purposes of this study only adult humeri, ulnae, radii, femora, tibiae, and fibulae were evaluated. This was due, in part, to time constraints.

b. Calculation and Correlation:

Once the data had been acquired, change (Dv) could then be compared to the information collected during Part Two of the research. Calculations and evaluations of the observed correlations were completed to assess the trends in the data; other factors that were observed during Part One of the data collection were also compared and evaluated to observe what other trends in the correlations could be found.

Whilst a number of comparisons were made, the main comparison for this study was between the change in preservation (Dv) and the amount of research conducted on the skeletons. This comparison will be explained in detail together with what the outcomes mean for this research. To compare these factors, the data are illustrated, as appropriate, and the correlations shown are calculated using Pearson's correlation coefficient. The calculation for Pearson's is as follows (Figure 3.11).

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where: $(x_i - \bar{x})$ is each x-value minus the mean of x

$(y_i - \bar{y})$ is each y-value minus the mean of y

Figure 3.11: Equation to calculate Pearson's Correlation Coefficient (Neyman and Pearson 1933)

The value of the correlation (r) indicates the relationship between the two factors (Table 3.8). Values for correlation can range from 1 to -1 with anything above 0.7 considered a very strong positive correlation and anything below -0.7 considered a very strong negative correlation (Evans 1996). Anything between these values was considered to have a moderate, weak or no correlation (see Table 3.8). If a positive correlation was found, this meant that the more research that had been conducted, the higher the change in preservation. If a negative correlation was found, it meant that the more research conducted, the lower the change in preservation. If no correlation was found, this meant that the amount of research had no or very little effect on the preservation of the remains.

Table 3.8: Strength of Correlations (Evans 1996)

	Coefficient, *r*	
Strength of Association	Positive	Negative
Weak	0.1 to 0.3	-0.1 to -0.3
Moderate	0.3 to 0.5	-0.3 to -0.5
Strong	0.5 to 1.0	-0.5 to -1.0

Once an r value has been calculated, there is a need to determine whether this value is statistically significant. This was achieved by evaluating the p-value (the value of probability) against a predetermined α value of 0.05, which is the standard in social science (Neyman and Pearson 1933; Quinn and Keough 2002). If the p-value is below 0.05 ($p<0.05$), the data are statistically significant, and the null hypothesis (H0) can be rejected. Confidence can be placed in the conclusions that there is a link between the factors, and that the patterns in the data did not happen by random chance. If the p-value is above 0.05 ($p>0.05$) we can say the data are not statistically significant and we must fail to reject the null hypothesis as there is a high probability the patterns in the data are by chance. In this study the p-value was calculated with the Student's T-Test (Gosset [Student] 1908). For this thesis the H0 is there is no difference between the two comparisons, and the observed difference is due to random sampling or coincidence. To consider the data and testing to be successful, the H0 must be rejected.

iv. Other Tested Correlations

Once these data were evaluated, other comparisons were made with the data collected from the museums (Appendix 12). Change in preservation was compared to various other factors, discussed below.

a) Change vs Start Preservation- Start preservation, as defined in Section 3.1.2 (i), is the retrospective baseline preservation assessment. Depending on the documentation that was used, this assessment may reflect the condition of the skeletal remains immediately after excavation, at accession, or following a period of curation. Table 3.10 provides the dates of excavation and accession for the collections used in this study as well as the dates at which the documentation used in establishing the start preservation was created. Whilst the retrospective baseline preservation assessment may not reflect the condition of the skeletal remains at excavation or accession, it does reflect the earliest reliable documentation available for these skeletal collections. It was expected that the worse the start preservation then the greater the amount of change in preservation that would be observed. It is hypothesised that poorly-preserved remains will deteriorate faster. Poorly-preserved remains, whether they deteriorated due to the burial environment or previous storage conditions, will be more susceptible to damage than well-preserved remains. Chemical damage from the burial environment (soil) can weaken the bone either through mineral leeching (of the hydroxyapatite) or degradation of the collagen proteins in the bone (Child 1995a; Gordon and Buikstra 1981; Jans et al. 2004; Kontopoulos et al. 2016). Previous storage conditions, if not up to current standards, may have led to damage of the skeletal remains. Improperly-sized boxes, without adequate packing material, can lead to rubbing between the bones that erodes and damages the surface. Small boxes that do not adequately fit the larger skeletal elements can lead to breakages, whilst improperly stacked boxes can cause crushing damage, particularly of the less robust bones. Acidic packing materials, such as newspaper, or insufficient packing material can also cause damage to the bones (Bonney et al. 2020 p.227; Cassman and Odegaard 2006 pp.49-75; Garland et al. 1988; Janaway et al. 2001; Watkinson and Neal 1998). Damage to skeletal remains is not reversible and even once the remains are cleaned and properly stored poorly-preserved remains will be more fragile than well-preserved remains. Regardless of the factors leading to deterioration, it is believed that the worse the preservation, the more fragile the remains and therefore the more prone they are to further damage (BABAO 2010 p.14).

b) Change vs Time Period- Time period is the approximate age of the remains. Roman remains will be between 2000 years old and 1600 years old, while post-medieval remains will be around 500 to 100 years old. The aim of this comparison was to assess if the age of the remains affected the level of change in preservation in the remains. It was expected that the older the skeletal remains, the greater the amount of change in preservation that would be seen, simply because the remains are physically older and have therefore spent longer in the ground being affected by the burial environment (Child 1995b; Gordon and Buikstra 1981; Pokines and Baker 2013 pp.74-87). Bone degrades in the burial environment through three interrelated processes: the hydrolysis of bone collagen, the dissolution of hydroxyapatite, and microbial action that can affect both organic and inorganic components of bone (Child 1995b; Collins et al. 2002; Kontopoulos et al. 2016). These processes are influenced by multiple factors, the most important of which are time since death, temperature, soil pH, hydrology, and the presence of microbes (Child 1995b; Collins et al. 2002; Kontopoulos et al. 2016). Time in the burial environment (approximately measured by the time period of the remains) as a deterioration factor is discussed here. Soil pH is discussed below in Section 3.1.2. (iv. e). Temperature relates to broad patterns of soil temperature (e.g., in temperate or tropical climates) and was not a factor in this research as all the remains were excavated in the UK (Child 1995b). The other factors of hydrology and microbial composition are often not recorded and therefore could not be evaluated in this research. In similar environments bones buried in the Mesolithic would be expected to have degraded more than bones buried in the post-medieval period. Obviously skeletal remains are excavated from a variety of burial environments; therefore, this relationship will be complicated by other factors. However, in general terms it is believed that older remains may have degraded further in the burial environment causing these remains to be more fragile and susceptible to change. This deterioration may not be visible in gross observation, as recorded in start preservation, but may instead lead to chemical and structural instabilities. A lack of collagen in bone is not visible externally but will weaken the bone and result in less robusticity particularly in relation to bending forces (Collins et al. 2002; Figueiredo et al. 2012). Similarly, microfractures may not be visible to the naked eye, but will compromise the structural integrity of the bone.

c) <u>Change vs Time Out of the Ground</u>- Time out of the ground is simply the amount of time that has passed since the remains were excavated. The aim of this comparison was to evaluate if there was a significant difference between the preservation of remains that had been out of the ground for a short period of time and those that had been out of the ground for a longer period of time. It was expected that the longer the remains had spent out of the ground the greater the change in preservation. This was due to the potential importance of the environmental conditions of storage (Bonney et al. 2020 p.227; Cassman and Odegaard 2006 pp.49-75; Garland et al. 1988; Janaway et al. 2001; Watkinson and Neal 1998). Storage conditions consist of a suite of factors that are discussed in detail below in Section 3.1.2 (iv f). Furthermore, the longer the human remains had spent out of the ground the longer the opportunity for access, which was thought to impact the preservation (Caffell et al. 2001).

d) <u>Change vs Museum Type/Size</u>- Does the type of museum and different funding methods affect deterioration, and does the size of the museum have an impact on the preservation of the skeletal collections? Although smaller museums were used in this research, they were still split into groups by size. It was expected that university-run museums would have the highest amount of change in their collection. This is primarily because university collections are often used for teaching. It was also expected that skeletons curated in the smaller museums with fewer staff and less funding would show greater change in the preservation of their skeletal collections.

e) Change vs Soil- Does the pH value of the soil affect the preservation of the skeletal remains? In soil, pH 0-6 is acidic, 8-14 is alkaline and 7 is neutral. The aim of this comparison was to evaluate what effect the pH of the burial environment had on the preservation of the remains once excavated and curated. In this research, soil pH was used as a proxy for the burial environment, which often is not recorded (at least for the collections used in this research). Soil pH values were determined using GIS (Geographic Information System) maps of England, taken from UKSO.org. It was expected that the lowest amount of change in preservation would be found in neutral pH level soil (pH 7) and the further the soil pH deviated from this value, the more change would be seen (Pokines and Baker 2013 p.76). It is understood that soil pH can change from one area of a field to another, yet it is impossible to record the soil pH of every site. Instead, average pH levels of the sites were used.

f) Change vs Storage- Storage, although a complicated risk factor to quantify, has an important effect on preservation. This is because the majority of the time spent by the remains out of the ground is spent in storage. The storage facility represents a number of variables: whether the facility is secure, protects the remains from sunlight, is consistent in temperature and humidity, and free from pests and mould. Regular inspections of the facility help to ensure these conditions are being met. Within the facility the shelving provided for human remains represents another set of variables: is the storage area dedicated to storing human remains, are the shelves sturdy and made of a suitable material, are the remains kept 10 cm off the ground, are the boxes of remains stacked on top of each other, and are the remains kept in an organised fashion. Other variables include whether the remains are kept in boxes of appropriate size, whether the packing materials are sufficient to prevent abrasions and protect the remains whilst being acid-free, whether consolidants have been applied to the bones, and whether the storage facility employs a specialist in human remains. For the purposes of this research, specialist staff were defined as anyone who had formal education (university degree) or training (Continuous Professional Development courses) in the care and handling of human remains; this included conservation staff and collection care managers. Guidelines for storage of human remains, which explain the expected basic standards, have been established for museums (Cassman et al. 2006 pp.49-75; Clegg 2020 p.75-76; DCMS 2005; Garland et al. 1988;

Janaway et al. 2001 pp. 199-208; Redfern and Bekvalac 2017 p.374; Society of Museum Archaeology 2020; Watkinson and Neal 1998). All of this information was collected during the visits to the respective museums. Due to the potential variability in the answers that could be given, the recording of these factors was not part of the multiple-choice questions on the Museum Information recording sheet. Instead, this information was recorded in the notes section, to allow full and varied responses to be given, not constrained by limited options. In Chapter 4, factors that pertain to storage are summarised in Table 4.5 and a score given to each museum's storage facility (met requirements: yes 1, or no 0), with a maximum score of 16. Photographs of the museum storage facilities (where available) are presented in Appendix 14. This score only represents the current state of museum storage. Whilst it is understood that these conditions will have changed over time, these changes cannot be quantified unless museums have kept detailed records of past storage practice. This issue and its impact will be considered more in the Discussion Chapter (Section 5.2.3). This storage value was compared to preservation change to explore their relationship. It was expected that the higher (better) the storage value, the lower the change in preservation.

g) Access Factors- In addition to the comparisons discussed above, other factors that could influence access were evaluated. This was because the necessary data had already been collected. These comparisons give us greater insight into what impacts access to a museum collection, and what can be done to increase this access and research, or limit that same access.

The same statistical tests used on the primary comparison were conducted on each of the comparisons above.

3.2 Materials

At the start of this research, museums across England that were thought to hold human remains were contacted. This list of museums was based on the surveys conducted by L. White (2011). L. White's PhD considered the impact and effect of the then newly-introduced Human Tissue Act (HTAct 2004) and the Guidance for the Care of Human Remains in Museums (DCMS 2005), a document on museum practice and the human remains they curate. As part of this research, L. White sent a survey to all the museums in England asking if they held human remains, allowing her to focus directly on those museums that did hold human remains for her research. Approximately 262 museums of the 806 surveyed replied that they had human remains stored in their museum in some form (White, L. 2011); the list of 262 museum was used as a starting sample for this research. Each of the 262 museums were contacted by email and were asked if they did hold human remains and if they would potentially be willing to take part in this research. Twenty-nine (11%) of these museums were uncontactable, primarily due to the museums no longer being open. Of the remaining museums, approximately 94 (40%) responded to the initial contact and, of these, only 34 (36% of the 40% that responded) replied that they did still hold human remains and were willing to take part in this research. The remaining 60 museums either did not have, or no longer held, human skeletal remains. With the potential sample size reduced, the 34 museums were contacted once more, to obtain specific information about their collections, including the number of collections they had and the number of skeletons for each site curated. As well as this information, details about their standards of documentation and use history were also collected. This allowed the museums to be ranked in order of perceived usefulness for this study. With information about the numbers of collections and sizes of those collections, as well as standards of documentation, a group of museums could be created as being the most suitable museums for use in this study. The geographic locations of each of the museums used in this thesis can be found in Figure 3.12.

By selecting museums that had documentation practices consistent with best-practice guidelines and complete inventories of their human remains, this research effectively also selected for other policies as well, such as a human remains policy, and guidelines for staff instructing them on how to deal with human remains (See Table 3.9). All of these policies would help to protect the human remains in some way. As all the museums had similar standards of documentation and policies, as they were all accredited institutions, it would be meaningless to compare them to one another, as the standards would all be high. Instead, the data would need to be compared to a museum with no policies and no (or very little) documentation; however, this presents a problem for this research, as this excellent level of documentation is needed to create the retrospective baseline preservation assessment and to calculate the change in preservation. While poor documentation and a lack of specific human remains policies are expected to negatively impact the preservation of human remains in museums, the significance of this impact is unknown; this issue was beyond the scope for this thesis. When the results of this thesis are considered it must be remembered that they are from institutions that had excellent documentation and dedicated human remains policies and the results may reflect this.

Table 3.9: Summary of the museum information showing the type, size, and quality of the documentation for each of the museums used in this research.

Museum	Location	Type	Size	Human tissue authority licence	Staff Guidelines[1]	Human Remains Policy	Complete Inventory	Number of Collections	Total Number of Skeletons recorded[4]
Verulamium	St Albans, Hertfordshire	Council	Medium	No	Yes	Yes	Yes	3	12
Worcester Museum	Worcester, Worcestershire	Council	Medium	No	Yes	Yes	Yes	6	32
Saffron Walden	Saffron Walden, Essex	Other[2]	Medium	No	Yes	Yes	Yes	1	91
Great North Museum	Newcastle upon Tyne, Northumberland	Shared University	Large	No[3]	Yes	Yes	Yes	5	12
National Civil War Museum	Newark, Nottinghamshire	Council	Small	No	Yes	Yes	Yes	6	72
							Total:	21	219

1: Staff Guidelines refer to general guidance on ethics and practice, with a section that includes human remains. 2: Other refers to the joint venture between the private Saffron Walden Museum Society and the Uttlesford District Council. 3: Although the museum does not hold a HTA licence, Newcastle University does. 4: This column refers to the number of skeletons observed at each museum; for the total number of skeletons in each collection at these museums and how many of these skeletons were analysed, see Table 3.10.

Below and in Table 3.10, the collections and skeletons that were used in this study are presented along with background information about the museums that curate them. Although full demographic information of the collections is presented; in many cases not all of the skeletons were available for study. This was because they were being curated elsewhere, were being used by another researcher at a different location, or due to time constraints of the PhD research. Where possible, background information about the archaeological site is presented, but in some cases this information was minimal or unpublished. Some of the sites include non-adult skeletons, but as mentioned above (3.1.2 i) non-adult remains were not used in this research; therefore, although the non-adults are mentioned in the total numbers for a site, they are not included in the number studied (n). Age-at-death was not recorded specifically as the major differences are found between adult and non-adult remains and only adult remains were used in this research. Further distinction between adult age groups was not deemed necessary. While there may be increased fragility associated with skeletal remains from elderly individuals, particularly those suffering from osteoporosis, ageing methods in archaeology are not well-suited to distinguishing between middle-aged remains and older age groups; often the oldest age range used is 45+ years (Alayan et al. 2018; Brothwell 1981; Godde and Hens 2015; Roksandic and Armstrong 2011). More recent research has applied transition analysis to the issue of estimating age-at-death in human skeletal populations; however, these analyses are conducted via a variety of methods (e.g., Rostock and Forensic approaches) and a consensus regarding which model is most appropriate has not yet been reached (Godde and Hens 2015). Furthermore, as the collections used in this thesis were derived from different time periods and regions, it would have been necessary to apply different models to each collection (Godde and Hens 2015). Sex was also not recorded for this research. Firstly, the difference in the robusticity of long bones between males and females is most significant among non-adult remains, particularly those aged between 0 and 4 years (Bello et al. 2006). Secondly, as only adult long bones were required for this research, determining sex would have involved removing and analysing elements of the skull and pelvis potentially causing unnecessary disturbance. Thus, for this research the collections of skeletal remains were not divided into categories based on age or sex, instead being evaluated as one population.

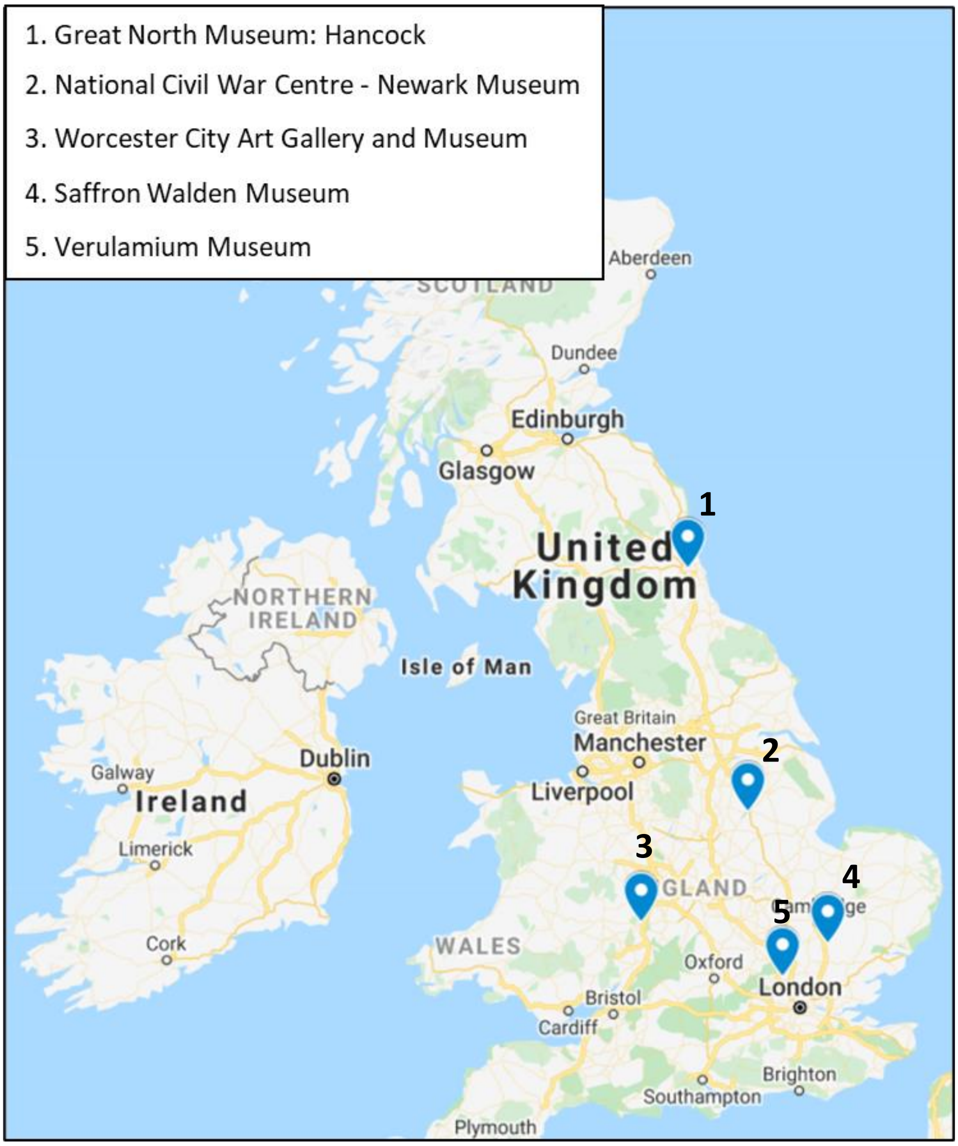


Figure 3.12: Map showing the locations of the museums used in this research

As briefly mentioned above in Section 3.1.2 (i) there was a limitation with regards to the creation of the retrospective baseline assessment using the available documentation, as not all of the documentation was created at accession. For some sites, such as Folly Lane, the documentation of the skeletal collection was conducted on accession, but not published until 8 years later as part of the site monograph. In other cases, evaluations were conducted before the collections arrived at the museum, during post-excavation processing. Some collections lacked detailed documentation until condition assessments were conducted significantly after they were accessioned by the museum. This was particularly significant for the Ad Pontem collection from Newark Museum, originally excavated in 1963-1965 and accessioned during the 1970s, but the only reliable condition assessment for this collection was produced in 2008 when the collection was moved. This issue is particularly significant for calculating the change in preservation compared to the time out of the ground. The change in preservation, based upon the start preservation had to be calculated from 2008, whilst the time out of the ground was calculated from excavation (some 40 years earlier). Whilst it would have been possible to calculate time out of the ground from 2008, this would have given an artificially young collection. Instead, the original excavation dates were used, and the data collected must be interpreted with caution. In each case the best documentation available was used to create the retrospective baseline assessment used to determine the change in preservation. This meant that there were some inconsistencies between the date of the documentation and the dates of excavation or accession. Despite these difficulties, the collections selected for this research had the most complete documentation available among the 34 museums curating human remains that were willing to take part in this research. The specifics of available documentation are provided below.

Table 3.10 presents information on each of the collections used in this research. The number of individuals in each collection of human skeletal remains is provided, as well as how many of these individuals were observed and recorded for this research. The number of times each collection was accessed for research is also recorded in Table 3.10. Information on the documentation used to create the retrospective baseline assessments includes the source of the skeletal reports and/or photographs used, and the date these documents were produced. If the date of a document was unknown then a range of dates was provided covering their likely period of origin. For published monographs the "Estimated date of baseline" often predates the date of publication, as it takes time for documents to pass through the publication process. However, it should be noted that many of the documents used in this research are out of print or unpublished and can only be found within the museums themselves.

Table 3.10: Summary of each of the skeletal collections used in this thesis. "N" = the number of skeletons in each collection. Published citations used in retrospective baseline assessments are provided where available. However, for several collections only internal documents, collections database or unpublished reports were available; for these collections specific citations cannot be provided. Under access the entry 2 indicates that the Wicken Bonhunt collection was accessed twice, but one of these occasions involved only 3 skeletons; the remainder of the collection has only been accessed once.*

Collection	*N*	*Recorded*	Excavated	Accession	Period	Access	Estimated date of baseline	Documentation Used for Baseline (Start)	Source
Folly Lane	3	2	1991	1991	Roman	6	1991	Monograph, with drawings and photographs	Mays and Steele 1999 (in Niblett 1999 Monograph)
Wheathampstead	1	1	1998	1998	Iron Age	6	1998	Full skeletal inventory + photograph	Internal Museum Report; Photograph held in storehouse
St Stephens	20	9	1984-1989	1989	Roman	2	1988-1989	Unpublished excavation reports, skeletal inventory, photographs	Internal Museum Report (held in storehouse); Display information Verulamium Museum
Worcester Tech College	17	17	2007	2008	post-medieval	11	2008	Full report + photographs	Sworn et al. 2010
Wormington Compression	1	1	2000	2003	Roman	1	2003	Excavation and skeletal report	Coleman et al. 2003 (draft copy); Coleman et al. 2006
Sainsbury St John	4	3	2008	2008	Roman	1	2008	Skeletal Report	Western G. 2009; Wainwright 2014
Old Yew Hill Wood	1	1	1999	1999	Iron Age	1	1999-2006	Monograph (Skeletal report)	Griffen et al. 2006
Deansway	7	7	1989	1989	medieval	1	1989	Post excavation assessment report	Unpublished reports (held in storehouse); Museum display
Bredon Norton	4	3	2009	2010	Roman	1	2009	Monograph (excavation + skeletal)	Allen et al. 2016; Joyce 2009
Wicken Bonhunt	222	91	1967-1974	1997	Anglo-Saxon	2*	1974-2010	Skeletal Report	Unpublished Report Bari Hooper (draft copy)
Summer Hill	4	4	1937-1938	1972	Bronze Age	3	1938	Archaeological Report (Description)	Bulmer 1938; Society of Antiquaries Newcastle Upon Tyne (SANT) unpublished archive
Bewes Hill Cist	4	4	1939	1971	Bronze Age	2	1939-1971	Archaeological Report (Description)	Society of Antiquaries Newcastle Upon Tyne (SANT) unpublished archive
West Wharmley	2	2	1928	1928	Bronze Age	2	1928	Archaeological Report (Description)	Society of Antiquaries Newcastle Upon Tyne (SANT) unpublished archive
The Sneep	1	1	1889	1910	Bronze Age	2	1892	Archaeological Report (Description)	Hedley 1892; Society of Antiquaries Newcastle Upon Tyne (SANT) unpublished archive
Hexham Golf Course	1	1	1921	1956	Bronze Age	2	1921-1956	Archaeological Report (Description)	Society of Antiquaries Newcastle Upon Tyne (SANT) unpublished archive
Ad Pontem	3	3	1963-1965	1971/2008	Roman	2	2008	Internal Condition Assessment 2008	Newark Museum database [accessed 2018] (K. Winter pers. comm. 2018)
Lincoln Road	21	21	1977	1977/2008	medieval	1	2008	Internal Condition Assessment 2008	Newark Museum database [accessed 2018] (K. Winter pers. comm. 2018)
The Friary	12	12	1978	78-84/2008	medieval	1	2008	Internal Condition Assessment 2008	Newark Museum database [accessed 2018] (K. Winter pers. comm. 2018)
East Stoke	13	13	1980s	1980s/2008	medieval	1	2008	Internal Condition Assessment 2008	Newark Museum database [accessed 2018] (K. Winter pers. comm. 2018)
Newark Castle	31	22	1994	1994/2008	Anglo-Saxon	1	2008	Internal Condition Assessment 2008	Newark Museum database [accessed 2018] (K. Winter pers. comm. 2018)
Staythorpe	1	1	1997	1997/2008	Mesolithic	2	2008	Internal Condition Assessment 2008, Skeletal Report	Newark Museum database [accessed 2018] (K. Winter pers. comm. 2018); unpublished (approx. 2001) Archaeological Research and Consultancy at the University of Sheffield (ARCUS) report pg.81
Total Skeletons Observed		219							

3.2.1 Verulamium Museum

The museum is situated within the old Roman city of Verulamium, previously the Iron Age settlement of Verlamion, now St Albans (Hertfordshire). The original Roman town was sieged and razed by Boudica in 61 A.D. but was rebuilt and became an important and prosperous trading centre. The museum itself was established following the excavations of the Roman town by Mortimer and Tessa Wheeler and holds many of the artefacts they uncovered. In 1996 the museum was further extended with a new distinctive domed entrance. The museum is noted for its large and detailed sets of mosaics and a large collection of Roman artefacts and a male skeleton in an ornate lead coffin (St Stephen Collection B22) that is on display in the museum (St Albans Museum 2018). The sites with skeletons available for study are listed below.

i. Folly Lane

The site of Folly Lane is located approximately 0.5km northeast of Verulamium and is thought to be part of the original Iron Age oppidum of Verlamion (Hertfordshire). In 1991, archaeologists discovered the remains of a large royal burial with cremated remains and a tumulus mound, thought to belong to a Celtic client king during the Roman period, suggesting that unlike some of the local tribes, this king worked with the Romans. In the surrounding ditch three inhumed skeletons (only two with sufficient documentation; n=2) were found, which make up the non-cremated remains from this site (Niblett 1999). A monograph was created sometime between excavation and accession of the collections, but not published until 1999 (Niblett 1999).

ii. Wheathampstead

The site of Wheathampstead (Hertfordshire) is thought to be an Iron Age settlement that predates the Roman city of Verulamium and was part of the territory of a powerful tribe, the Catuvellauni. The earliest capital of the tribe is likely to have been situated near Wheathampstead, and the presence of the massive earthworks known as "Devils Dyke" supports this hypothesis. In 1998, a female skeleton along with a neonate were found near the city centre during a routine building extension. The two skeletons make up the only individuals found at this site and the associated pottery and coinage suggest a date between A.D. 10 and 30 (n=1) (Wheathampstead.net 2017). A skeletal inventory with photographs was produced at accession but was not published.

iii. St Stephens

This site was excavated throughout the mid to late 1980s and was thought to form a part of the larger nearby site of King Harry Lane (Hertfordshire) excavated in the early 1960s (Stead and Rigby 1989). The site is made up of several hundred cremation burials, both pits and urns, and around 20 inhumation burials, although for some of the burials only the grave cut and coffin nails remained (no skeletal remains). As a consequence, only a small number of skeletons were available for study (n=9).

The site is thought to form part of the cemetery for the Roman town of Verulamium, although it was most likely located outside of the city walls. One of the inhumations from this site was found in the lead coffin mentioned above. The skeleton is currently on display in the museum and has had a facial reconstruction (Verulamium Museum 2017). An excavation report, skeletal report and photographs were produced at the time of accession, but they were not published.

3.2.2 Worcester City Museum

The Worcester Museum (Worcestershire) was originally established in 1835 under the name of The Hastings Museum, after Sir Charles Hastings. In the 1860s the museum went into decline. Then, in 1879, the museum amalgamated with the local library and art gallery, leading to an increase in funding. In 1894 the foundation stone of the new building was laid by King George V and the building reopened in 1896 as the Worcester City Art Gallery and Museum, where it remains today (Museums of Worcestershire 2018). The sites with skeletons available for study are listed below.

i. Worcester Technical College

Archaeological investigation took place at the All Saints building of Worcester Technical College (Worcestershire), while constructing a new entrance and fire escape. Archaeology for several periods was discovered ranging from prehistory through to post-medieval. The post-medieval deposits produced 24 articulated individuals, 17 of whom were adults (n=17) ranging in age from young to old, who were thought to be associated with the earlier St Andrew's graveyard (Sworn 2007). A skeletal report was produced as part of the excavation; the report was not published until 2010, although preliminary reports were made available earlier (Sworn 2007; Sworn et al. 2010).

ii. Wormington Compression Station

In 2000, excavations took place in four locations along the proposed route of a new gas pipeline between Wormington and Tirely in Gloucester. The Wormington Compression Station (Gloucestershire) site returned finds from several periods including the Bronze Age up to the post-medieval period. One skeleton was found dating from the Roman period (n=1) (Coleman & Hancocks 2005). A draft skeletal report was produced in 2003 with the full published report being finalised in 2006 (Coleman et al. 2006; Coleman et al. 2003).

iii. Sainsbury St John

Excavations took place ahead of the proposed construction of a Sainsbury's Supermarket at the site of St John's in Worcester (Worcestershire). The archaeological survey prior to construction uncovered several periods of archaeology, including four skeletons from the late Roman period (Western 2009). However, only three had the required documentation to be used in this research (n=3); the documentation was published in 2009, shortly after excavation (Western 2009).

iv. Old Yew Hill Wood

Excavations took place in 1999 along Old Yew Hill Wood in Church Lench, Worcester (Worcestershire). One Iron Age burial was found containing an articulated skeleton (n=1) (Griffin et al. 2006). The documentation was published seven years after excavation in 2006 (Griffin et al. 2006).

v. Deansway

Deansway was one of the biggest excavation projects to take place within the city of Worcester (Worcestershire) and gave a snapshot of the origins of the city. The excavation started in 1986 and uncovered several periods of buildings spanning the life of the city. A large medieval workshop was discovered along with associated finds, as well as seven skeletons also dating from the medieval period (n=7) (Worcester Museum nd.). The unpublished reports for Deansway were produced during excavation in 1989 and are stored in the museum store.

vi. Bredon Norton

At the site of Bredon Norton (Worcestershire), Iron Age and Roman sites were found prior to the building of a "water security of supply pipeline" between Worcester and Gloucester, which was a large archaeological undertaking. During the excavation four articulated skeletons were found along with a number of disarticulated remains, dating from the Roman period (Joyce 2009). Of these four, however, only three were available for observation at the storage facility (n=3). An unpublished report was produced during excavation in 2009 (Joyce 2009) and the monograph was published in 2016 (Allen et al. 2016).

3.2.3 Saffron Walden Museum

The museum of Saffron Walden (Essex) opened in 1835 and stands in the grounds of the old Walden Castle, a Norman building. The museum itself claims to be one of the oldest purpose-built museums in the country. Unlike most museums, the Saffron Walden Museum is neither independent nor local government run; instead, it is operated as a joint venture. The collections are privately owned by the Saffron Walden Museum Society, while the museum itself is managed and run by the Uttlesford District Council. This offers a unique solution to the financial issues facing both public and independent museums (Saffron Walden Museum Society 2018). The site with skeletons available for study is listed below.

i. Wicken Bonhunt

Wicken Bonhunt (Essex), was an Anglo-Saxon village found in the modern-day village of the same name whilst undertaking the widening of the M11 motorway. Alongside the village, an Anglo-Saxon cemetery was also found dating from A.D. 410 – 1065. Two hundred and twenty-two individuals, of various ages, were excavated by Bari Hooper along with a number of comingled remains during a period of work between 1967 to 1974. Unfortunately, no full report has ever been published for the site; only incomplete draft copies exist (Hooper nd.). Due to time constraints, only a sample of the collection was examined (*n=91*).

3.2.4 Great North (Hancock) Museum Newcastle upon Tyne

The Great North Museum (Northumberland) was originally built in 1884 to house the growing collection of the Natural History Society of Northumbria and was originally named the "New Museum of Natural History". When one of the lead supporters of the museum, John Hancock, who had secured much of the funding, died, it was decided that the museum should instead be called the Hancock Museum. The museum remained largely unchanged until 2006, when it went through a major £26 million redevelopment and merged with the Newcastle University's Museum of Antiquities and Shefton Museum. It reopened in 2009 (Hancock 2018). The Great North Museum is unusual in the way it is run, as the museum collection is partly looked after by the university, which is why it is referred to in this research as a shared university museum. The sites with skeletons available for study are listed below.

i. Hexham Golf Course

A Bronze Age stone lined grave was found 200 yards west of the boundary wall of St Andrew's cemetery in Hexham (Northumberland). Excavations took place in 1921 during the construction of a new green for the Hexham golf course. The skeleton was formally accessioned 35 years later in 1956 (n=1) (Keys to the Past "A" nd.). Documentation for this collection was unpublished and is believed to date sometime between excavation and accession.

ii. West Wharmley

A Bronze Age cist was discovered in a field near West Wharmley Farm, near Hexham (Northumberland), while the field was being ploughed. The finds, including the skeletal remains, were accessioned by the Museum of Antiquities in 1928 (n=2) (Keys to the Past "B" nd.). Documentation for this collection was unpublished, but dated circa 1928.

iii. The Sneep (Tarset with Greystead)

A stone lined grave was discovered north of Hexham (Northumberland) in 1889, after a nearby stream eroded away the side of the hill in which it was situated. One skeleton was found alongside several flint tools dating from the Bronze Age (n=1) (Keys to the Past "C" nd.). A report was produced following excavation in 1892 (Hedley 1892); further records were available in the archive relating to accession in 1910.

iv. Bewes Hill Cist (Beacon Hill)

Four individuals were discovered in Blaydon (Northumberland) in 1939 and were handed over to the museum in 1971 in a box of mixed remains, which were later reorganised and placed together. The remains are thought to be associated with the Bronze Age Bewes Hill Cists (n=4) (Museum of Antiquities 1971). Documentation was produced circa 1971 during accession but remains unpublished.

v. Summer Hill

A group of six Bronze Age cist burials were found throughout the 1930s within the city of Newcastle upon Tyne (Northumberland). The site is located on top of a hill overlooking the River Tyne valley. Not all the cists that were discovered contained human remains; some only contained grave goods (n=4). One of the cists, including the human skeletal remains, is currently on display in the Great North Museum (Durham Nature 2012). A report was published following excavation in 1938 (Bulmer 1938); further documents relating to accession in 1972 are held in the archive.

3.2.5 Newark National Civil War Centre

The Newark National Civil War Centre (Nottinghamshire) opened in 2015 at a cost of £5.4 million. It was designed to be the forefront museum in Britain dealing with the Civil War, because Newark itself played a key role in this conflict (National Civil War Centre 2015). While the modern museum deals almost exclusively with the Civil War, there is still a small section on the local history of Newark and the surrounding area, including the Iron Age "Newark Torc" (Portable Antiquity Scheme 2016). The museum is set within the area of an earlier museum and that of the "Old Magnus school building" which is incorporated into the structure of the new modern museum (National Civil War Centre 2018). The store contains a larger variety of objects than are found in the museum itself and it is where several collections of human remains are now stored. The sites with skeletons available for study are listed below.

i. Ad Pontem

Ad Pontem meaning "near the bridges" is a Roman area within the boundary of Newark (Nottinghamshire). The area is made up of a collection of small Roman forts as well as at least one Roman villa. During several excavations in 1963-1965 a number of human bones were found alongside a large number of animal bones, including cattle and dogs; three individuals were available for study (n=3) (PastScape 2015). The collection was accessioned in 1971, but detailed documentation was only available from 2008 when a condition assessment was undertaken as part of the relocation of this collection.

ii. East Stoke battlefield

Thirteen skeletons were found by a metal detectorist in 1980s and were thought to be associated with the Tudor (medieval) battle of Stoke Field (Nottinghamshire). The battle is considered to be the last true battle of the War of the Roses and the bloodiest. It was fought between the newly crowned king, Henry VII, and Yorkist rebels. (n=13) (Historic England 1995). The collection was excavated and accessioned in the 1980s; however, reliable documentation can only be found from 2008, when the collection was moved.

iii. The Friary

In 1978, a medieval cemetery was excavated to make space for new building works in Newark (Nottinghamshire). It was thought to be associated with the nearby Newark Friary (Grey Friars), although there is no direct evidence to support this. The Friary itself was short lived, founded in 1507 by Henry Tudor (Henry VII) and dissolved by his son Henry VIII in 1539. Twelve adult skeletons of both sexes were found alongside many children, and all adult skeletons were available for study (n=12) (Historic England 2000). The collection was accessioned between 1978 and 1984; however, reliable documentation can only be found from 2008, when the collection was moved.

iv. Lincoln Road (St Leonards)

This was a 12th century (medieval) cemetery, thought to be associated with the possible leprosy hospital in the complex of St Leonard's Church (Nottinghamshire). The remains were found in 1977 prior to planned building works at the site. At least 21 individuals were found, many with pathologies, supporting the idea that the cemetery was associated with the nearby hospital (n=21) (Newark Museum 2018). The collection was accessioned in 1977; however reliable documentation could only be found from 2008.

v. Newark Castle

Newark Castle (Nottinghamshire) was a medieval castle and bishops' residence, and one of only a handful of episcopal castles in England. It is also reported to be where King John died of dysentery in 1216. However, the castle was built on top of an earlier Saxon motte and bailey castle to guard the river crossing. In 1993-1994, an Anglo-Saxon cemetery was found near the medieval gate house which contained 50 graves, including 20 children and 31 adults dating to between A.D. 950 and 1070. Only 22 of the skeletons were available to study (n=22) (Historic England 2016a). The collection was accessioned in 1994 after excavation, but reliable documentation could only be found from 2008.

vi. Staythorpe Power Station

A single adult femur was found in a borrow pit during the construction of the Staythorpe power station C (Nottinghamshire) which opened in 2010. Radiocarbon dating of the femur showed it was from the Mesolithic, 5735-5630 B.C. (n=1) (Archaeological Research and Consultancy at University of Sheffield 2001). Excavation was conducted during the initial planning process for the power station in 1997, and the femur was accessioned that same year. An unpublished ARCUS report was produced in 2001; additionally a condition assessment was produced in 2008.

3.2.6 Summary

Above, the human remains that were used in this study have been presented along with background information about the museums that house them. In the next chapter (Chapter 4) the previously-described methods will be implemented on the collections discussed above and the results will be presented.

Chapter 4: Results

This chapter presents the analysis of the data collected. For an outline of the statistical methods used to evaluate these data, see Chapter 3. The focus of this research was to examine the factors contributing to the deterioration in preservation of adult human skeletal remains held in several English museums, and primarily whether access to the collections and use of them by researchers was a significant risk factor for preservation. Other potential causes of deterioration in preservation were also analysed and evaluated, providing a comprehensive understanding of the potential reasons behind any deterioration of the skeletal remains held in the selected English museums. The layout of this chapter is as follows. Section 4.1 presents the robustness test, validating the methods and data used in this research. Section 4.2 shows the results of the primary comparison of the data generated in this research, the relationship between access and the change in preservation state of the skeletal remains. Section 4.3 shows the results of the secondary comparisons compared to preservation change. Finally, Section 4.4 compares some of the factors to the amount of access, to see which of the discussed factors impacted the amount of access.

4.1 Test of Robustness

Table 4.1: Robustness Test - Change vs. Access – Sample of Data Evaluated using Five Categories

Pearson Correlation Coefficient			
r		r^2	
0.15783		0.02491	
Statistical Significance: T-test			
p=	α=	*p*>α	H0
6.36506E-05	0.05	FALSE	Reject

As explained in Chapter 3, the robustness of the data collected must be evaluated to ensure the validity of the conclusions reached in this research. To evaluate robustness, the seven preservation categories used (0,1,2,3,4,5,5+) were collapsed to five (0,1,2,3,4) for a sample of the data. If the assumptions made in both sets of data (seven categories and five categories) were the same, the data could be considered robust. Values for changes in preservation from start to current state were compared to the amount of access for use by researchers. To evaluate the link between access and deterioration for the new data set consisting of five categories, the Pearson Correlation coefficient (r) was calculated. The coefficient value was also squared (r^2) to allow better comparison between data sets, yielding values from zero to one. The statistical significance (*p*-value) of the data was then calculated using a Student's T-test (see Table 4.1).

Robustness is a test of the assumptions made from the data as to whether they remain valid with the different versions of the created preservation scale (scale with 5 preservation categories and original scale with seven preservation categories). With robust data, we can be confident that the conclusions drawn from the data are accurate and reliable. If we compare the data collected here with the values from the full seven category test (see below Section 4.2), we can see that they are comparable - both having weak positive correlations. Furthermore, as the data were shown to be statistically significant, we can say that the same assumptions can be drawn from both sets of data. Therefore, we can be confident that the conclusions and assumptions made with the seven-category data set are robust to being violated – meaning they can be violated without any serious error occurring – and the data created are not based specifically upon the preservation scale used.

4.2 Primary Comparison: Change vs. Access

The primary comparison to be made in this research was to evaluate the relationship between the amount of change in the preservation of the skeletal remains and the number of times those remains were accessed. This is an important comparison because potentially it shows the effect handling the human

Table 4.2: Number of Times Accessed vs. Change in Preservation

Pearson Correlation Coefficient			
r	r^2		
0.17646	0.03114		
Statistical Significance: T-test			
p=	α=	*p*>α	H0
1.30977E-29	0.05	FALSE	Reject

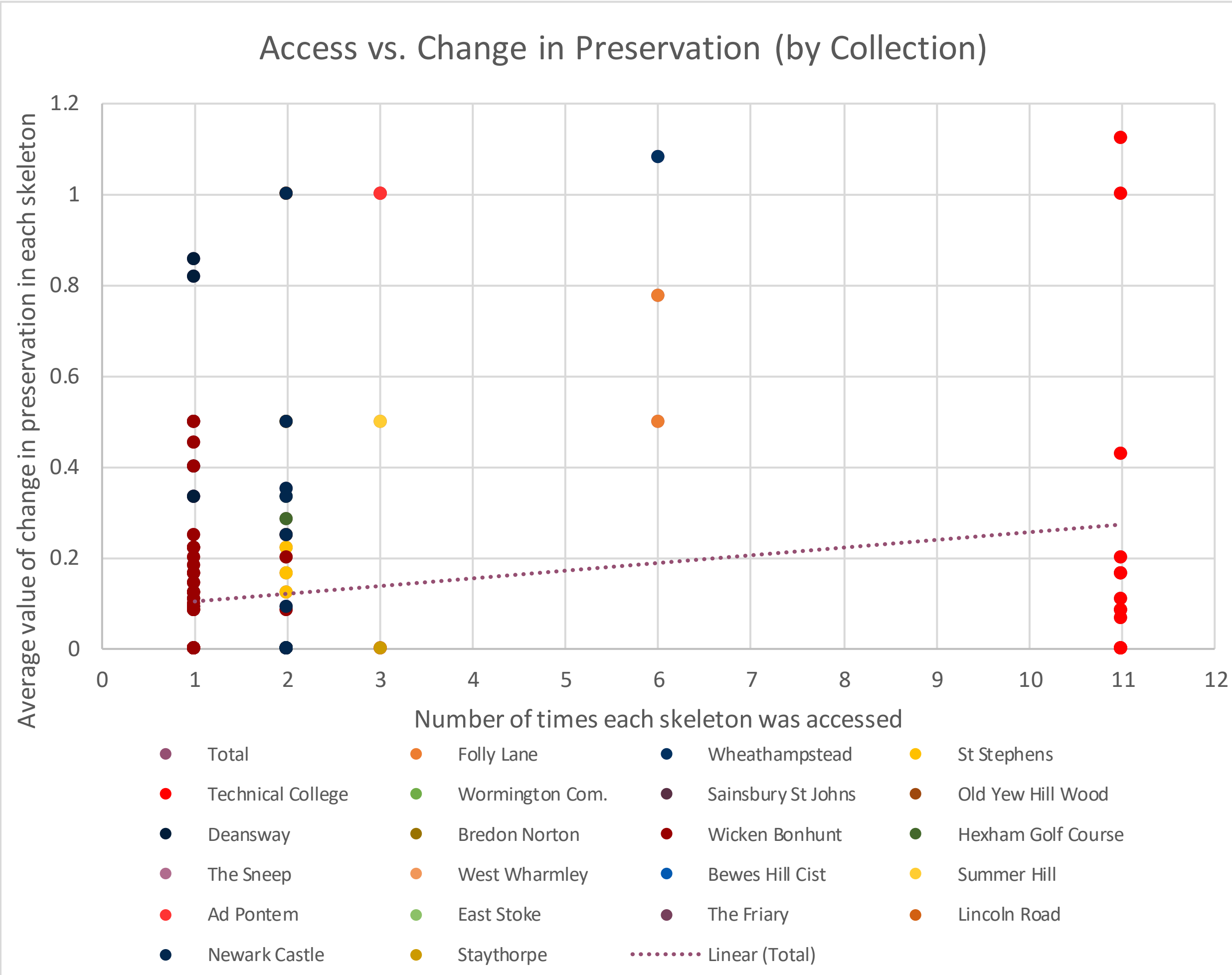


Figure 4.1: Number of times sites have been accessed compared to the change in preservation for the skeletons from each site studied (based upon the preservation scale created for this research).

remains for research purposes has on their preservation. It also provides an understanding of the damage researchers can inflict on human remains, and prompts us to reflect on the cost versus value of research. It was predicted that the more access there was to a collection the greater the change in preservation. Figures 4.1 and 4.2 show the relationship between the number of times the skeletal collections were accessed and the amount of change in the preservation. Figure 4.1 shows the breakdown of the data by collection, with each colour representing a different collection and each point representing a skeleton from that collection; the average value of change was calculated using the process outlined in Section 3.1.2 (iii). Figure 4.2 presents the data without dividing the data by site. The trendline – a line indicating the general course of the data – in Figures 4.1 and 4.2 shows a weak positive correlation. This trend is supported by the data displayed in Table 4.2. This suggests that the number of times skeletal collections have been accessed does have some effect on the change in preservation recorded for those remains, even if this effect is minor. The statistical significance testing of the results returned a *p*-value lower than α=0.05. The *p*-value indicates the probability that these results could have occurred by chance; α indicates the point at which statistical significance can be established. If α is greater than the *p*-value the null hypothesis (H0) is rejected and the correlation is deemed statistically significant. The α value commonly used in archaeological research is 0.05 (Kim and Choi 2019). Using these data, we can confidently reject the H0 which was set out in Section 3.1.2 (iii) in the Methods and Materials Chapter. Instead, we can say there is evidence that a relationship exists between the number of times the collections were accessed and the change in preservation, one that is unlikely to have been caused by chance.

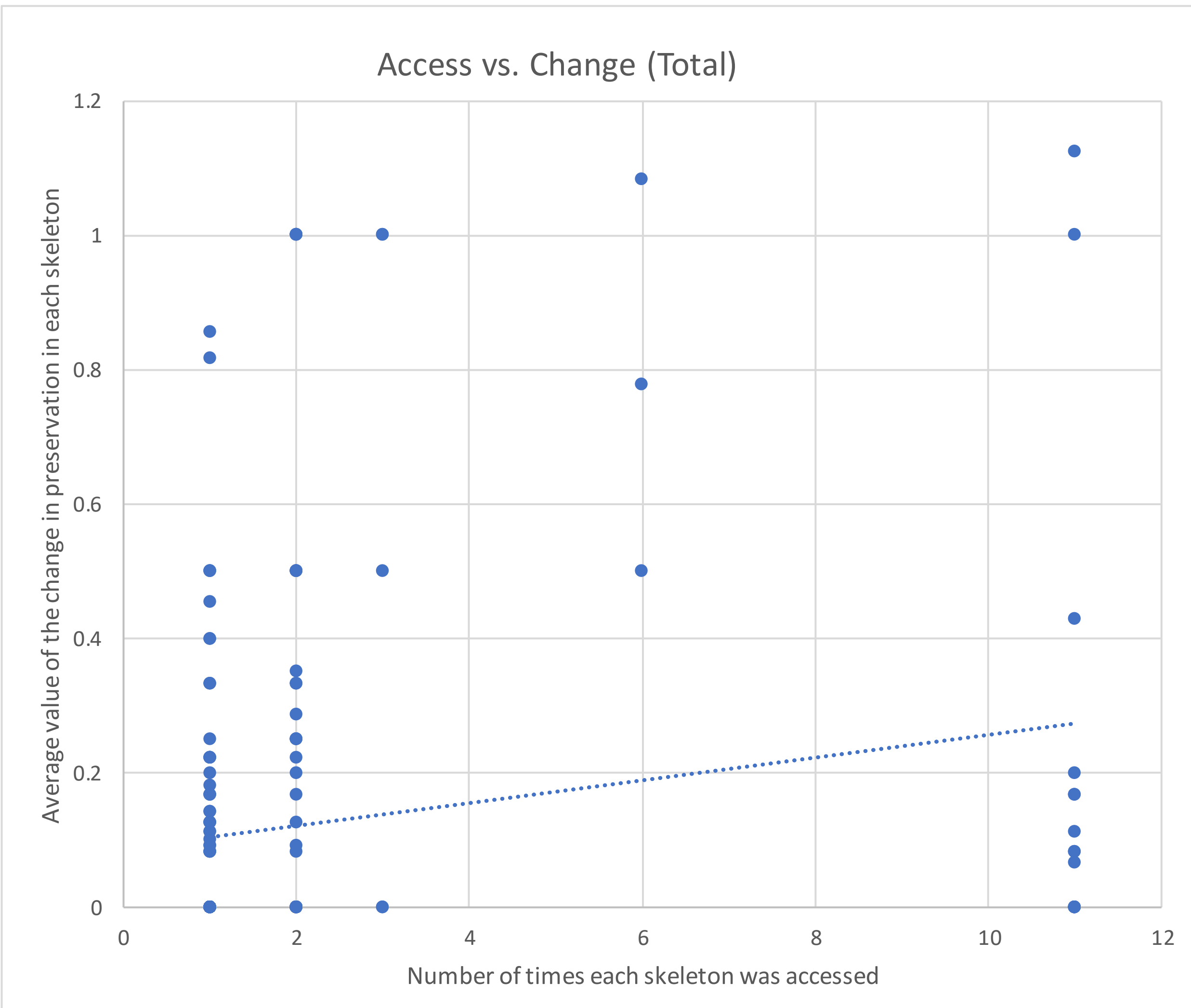


Figure 4.2: Number of times accessed vs. change in preservation, not separated by site; each dot is one skeleton (based upon the preservation scale created for this research).

4.3 Secondary Comparisons

During the course of the research, it became clear that other factors could impact the preservation of skeletal remains, and these factors were outlined in Section 3.1.2 (iv). The extent to which these factors influenced preservation was examined to determine whether research access did have any impact.

4.3.1 Start preservation

Start preservation, as defined in Section 3.1.2 (i), refers to the skeletal preservation as recorded in the earliest reliable documentation, whether this dated to excavation, accession, or later. This documentation was used alongside the preservation scale created for this study to retrospectively estimate the baseline condition for the skeletal remains. The retrospective baseline assessment provides a starting point to determine how much change has occurred. It was expected that the worse the start preservation the greater the change in preservation would be observed.

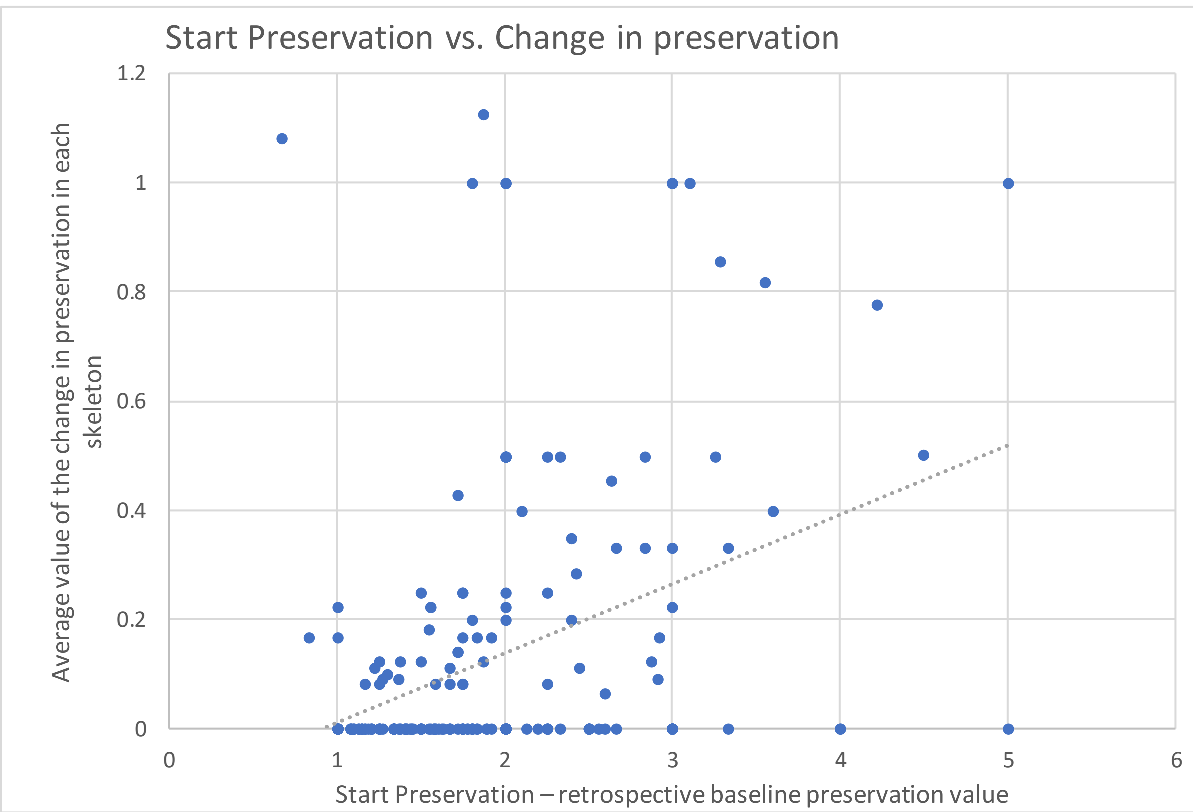


Figure 4.3: Start preservation compared to change in preservation, each dot is one skeleton (based upon the preservation scale created for this research).

The results displayed in Figure 4.3 and Table 4.3 show a moderate positive correlation, suggesting the start preservation did have an impact on the degree of change in preservation observed in the skeletal remains. The average value of change was calculated using the process outlined in Section 3.1.2 (iii).

The statistical significance of these data was calculated as p=1.7E-122 (Table 4.3), which is well below the α= 0.05 value used in archaeology. This suggests that the relationship seen between these two sets of data is statistically significant. Using these results, we can confidently reject the H0 (described in Section 3.1.2 iii.) that there is no link between the start preservation of the remains and the change in preservation over time. Instead, there is evidence for a connection, and the patterns observed are unlikely to have been caused by chance.

Table 4.3: Start Preservation vs. Change in Preservation

Pearson Correlation Coefficient	
r	r^2
0.37604	0.14140

Statistical Significance: T-test			
p=	α=	p>α	H0
1.7271E-122	0.05	FALSE	Reject

4.3.2 Time Period (Age)

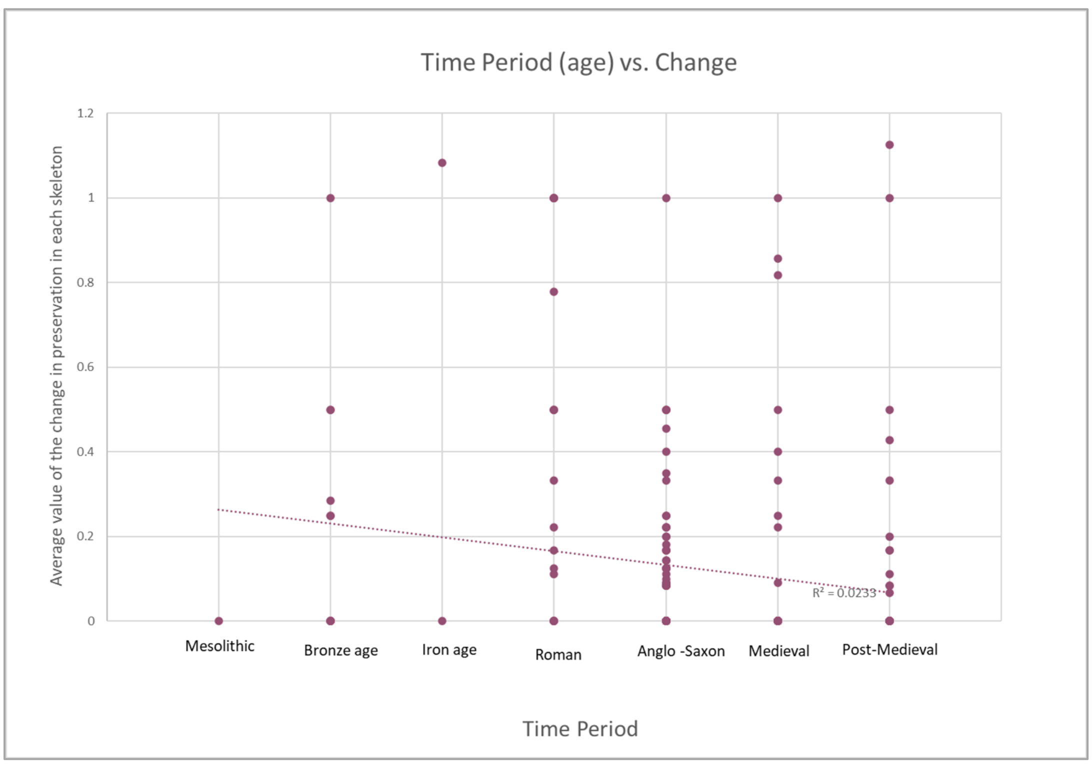


Figure 4.4: The time period of the remains in relation to the change in preservation, each dot is one skeleton (based upon the preservation scale created for this research).

The age of the remains was seen as a plausible underlying cause of deterioration. Older remains will have been considerably longer in the ground, and it was predicted that this difference (in some cases as much as 1000 years) could have some impact on the preservation. Age was split into broad periods from the Mesolithic to the post-medieval period. Older skeletal remains, having spent longer in the burial environment, were expected to show greater change in preservation. This is due to the deteriorating factors associated with the burial environment discussed in detail in Section 3.1.2 (iv. c). Changes in chemical composition, such as the loss of collagen, are not visible through observation alone and therefore would not be recorded as part of the start preservation. Microfractures, would not necessarily be observed during condition assessments. These types of damage, not readily apparent, were considered to be more likely among remains that had been buried for longer periods of time (Child 1995b; Collins et al. 2002; Kontopoulos et al. 2016; Pokines and Baker 2013 pp.74-87).

The data displayed in Figure 4.4 and Table 4.4 show a weak negative correlation between the age of the remains, or time period, and the change in preservation seen in the remains. This suggests that there is some link between the age of the skeletal remains and the level of change in preservation observed. Once again, the average value of change was calculated using the process outlined in Section 3.1.2 (iii).

Table 4.4 shows the results for the test of statistical significance; the data returned a *p*-value lower than α=0.05. Using these data we can confidently reject the H0 that states there is no link between age (time period) and change in preservation. Instead, the time period of the remains does have some impact on change in preservation over time, with older remains experiencing more change in the observed state of preservation.

Table 4.4: Time Period vs. Change in Preservation

Pearson Correlation Coefficient	
r	r^2
-0.15260	0.02329

Statistical Significance: T-test			
p=	α=	*p*>α	H0
4.6932E-218	0.05	FALSE	Reject

4.3.3 Storage

The quality of storage conditions is another factor that can affect the preservation of human remains. Second only to burial, archaeological human remains will spend the largest amount of their time in storage. However, storage conditions are difficult to quantify, consisting of several variables, some of which have a greater effect on preservation than others. Table 4.5 is based on the best standards for storage; a full discussion of these standards can be found in Section 3.1.2 (iv. f). These data were collected using the form presented in Appendix 12, as well as free text descriptions. The details of what information was collected as free text is given in Section 3.1.2 (i). The collation of these descriptions into categories can be found in Appendix 13. For this test, the museum names were replaced with letters for anonymity. As mentioned in Section 3.1.2 (iv. f), this storage quality score only represents the current state of museum storage and does not account for variations in storage quality over time. Photographs of the current museum storage can be found in Appendix 14. The impact of this limitation is evaluated in Chapter 5.

Table 4.5: Scores for the variables relevant to museum storage; a score of 1 indicates the museum met the criterion and 0 that it did not. The totals presented were used to generate a "storage quality value" for each museum. For the purposes of this research, a specialist was anyone who had a formal education in human bioarchaeology, or another related subject such as collections care.

Museum	Secure Storage	Dedicated Storage	Protected from Direct Sunlight	Temp. (10°C-25°C)	Humidity (55%)	Pest Free	Mould Free	Regular Inspection	
A	1	0	1	1	1	1	1	0	
B	1	1	1	1	1	1	1	0	
C	1	0	1	1	1	0	1	0	
D	1	0	1	1	1	1	1	0	
E	1	0	1	1	1	1	1	0	
Museum	**Suitable Box**	**Suitable Packing Material Used**	**Sturdy Metal Shelving**	**Shelves at Least 10cm from Ground**	**Boxes not Stacked**	**Ordered**	**Consolidants not Used**	**Specialist on Staff**	**Total**
A	1	0	1	1	0	0	1	0	10
B	1	1	1	1	0	1	1	0	13
C	1	1	1	1	0	1	0	0	10
D	1	1	0	0	1	1	1	0	11
E	1	1	1	1	0	1	1	0	12

The museums were ordered according to storage quality value and the value was compared against the change in preservation of the human remains held at each museum. It was expected that the higher the storage value, that is better storage, the lower the change in preservation would be.

Table 4.6: Storage Value vs. Change in Preservation

Pearson Correlation coefficient	
r	r^2
-0.34095	0.11625

Statistical Significance: T-test			
p=	α=	*p*>α	H0
8.8049E-240	0.05	FALSE	Reject

The results displayed in Figure 4.5 and Table 4.6 show a moderate strength negative correlation; the average value of change was calculated using the process outlined in Section 3.1.2 (iii). As expected, the higher the storage value the less change occurred in the preservation of the remains over time. Table 4.6 shows that the statistical significance testing returned a value well below α=0.05. This means we can confidently reject the H0 that states there is no link between the storage value (quality) and any change in preservation, or that this link is caused by random chance. Instead, the quality of storage used by a museum does have an impact on the preservation of the human skeletal remains stored.

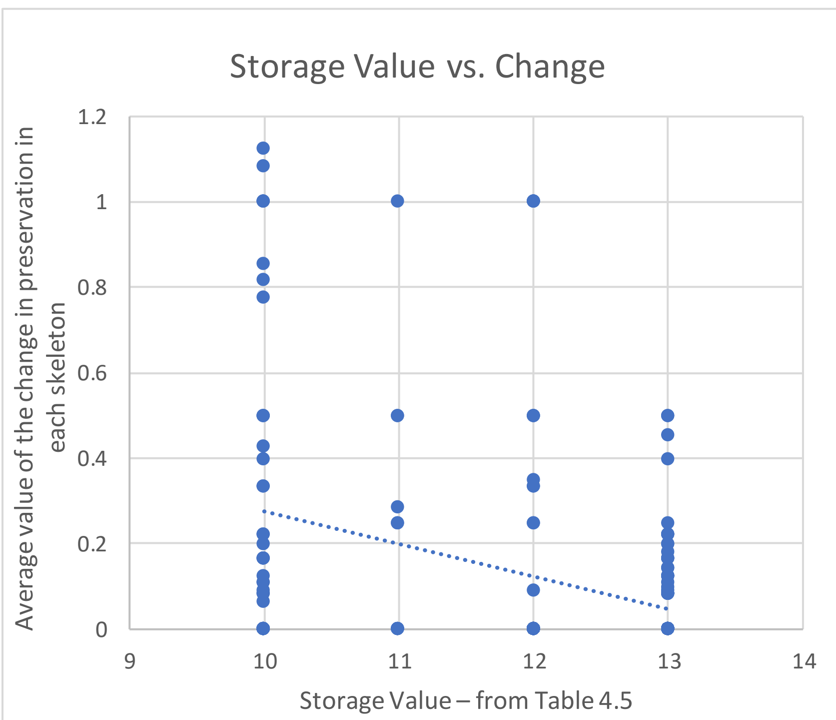


Figure 4.5: Comparison of storage quality and change in preservation (based upon the preservation scale created for this research).

4.3.4 Time Out of the Ground

Time out of the ground is defined as the time that has elapsed since excavation of the remains. This includes the period that the remains have been in the care of the museum. It was expected that the longer the remains had spent out of the ground the greater the change in preservation would be.

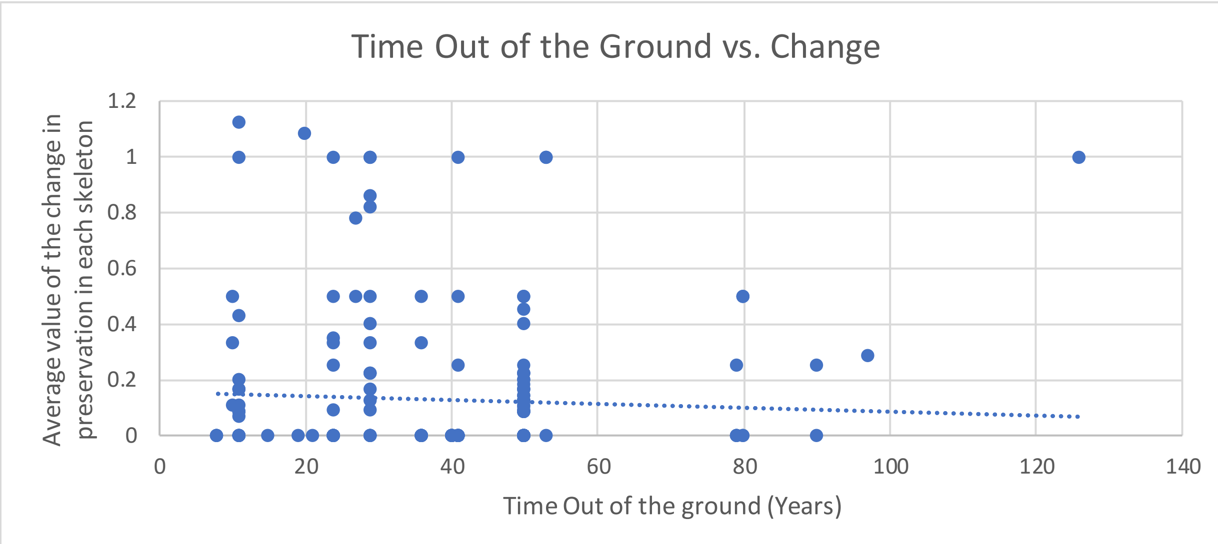


Figure 4.6: Comparison of the time the remains have been out of the ground and the change in their preservation (based upon the preservation scale created for this research).

Figure 4.6 and Table 4.7 show that there is no correlation between the time the skeletal remains have been out of the ground and the change in preservation seen in the remains (a value between -0.1 and 0 indicates zero correlation). Although no correlation was found, the statistical test (Table 4.6) shows that the results are still meaningful. This is because the low *p*-value implies that the pattern has not been created randomly and we can still reject the H0. Although there is no correlation between the two data sets, there is still a link; the pattern, or lack thereof, was not a coincidence. This will be discussed in more detail in Chapter 5.

Table 4.7: Time Out of the Ground vs. Change in Preservation

Pearson Correlation Coefficient	
r	r^2
-0.04864	0.00237

Statistical Significance: T-test			
p=	α=	*p*>α	H0
4.1763E-125	0.05	FALSE	Reject

4.3.5 Museum Type and Size

It is no secret that in the last few decades the museum sector in the UK has been suffering from a serious lack of funding (Kalia 2019; Kendall 2018a; Kendall 2018b). As different types of museums acquire funding from a variety of funders, some have endured better than others. For example, local government-run museums have fared the worst (Steel 2018), due to the governmental programme of austerity and the years of budget cuts the heritage industry as a whole has faced. Thus, the type and size of a museum may have an effect on preservation of the human remains it curates. Both of these factors are investigated below.

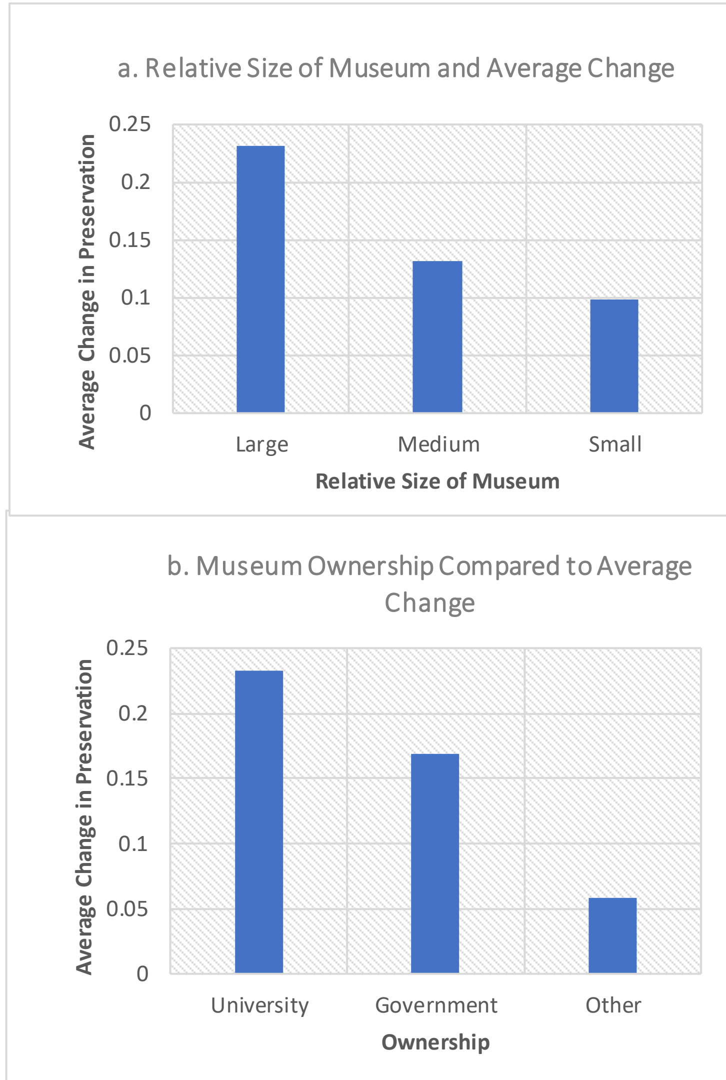


Figure 4.7 a: Size of museums compared to average change in preservation; b: Ownership of museums compared to average change ("other" refers to Saffron Walden Museum, which is partly owned by a trust). (Based upon the preservation scale created for this research).

Average change was calculated by summing all of the "change in preservation" values for each skeleton, then dividing this figure by the number of skeletons in each "type" category (large [n=1], medium [n=3] or small [n=1]; University [n=1], Government [n=3] or Other [n=1]). It was expected that museums partly run by universities ("shared") would have the highest amount of change in preservation of their collections, as it was assumed that they are more likely (and more often) to be used for teaching and research purposes, than those at the other "types" of museums. Smaller museums, with fewer staff and less funding were also expected to have more change in levels of preservation in their skeletal collections because of lack of resources available to dedicate to the curation of human remains.

Figure 4.7a shows how the size of the museum can affect the change in preservation of the remains. Based on the data, collections curated in smaller museums seem to undergo the least amount of change in preservation. This comparison will be discussed more in Chapter 5. Figure 4.7b shows how different management of the museums in this study affected change in the preservation of the skeletal collections they curated. The results show that the "other" management style used by the Saffron Walden museum (jointly owned by a local authority and a trust) correlated with the least amount of change; once again this factor will be discussed in more detail in Chapter 5.

4.3.6 Soil pH

The influence of the burial environment on the preservation of human remains consists of a myriad of inter-related factors (Garland and Janaway 1989; Mays 2010b pp. 22-24); however, the pH value of the surrounding soil, in particular, has consistently been shown to affect the state of preservation of human remains (Garland and Janaway 1989 p. 18; Mays 2010b pp. 22-24). Furthermore, the adherence of soil to bone may result in further deterioration after excavation; when the soil dries and flakes off it can take the bone surface with it. Soil pH for each site was estimated from the GIS (Geographical Information System: UKSO.org 2018) survey maps of England. It was expected that the lowest amount of change in preservation over time would be found in a neutral soil with a pH value of 7 and the further the pH deviated from this the more change would be seen. The average value of change in preservation was calculated using the process outlined in Section 3.1.2 (iii).

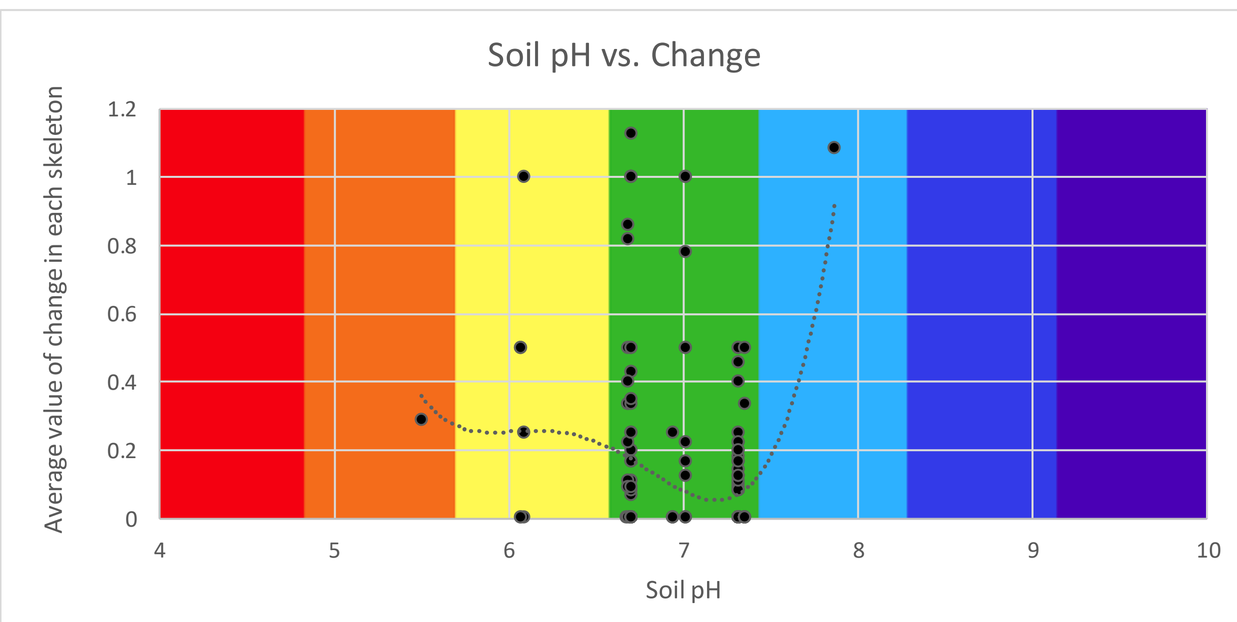


Figure 4.8: Comparison of the soil pH of the sites excavated and change in preservation, each dot represents one skeleton. (Based upon the preservation scale created for this research).

Table 4.8: Soil pH vs. Change in Preservation

Statistical Significance: T-test			
p=	α=	*p*>α	H0
8.0897E-256	0.05	FALSE	Reject

An *r* value could not be calculated for these data as Pearson's correlation coefficient can only calculate linear correlations, which would not be suitable for the data. Instead, a polynomial trendline (defining a pattern in data that is curved or does not fit a straight linear trendline) was used to emphasise the patterns in the data (Figure 4.8). The data show that the lowest level of change in preservation can be found around a soil pH of 7, or neutral, where the majority of the dots are grouped. Some outliers can be found in the data, particularly with skeletons buried in soil of a neutral pH having high levels of change in preservation. These outliers can be explained by looking at the other factors that can influence the preservation of the skeletal remains, which have been discussed above. Table 4.8 shows that the results for statistical significance testing return a value below α=0.05. This means we can confidently reject H0 that states there is no link between soil pH and change in preservation, or that the link between these two sets of data is coincidental. Instead, pH does have an effect on preservation levels observed in the skeletal remains considered.

4.4 Access Factors

Assessing the amount of access and the influence it had on the preservation of human remains was the primary aim of the research (Section 1.5.1 – Aim 1 and Section 4.2). As such, it was deemed pertinent to analyse which factors affected access. It should be noted that the maximum number of research visits found within these collections was 11, with the majority of these collections experiencing one or two research visits (see Table 3.10). Therefore, the range of access experienced by the collections in this study was relatively low. Some well-known collections, such as Christ Church Spitalfields, London, experience significantly higher amounts of access (accessed at least 52 times over a period of 19 years – Roberts and Mays 2011 p. 628), which could skew the data. However, the majority of the collections held in museums in the UK are not as well-known and experience far less access for research (Roberts and Mays 2011). Research by Mays (2010c) has shown that repeat research on skeletal collections occurs largely (91%) on collections of 100 individuals or more. Yet data published in 2010-11 found that only 13% of skeletal collections in the UK are comprised of over 100 burials (Mays 2010c; Roberts and Mays 2011 p.629). The regional museums and their smaller skeletal collections utilised in this research are more representative of the amount of access experienced by skeletal collections in museums. Therefore, although well-known collections are not included, the conclusions drawn here are more representative of UK museums, and the data do provide useful insights into the factors that affect access to collections by researchers. These findings will allow museums to better understand and manage access for research in the future. Although this study endeavours to understand these factors, these data are less reliable because this study was not initially designed to evaluate these correlations.

4.4.1 Access vs Time Out of Ground

This comparison evaluated whether the time the remains had been out of the ground had an impact on the number of times they were accessed. Theoretically, the longer the remains are out of the ground, the more opportunities researchers will have had to access them. Thus, it was predicted that the longer the skeletal remains had been out of the ground, the more they would have been accessed.

The data in Figure 4.9 and Table 4.9 show a strong negative correlation between the number of times a collection has been accessed and the time the collection has spent out of the ground. This correlation was not expected. Table 4.9 shows a *p*-value lower than α=0.05. This means that we can confidently reject the H0, suggesting that the probability that this pattern was created by chance is extremely unlikely. This implies that there is a strong negative relationship between the time the skeletal remains have spent out of the ground and the number of times they have been accessed by researchers.

Table 4.9: Time Out of the Ground vs. Number of Times Accessed

Pearson Correlation Coefficient	
r	r^2
-0.51215	0.26230

Statistical Significance: T-test			
p=	α=	*p*>α	H0
3.7025E-116	0.05	FALSE	Reject

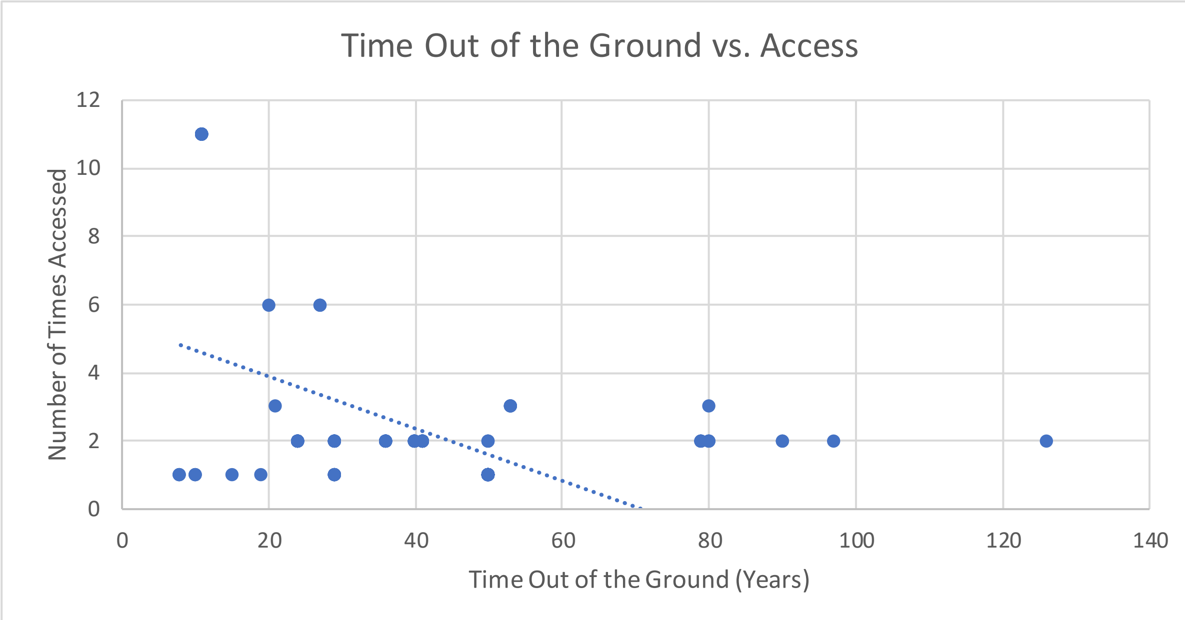


Figure 4.9: Comparison of the time the remains have been out of the ground and the number of times they were accessed.

4.4.2 Access vs Time Period

This comparison was created to evaluate the impact time period had on access. Time period was not a controlled variable in this research and, as such, the number of individuals in each of the time period categories was uneven. This disparity should be remembered when considering the results of this comparison. No prediction was made regarding which time period would have human remains accessed more frequently than other time periods. Research questions should theoretically cover human remains from all periods equally, although in practice this may not be the case as some periods may generate different research questions from others.

Table 4.10: Time period vs. Number of Times Accessed

Pearson Correlation Coefficient	
r	r^2
0.38769	0.15030

Statistical Significance: T-test			
p=	α=	*p*>α	H0
2.66756E-40	0.05	FALSE	Reject

The results presented in Figure 4.10 and Table 4.10 show a moderate strength positive correlation between the period in which the skeletal remains were interred and the number of times the remains were accessed. This implies that, from the data collected, the more recent periods appear to be more popular with researchers. Table 4.10 shows that the *p*-value returned from the T-test was below the α value of 0.05. Therefore, we can reject the H0 - no link between these two sets of data – and reject that the link between them is coincidental. Instead, there is a relationship between the time period in which the skeletal remains were buried and the number of times they have been accessed.

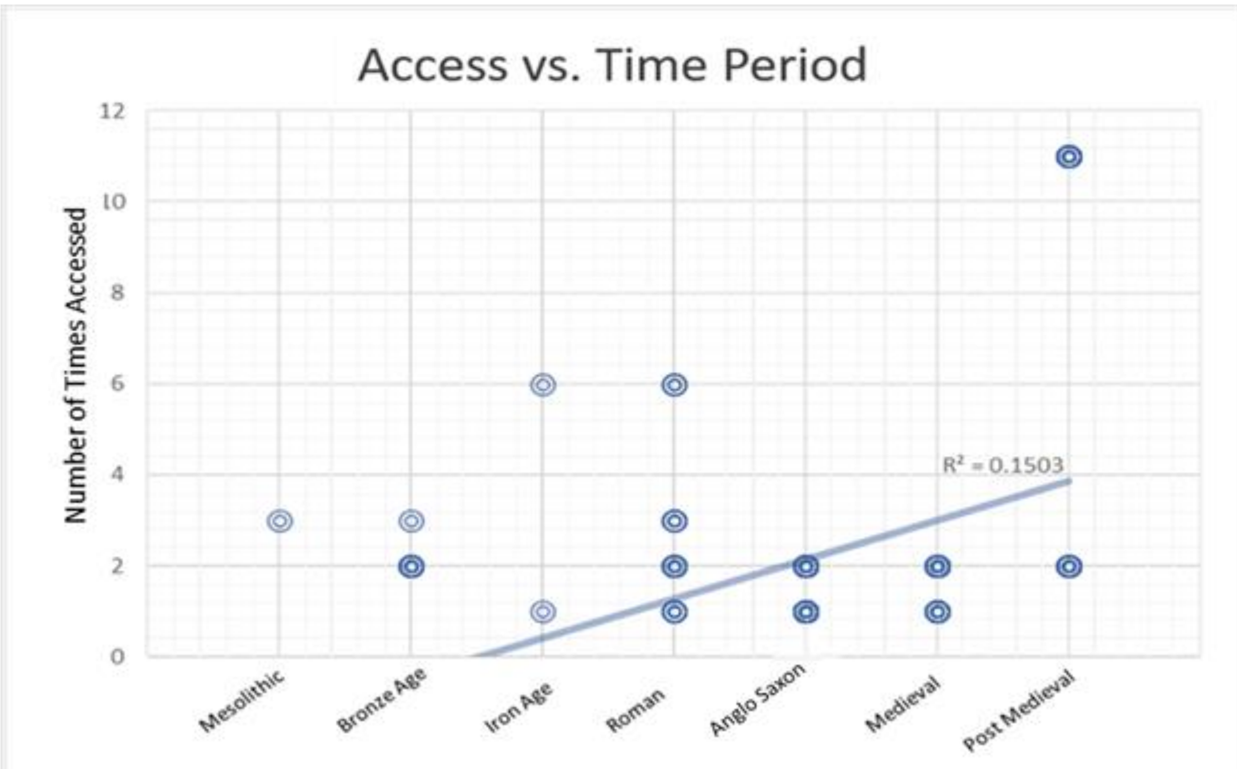


Figure 4.10: Comparison of the time period of the collections and the number of times accessed. The shade of the data point demonstrates the variation in the number of individuals in each time period, with the darker points indicating time periods comprised of more individuals.

4.4.3 Access vs Start Preservation

The start preservation is an estimation of how well-preserved the remains were at the start of curation. If the skeletons from a site had better preservation, then more detailed and useful data would be collected, and more knowledge could potentially be gained through the research. This would suggest that the better-preserved remains would have been accessed most often.

Table 4.11: Average Start Preservation vs. Number of Times Accessed

Pearson Correlation coefficient	
r	r^2
0.14812	0.02194

Statistical Significance: T-test			
p=	α=	*p*>α	H0
0.034047	0.05	FALSE	Reject

Figure 4.11 and Table 4.11 show a weak positive correlation between the data, suggesting that the worse the preservation of the remains, the more times they were accessed. This result was not expected and will be discussed in greater detail in the Chapter 5. Table 4.11 shows that when statistical significance was tested, a *p*-value below α=0.05 was returned, meaning the data were statistically significant. Therefore, H0 was rejected indicating that the links between these variables were not caused by random chance. It should however be noted that the value returned (*p*=0.034047) was only just below the threshold for significance. Although the correlation is still significant, this is the least reliable result produced in this study.

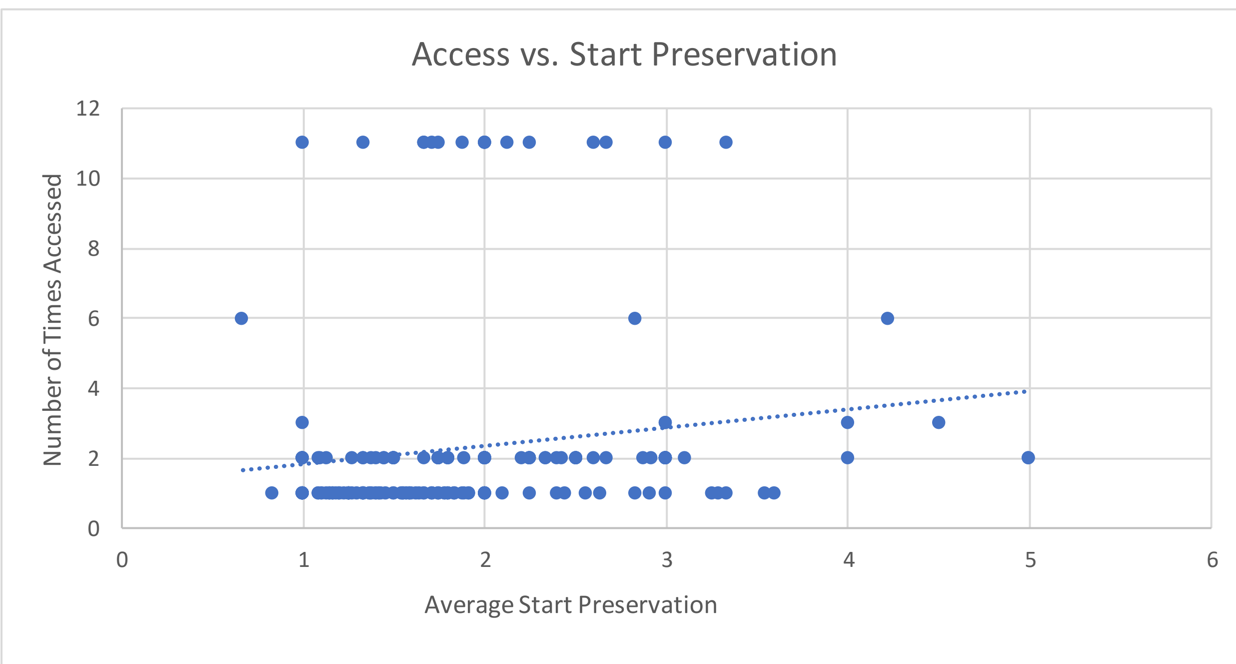


Figure 4.11: Comparison of the average start preservation and the number of times accessed (based upon the preservation scale created for this research).

4.4.4 Museum Type vs Access

Does the type of museum have an impact on access, or is a particular type of museum more inclined towards encouraging research? Are museums that have been struggling with funding less likely or able to encourage research, or is it simply whether or not the collections are known by researchers and have research potential? It was predicted that the larger museums would have collections that were accessed more because larger museums tend to have the funding, facilities, and staff to encourage and support research. It was also predicted that "shared" university museums would have the greatest amount of access because these institutions already have research facilities and should thus encourage and support research.

"Average access" was the sum of all the access values for each skeleton divided by the number of skeletons. This was calculated for each type and size of museum. Figure 4.12a shows that the museums run by local councils had collections that were accessed more than the shared university museum, or other museum. Figure 4.12b shows that the difference between the number of times the collections were accessed at small, medium, and large museums was minimal. The total difference was approximately 0.4, significantly less than the total difference observed in the type of museum, which was between 1 and 2. These comparisons will be discussed in greater detail in Chapter 5.

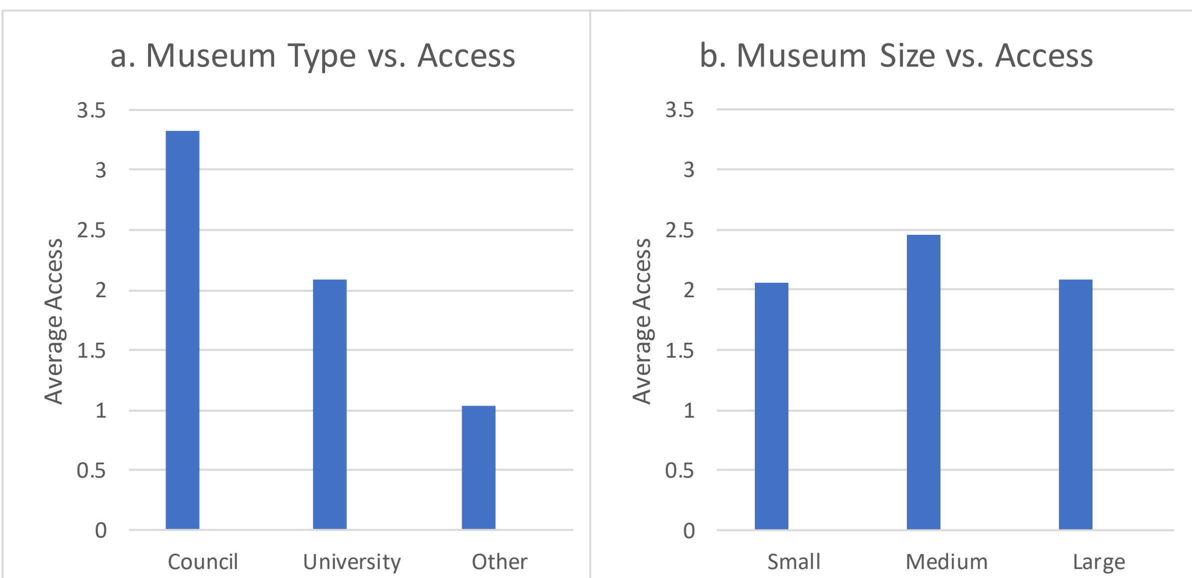


Figure 4.12: a: Average access to museums run by councils, universities and 'other'; b: Average access to museums according to the size of the museum. (Other once again refers to Saffron Walden Museum, which is partly run by a trust.)

4.5 Summary

In this chapter the data collected and their statistical analyses were presented. The primary research focus has been the link between access to, and deterioration in the preservation of the human skeletal remains of interest. Other potential variables that could affect preservation were also analysed. Additionally, factors have been presented that have the potential to influence access to collections by researchers. These were analysed to determine which factors significantly increased or decreased amount of access. In the next chapter, the data presented are discussed in relation to the original hypotheses and questions outlined in Chapter 1.

Chapter 5: Discussion

In this chapter, the results of the research outlined in the preceding chapter are considered in more detail. The original hypothesis proposed that accessing human skeletal remains for research purposes in museums or other institutions has a detrimental impact on their preservation. This was analysed, and the extent to which access impacts preservation was explored. Other factors that impact the preservation of human remains are then considered. The research outcomes are discussed: in particular, whether the initial predictions matched the observed patterns, i.e., whether the overarching hypothesis could be accepted or rejected. Where the observed patterns in the data failed to match the predictions, the potential reasons are discussed. The use of the "mean average" to calculate change in preservation of the human remains is defended. Furthermore, the use of parametric tests for ordinal data is upheld, as well as the use of parametric testing more generally in archaeology. A cost assessment of the variables related to the storage of human remains in museums is then presented, to allow museums to understand the cost of improving their storage, as well as which improvements have the best value for money. Lastly, the wider implications of this research are discussed, including outlining cost-saving strategies to help museums finance the effective long-term storage and preservation of human remains in their care. The problems museums are currently facing are outlined and potential solutions presented, including the controversial topic of deaccessioning human remains and how we might limit loss of information via recent technological advances. In relation to storage, problems facing commercial archaeology companies are also discussed.

5.1 Primary Comparison - Access vs. Change

The primary aim of this study was to evaluate the relationship between observed change in the preservation of a curated skeletal collection and the amount of research carried out on that collection – estimated by using records recording the number of times the collection was accessed. To satisfy time constraints primarily set by the museums, only adult long bones were evaluated for this study. Long bones are not used for every research project on human remains; thus, there is no guarantee that when an individual is accessed for a study the long bones were handled (which is why care was taken when ascertaining the form of access). Further, the pattern of degradation experienced by human remains may not be consistent between long bones and other skeletal elements. However, to fully evaluate the preservation of each individual skeleton would have required both additional time and space, neither of which were readily available from the museums visited.

"Access" was defined as any time anyone removed skeletal remains from their storage box for any purpose, provided that this included the long bones (even if this was moving the long bones, to gain access to another bone). "Change in preservation" was defined as how much deterioration in preservation had occurred in the skeletal remains since they were accessioned, or last recorded. This was calculated by taking the current preservation (observations of the long bones of the chosen skeletal collections) and from that subtracting the start preservation. Start preservation, defined in Section 3.1.2 (i), was created using photographs, excavation records, skeletal reports, and any other relevant documentation to establish a retrospective baseline preservation assessment. This comparison produced an estimate for the amount of deterioration that had taken place for the long bones of each individual skeleton. However, it must be noted that this estimate could be flawed. If the start preservation indicated by the documentation was better than the initial preservation of the bones, then the inferred damage would be over-estimated, showing a greater change in preservation. Conversely, if the start preservation estimated was worse than the initial condition of the bones, then the inferred damage would be an under-estimate. Furthermore, there is no reason to assume that the variation between the estimated start preservation and the actual initial conditions of the bones would be consistent between skeletal elements, individuals, or collections. To establish the reliability of this research, further analysis of the methodology is needed, and this evaluation is outlined in Section 6.4.

Access was hypothesised to have an effect on deterioration, with more access leading to more significant amounts of deterioration. This prediction was based on the research of Caffell and colleagues (2001), as outlined in Chapter 2; a positive correlation was expected in the data.

Working on the assumption that the retrospective baseline assessment did provide a reasonable approximation of start preservation, the data collected showed a weak positive correlation (r= 0.176) between the average amount of change in preservation in a skeletal collection and the amount of access to that same collection. This indicated that the greater the amount of access that had occurred, the greater the amount of change. This result supports the earlier hypothesis. The significance test was statistically significant, with a value well below the required alpha value of 0.05 (p= 1.309E^{-29}).

The data collected indicate that access does have an impact on the amount of change in preservation observed in the skeletal remains, and that more access increases deterioration in their condition. However, on the basis of the strength of the correlation (r=0.176 – weak correlation), the impact observed in this study was relatively minor. This is especially noticeable when the strength of this correlation is compared to the other correlations evaluated in this study, some of which had a much greater impact, particularly start preservation or museum storage rating (see Section 5.2). It should be noted however, that this study did not use well-known, frequently accessed collections, such as those curated by Museum of London or Natural History Museum (see Section 4.4). Thus, although there is a risk of deterioration in the state of preservation with access, this risk is minimal, provided there are suitable guidelines and precautions in place for those who access the remains. It is important to understand that once excavation has taken place the remains are subject to deterioration, whether they are accessed for research or not (Brown and Brown 2011 pp.99-100).

Research is vitally important in archaeology; it is the basis of our vocation and provides us with the data we need to draw conclusions about the past, allowing us to better understand the life experiences of individuals. For human bioarchaeologists, skeletal remains are arguably the key subject of this research and they contain a profusion of information, as outlined in the introduction to this thesis - Section 1.1. The more skeletal collections human bioarchaeologists can access that are appropriate to the questions they wish to answer, the better our understanding of past populations, and the more robust and nuanced our conclusions will be.

Once a collection has been used for research, its usefulness is not exhausted. Research by Roberts and Mays (2011 p.629) has shown that studies foster further research that require access to the same collections of remains, and therefore the collection would need to be retained for future research. In addition, the repetition of research for the purposes of corroboration or confirmation of conclusions, using newly developed methods, is also key for advancing scientific research, again suggesting the collections should be retained. As new technologies develop, these stored collections can be accessed once more and those new technologies can be applied, allowing further information to be ascertained from the collection (Buikstra and Gordon 1981).

A museum has a responsibility to be accessible not only to visitors but also to researchers – see below (Section 5.5.1). If a skeletal collection is to be stored and curated, yet not be used for research, the purpose of the curation is questionable. The impact of research access on the state of preservation of the human skeletal remains, for the collections used in this research, is low. Regardless of whether the human remains are studied, this research shows collections continue to experience taphonomic change whilst in storage (Redfern and Bekvalac 2017). This can be exacerbated by improper storage conditions; details of appropriate storage are discussed in Section 2.2.2 (ii). Improper boxes (boxes that are too small or are not strong enough) with improper packaging can cause damage to the skeletal remains inside through erosion/scuff damage (rubbing), fresh breaks, or chipping of the bone surface. If the boxes are stacked, then the remains can also experience crushing, and this is more likely to occur if non-archival cardboard is used. This type of damage was observed in the St. Andrew Fishergate collection, curated by York Archaeological Trust (Bowron 2003). Bowron (2003) observed approximately 1325 bones across 40 adult skeletons showing signs of scuffing or erosion and 834 incidents of fresh breaks. It should be noted, however, that the storage conditions for the St. Andrew

Fishergate collection during these observations met guidelines for boxes and packaging. Thus, these taphonomic changes occur even when storage conditions are considered acceptable. Taphonomic changes may also result from environmental conditions, with delamination and cracking observed in low humidity conditions and mould growth observed in high humidity conditions (Bowron 2003). These processes can lead to deterioration of skeletal remains or the obscuring of anatomical landmarks or pathologies (Redfern and Bekvalac 2017). This damage was significantly less common among the St. Andrew Fishergate individuals observed, with only 5 bones showing evidence of delamination and a further 16 showing cracking (Bowron 2003). Skeletal remains in curation experience continual deterioration and taphonomic changes regardless of the amount of access allowed to them. Therefore, concerns regarding preservation are not a strong reason to deny access for the purposes of research while a collection is being curated.

5.2 Secondary Comparisons

To provide context and comparison with the data generated on the effect of access on the deterioration of the skeletal remains considered in this study, six other potential risk factors for the preservation of skeletal remains were considered. These factors – start preservation, age of the remains, storage conditions, time out of the ground, museum type/size, and soil pH – are discussed in detail below. First, each factor was assessed to determine the impact it had on the deterioration of the remains. Second, actions that could prevent or lessen the effect of these factors are discussed.

5.2.1 Start Preservation vs. Change

Start preservation was defined in Section 3.1.2 (i) as a retrospective baseline preservation assessment dependent on the documentation available; see Table 3.10 for details on this documentation. This assessment estimated the preservation of the skeletal remains at or near the beginning of their curated life. However, in some cases, such as the Ad Pontem collection, the most reliable documentation dated from significantly after excavation and accession. The hypothesis was that initially poorly-preserved skeletal remains would experience a greater amount of deterioration (Section 3.1.2 iv a). Therefore, a positive correlation between the two variables would support the hypothesis. The data collected in this research showed that there was a moderate strength positive correlation (r= 0.376) between the start preservation and the change in preservation. This means that the higher the start preservation (categories 4 or 5 in this study indicating poorly-preserved skeletal remains), the greater the change in preservation, which was consistent with the hypothesis. However, issues may be found if the observed collections start at preservation category 5+, as the scale does not go any higher. This issue is unavoidable as the highest category is always going to be achieved by collections at some point. Therefore, once a collection gets to 5+ the preservation scale is no longer useful, and another method is needed to track changes. While no collections started at 5+ in this thesis, this could be a potential problem if this research is conducted on a wider set of data.

This moderate strength correlation shown in the results chapter (Section 4.3.1) indicates that the start preservation of the skeletal remains (the retrospective baseline preservation assessment) is an important factor when considering the changing preservation of skeletal remains stored in museums. Skeletal remains that are accessioned by a museum in a poor state of preservation will likely deteriorate more than well-preserved remains over the same period of time. This potential risk factor should, therefore, be considered by museums and other repositories that store or curate human skeletal remains for research purposes. However, this does not mean that remains that are poorly-preserved on a macroscopic level do not have any value; such remains may still be used in biomolecular analyses and other similar types of research or for training in these types of methods (Booth and White 2014). The start preservation, as shown by this research, also had a more significant effect on the preservation of skeletal remains than the amount of access. Thus, it could be argued that poorly-preserved remains should be deaccessioned by museums, unless these remains are of particular significance, for example rare pathological bones or prehistoric in date. This would create more space and save resources for better-preserved skeletal remains, as well as other archaeological materials. Skeletal remains that have better start preservation also will, according to the evidence presented in this research, retain information that is useful for researchers for longer. Deaccessioning skeletal remains will be discussed in more detail later in this chapter (Section 5.5.4) as deaccessioning is a complex issue rather than a simple solution to the on-going storage crisis.

A limitation in this comparison is the variation in the timing of the documentation used to create the retrospective baseline preservation assessment. These documents may have been created at excavation, at acquisition, during accession or even later (see Table 3.10 in Chapter 3). This variability may have had an impact on the results, as the time that elapsed between accession and the creation of the documentation may have caused discrepancies between the actual preservation of the remains at accession and their preservation at the time they were documented in the sources used to reconstruct their 'start preservation' (i.e. to establish the retrospective baseline assessment). Thus, during the period between accession and the creation of the documentation the condition of the remains may have deteriorated and this change would not be captured in this research. However, this variation in the timing of the retrospective baseline preservation assessment is unlikely to impact the correlation between start preservation and change. This correlation tested whether poorly-preserved remains deteriorated more than well-preserved remains while held within museums. However, the estimation of start preservation may have had unknown biases relating to state of preservation; well-preserved remains may be more accurately estimated by the retrospective baseline assessment than poorly-preserved remains or vice versa. Consequently, the results of this aspect of the research need to be viewed with caution until the methodology for estimating the 'start preservation' can be tested to ensure no such biases exist, or determine how potential bias can be adjusted for. Further research investigating the reliability of the methodology used to estimate start preservation is proposed in Section 6.4. The discrepancy between accession dates and the documentation used to create the start preservation will also have a significant effect on the comparison of time out of the ground vs change (Section 5.2.4). Yet, outside of a longitudinal study, a retrospective baseline assessment based on available documentation was the best possible method for determining the change in preservation over time. Therefore, despite some issues with the timings in the recording and creation of some of the documentation used in this thesis, it still represents the most complete documentation we have.

Determining start preservation was not without problems. Like many of the comparisons used in this thesis, concessions had to be made. Start preservation as mentioned in Section 3.1.2 (i) was the retrospective baseline preservation assessment, created from any available documentation or photographs. It was from this documentation that the problems arose. In Section 3.1.2 (i), the preferred documentation for creating the baseline was explained; this included photographs, skeletal reports, and excavation reports. Although photographs were the preferred method for establishing a retrospective baseline, the quality, resolution, and detail of these photographs varied significantly (probably due to the increasing quality of cameras and photography technology over time). In some cases, elements of a skeleton were obscured in the photographs that were taken *in situ* and therefore a preservation baseline could not be created; in these cases that element had to be discounted and could not be evaluated for this research. A further issue that was introduced in 3.1.2(i) was that *in situ* photographs can present bones as more complete than they are, as the soil matrix may hold fragmentary bones in place (Brothwell 1981). Once removed from the archaeological context and cleaned, the preservation of these bones will no longer be correlated with the *in situ* photograph. However, as discussed in 3.1.2(i) this can be mitigated by distinguishing between fresh breaks and those sustained whilst in the burial environment. Yet, some fresh breaks will occur in the interval between the taking of the *in situ* photograph and the accession of the remains by a museum. Thus, where *in situ* photographs were used in the creation of a retrospective baseline assessment the resulting change in preservation that was calculated may be an over-estimation of the damage that had occurred during curation. Similar to the photographs, the descriptions in the skeletal reports and excavation reports also varied significantly; their usefulness depended on the detail and clarity of the wording. The descriptions available for Skeleton 1442 from Sainsbury St. John in Western (2009), shown in the second example in Figure 3.7, provide an example of the type of detailed description that was useful for this study. However, as mentioned in Section 2.3.1 (iv), preservation of human remains has often been recorded along a "traffic light" system with the only indication of the condition of the remains given as "poor", "average" or "good". This type of description is insufficient for creating a retroactive baseline preservation assessment.

These problems with the documentation, which are vital to creating the retrospective baseline, if not managed properly could impact the reliability of the baseline preservation assessment. That is why choosing collections that had complete and reliable documentation was so important. Although the collections used in this research were selected for their excellent documentation, there were still issues encountered in establishing a retrospective baseline; see Section 3.2. Unfortunately, this need for detailed documentation also limits the ability to use this method on a wider scale as few collections are accompanied by this reliable documentation. The methodology for establishing a retrospective baseline from documentation should be evaluated to establish the accuracy and reliability of this methodology. The details of such an evaluation are discussed in full in Section 6.4 (Future Research) as the evaluation data would have a significant impact on the future use of this method. The evaluation of the method could have had an impact on the conclusions drawn in this thesis; however, this evaluation was not conducted as part of this thesis due to time constraints.

5.2.2 Age (Time period) vs. Change

As explained in Chapter 3, the time period of the skeletal collections was compared to any changes in preservation. This was to evaluate the effect age had on deterioration in the preservation of the skeletal remains. It was hypothesised that remains from earlier periods would experience more change in preservation; the older skeletal remains were expected to be more susceptible to further deterioration (Section 3.1.2 iv b). Henderson (1987 pp. 45-46) described three main factors affecting the preservation of bone *in situ*: the environment, including soil type and water levels; interactions with flora and fauna; and human activity, such as ploughing. The longer the bones are subject to these factors, the more damage could potentially occur (White and Folkens 2005 pp. 52-55). For example, a skeleton of a person who lived in the Bronze Age versus a post-medieval person would be thousands of years older, and this difference in age was predicted to have an effect on preservation in the ground, as the remains have been buried for longer. Consequently, a negative correlation was expected.

The results presented in the previous chapter showed a weak negative correlation between the age (time period) of the collections and change in preservation, meaning the hypothesis was supported; age does have an impact on the preservation state of skeletal remains. However, this impact was less than other risk factors analysed. The results should not be used to suggest only skeletal collections of recent date should be stored. Each time period is important and the value from one period cannot be shown to be greater than another. Instead, the data can be used to show that collections from different periods can deteriorate differently even to a small degree. Therefore, these collections require alternative considerations, which museums and other repositories need to explore. These considerations can be as simple as extra packaging in the box the remains are stored in, or more frequent condition checks. Thus, with older-aged collections additional attention must be given to storage conditions to prevent excessive deterioration.

5.2.3 Storage Quality vs. Change

Storage, as described in Chapter 3, was a challenging factor to quantify in relation to preservation change in skeletons. A value was assigned to each museum, which was derived from scores for each aspect of storage quality, as outlined in Roberts (2018 pp.96-98), Spectrum (Collections Trust 2017c) and The Collections Trust (2020a). A value of 16 would mean that the museum's storage was perfect and met all the conditions set forth. However, as shown in Chapter 4, no museum achieved a perfect score, and all had conditions that were not met. The information required for this comparison, as discussed in the Methods and Materials (Chapter 3), was recorded in the notes section of the form (found in Appendix 12), to allow more freedom in the responses. Importantly, the storage conditions were not weighted, and each "storage factor" was considered equal when calculating storage quality value. The museums were ranked in ascending order by the values they achieved. As aspects of storage evaluated were taken from guidelines on the appropriate storage of human skeletal remains (Cassman et al. 2006; Collections Trust 2020a; Garland et al. 1988; Janaway et al. 2001), it was hypothesised that a higher storage quality score would result in lower levels of observed deterioration. Therefore, a negative correlation was expected (Section 3.1.2 iv. f).

The results showed a moderate strength negative correlation (r= -0.34095) between the storage value and change in preservation, which means the hypothesis was supported – storage conditions did affect the preservation of skeletal remains in this study.

This was one of the strongest correlations found in this research. It shows that proper storage conditions are vital for the long-term preservation of human skeletal remains. Equally, this research shows how much potential damage improper storage can do to skeletal collections, and why museums and other storage locations must try their best to follow the published guidance and standards. No museum involved in this research had "unsatisfactory" storage, characterised as a score of less than 8/16 for storage quality. Even so, clear patterns can be seen within the data. This factor will be discussed in greater detail later (Section 5.4.2).

It should be noted that the storage conditions may not have remained consistent over the period of storage. The skeletal remains could have been stored in unfavourable conditions for 20 years, causing deterioration, and then have been moved to more favourable conditions. The observations of the storage conditions would only record the current storage conditions, not the past conditions and this could give a misleading impression of the correlation between storage conditions and bone deterioration. Two museums evaluated in this study had moved within the last 20 years; neither had accurate information for their previous storage facilities. However, it is likely that the older collections have also experienced a change in storage conditions at some point in the past. For instance, at the Great North Museum (Hancock) some of the skeletal remains had been stored in newspaper in the past; this is known only because these newspapers dated to the 1930s and were kept alongside the skeletal collections (now in separate plastic bags) for their historic value. This is an unfortunate and unavoidable limitation, as museums rarely have a record of the condition of their old storage facilities. No museum used in this study had complete accurate records of past storage conditions. Even if these records were available, using them may be problematic as storage conditions rated "acceptable" in the past may not be considered acceptable by modern standards. For example, newspaper was regularly used as "acceptable" packing material in the past but is now understood to be detrimental to bone preservation (Roberts 2018 p.92; SMA 2020). Therefore, some care must be taken when interpreting these results.

5.2.4 Time Out of the Ground vs. Change

"Time out of the ground" refers to the time since excavation and gives us a glimpse into the story of the skeletal remains since discovery. This is distinct from the age (time period) which was described as time since burial. The time out of the ground allows us to investigate the effects that long-term curation has on the preservation of skeletal collections. It was hypothesised that the longer the skeletal remains had spent out of the ground, the more time they would have experienced being handled and stored. Therefore, more change in preservation would be expected and consequently a positive correlation would be expected (Section 3.1.2 iv c). However, this expectation may be complicated by the fact that several of the museum collections were excavated long before any reliable documentation was produced (see Section 3.2). Four of the collections were excavated more than twenty years before the documentation used to establish a retrospective baseline was created (see Figure 3.10). This time gap potentially caused a discrepancy between the recorded start preservation and the preservation at accession for these collections. As the deterioration of human skeletal remains does not progress in a uniform fashion, the magnitude of change that occurred in the remains between accession and the creation of these documents is unknown. Whilst this issue would not have impacted the other comparisons in this research, it would have a significant impact on this comparison. However, this research could only be conducted by using the documentation that was available.

The *r* value calculated for these data was -0.0486. According to Evans (1996) this value indicates there was no correlation between these two factors; this correlation did not follow the predicted pattern. The data, however, passed a test of statistical significance ($p=4.1763E^{-125}$), which means that the lack of correlation was not caused by random variation or by chance. Instead, the data show that there is either no correlation or very little correlation between these two variables. This result is potentially due to the discrepancy between time out of the ground and the start preservation dates.

The lack of correlation suggests that time out of the ground does not affect the preservation of skeletal collections, at least for the collections observed for this study. This result was unexpected, and the underlying reasons for this observation are unclear. One argument is that storage location conditions for the collections used in this study were all satisfactory, and all rated 10 or above (see Chapter 4 for a specific breakdown). This suggests that the time the skeletal remains spent out of the ground, and therefore in storage, had comparatively little impact on preservation. However, due to the issue regarding the disparity between dates of excavation and dates of available documentation discussed above and in Section 3.2, these results should be interpreted cautiously. Whilst either of these explanations fit the data collected, future research is needed to confirm the findings. Ideally, to observe this effect of "time out of the ground" directly, the study would need to be conducted in a single museum, with relatively uniform storage conditions, which houses collections excavated over a broad time span. This comparison does not account for how many times the collections were used; however, as shown above (Section 5.1), access has comparatively little impact. This result once again emphasises the need for good storage.

5.2.5 Museum Type and Size vs. Change

The type and size of the museum were analysed together. This was primarily because the size of the museum and the type of museum both could have an impact on the same areas of museum organisation. These included, but were not limited to, the level of funding, number of staff, and the amount of space available – all of these were deemed potential factors that could impact the preservation of skeletal collections. Bar charts were used to display differences between museums. It was hypothesised that larger museums would have more resources at their disposal, which could be used for the care of their collections and that this would lead to lower levels of deterioration. This would balance out against the predictably higher amounts of access to their collections.

The type of museum was also expected to impact levels of preservation change, with shared university collections more frequently being used for teaching and research. On the other hand, local council museums, being less well-known compared to national museums (such as the Natural History Museum or the Museum of London) or universities, may remain unused for long periods of time. Thus, the hypothesis was that shared university collections would experience more change in preservation than collections held in local council museums.

The results showed that, contrary to the hypothesis, the larger museums actually had the greatest amount of change, compared to medium and small-sized museums. While the larger museums may have access to more funding and more resources, they also curate more collections and have much greater overhead (staff wages, building costs, etc.). A detailed financially-grounded study is needed to explore how funding structures affect the preservation of museum collections. This would fall into the field of museum finance and economics rather than archaeology. Nevertheless, the data collected here does give us an interesting glimpse into a pattern that warrants future investigation.

The amount of change observed in the collections when museums were divided by “type” followed the predictions made. The university group did have the largest amount of preservation change, but amongst the collections studied they also held the oldest remains (nearly 100 years since excavation) – therefore, there could be some bias. The council-run museums showed less change. However, the least amount of change came from the “other” category, a single museum controlled partly by the government but also by a charitable trust (which owns the building as well as the collections). This allowed funding and resources to be better applied (Kendall 2012; Sullivan 2017b). Therefore, this “type” of museum ownership appears to be most beneficial to the preservation of the collections. Although some concerns with trusts managing museums have been identified (Atkinson 2012; Knott 2016), the data collected suggests this structure can be beneficial for both the museum and the collections. However, the average amount of change shown in the data here was generally low. Other factors, which are discussed above, appear to have a more notable effect on the deterioration in preservation of skeletal remains.

5.2.6 Soil pH vs. Change

Soil pH of the archaeological sites studied, as described in Chapter 3, was taken from a collection of UK GIS soil acidity maps (UKSO.org) collated into a single UK wide map (Figure 5.1). This allowed for an easy approximation of soil pH for each site. The hypothesis proposed was that the closer to pH 7 (neutral) the soil was, the lower the amount of preservation change (Gordon and Buikstra 1981; Mays 2010b p.28). Higher amounts of change would be expected the closer the soil was to pH 1 (acidic) or pH 14 (alkaline). However, realistically the pH of the soil should never reach 1 or 14. Instead, soils should usually be slightly acid (5/6) or slightly alkaline (8/9) (Environment Agency 2019 p.13). Furthermore, in soil with extremely high or low pH levels, finding any preserved skeletal remains would be unlikely (Henderson 1987 p.46).

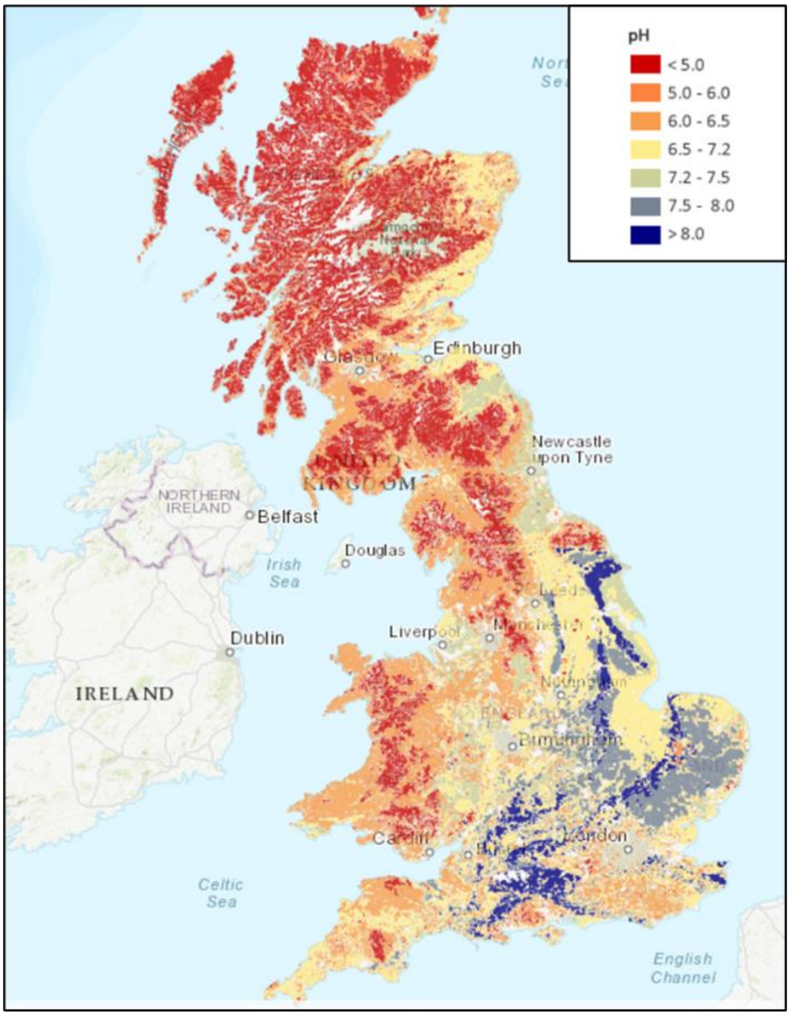


Figure 5.1: Map of the British Isles showing the soil pH in different regions. Red areas on the map indicate acidic conditions, whilst blue indicates alkaline conditions. Retrieved from http://mapapps2.bgs.ac.uk/ukso/home.html [accessed 13/10/2018]

The results showed that the lowest amount of change in preservation was found around the pH level of 7 (neutral), as hypothesised. A clear pattern can be seen between the pH level of the soil and the amount of preservation change in the skeletal remains. We must understand what this means for museums and other storage facilities. Archaeologists cannot control the pH level of the soil where remains are found. However, they can control what happens to skeletons following excavation, through the post-excavation process, which includes cleaning, recording, and packing. Skeletal remains that have come from particularly acidic or alkaline environments may benefit from extra care or consideration during acquisition, accession, and curation, such as extra packing material, or thorough cleaning. Therefore, it is important that archaeologists and museums work together to properly understand soil conditions and the impact they can have on skeletal remains, to ensure that the best care can be applied to these collections.

5.3 Factors Affecting Access

As mentioned in Chapter 3, analysis of factors that could potentially influence "access" to use skeletal remains were also evaluated, as the data pertaining to these questions had already been collected. These are factors that may influence whether researchers choose a collection for research or not. The results are discussed in more detail below.

5.3.1 Access vs. Time Out of the Ground

The time out of the ground, as discussed above, is the time since the remains were excavated. Time out of the ground was compared to the number of times the collection had been accessed. For one museum (National Civil War Centre - Newark), access was recorded from the last baseline assessment rather than from the time of excavation, and for these collections some years had elapsed between excavation and the most recent baseline assessment; thus, these results must be interpreted with caution. As discussed above, the data were collected by evaluating the best available documentation in order to provide accurate information for the primary comparison. Thus, collections were chosen on the basis of the excellent documentation, rather than consistency in timing between excavation and condition report. Despite these potential issues, patterns relating to the amount of times the remains were accessed for analysis and the time they had spent out of the ground were evaluated. The hypothesis proposed that the longer the skeletal remains had spent out of the ground, the more opportunities for research there would be; therefore, a higher amount of overall access would be expected. This would be shown as a positive correlation.

The results of this comparison showed a strong negative correlation, one of the strongest correlations measured in this research. This was the opposite of what was expected, i.e., the longer a collection had been out of the ground the less it was accessed, suggesting that as a collection ages, the likelihood of it being accessed for research diminishes. According to the data collected in this research, this establishes a research "life span" for collections, set at approximately 70 years, after which a collection is unlikely to be used for research again. This period of 70 years was based upon the pattern and slope of the trendline of the data shown in Figure 4.9. The reasons for this "life span" may not be immediately clear. However, if we look at the reasons why a particular collection is chosen for research, we begin to see how this pattern emerges.

There are several reasons why skeletal collections are chosen, but research suggests that the size of the collection may be the most significant influencing factor. Research from 2010 suggests that the collections used most often in the UK are those with over 300 burials, with those having over 100 burials also showing a higher incidence of repeat research (Mays 2010c p.198; Roberts and Mays 2011 pp. 628-629). To describe the pattern we see in the data from this study, an allegory of the "professor and the student" can be used:

> *<u>Professor and student allegory:</u> A professor advises their students to use a specific collection. As those students become professors themselves, they may tell their own students to visit the same collection. However, as time passes, new collections are excavated and are published in the current research literature; meanwhile the older collections are rarely studied, meaning they rarely appear in the current literature. This means the professor becomes less likely to recommend the collection to their current students. Over time, the collection becomes almost completely forgotten.*

If we look at this allegory and how collections for research are chosen, we can see that as a collection ages fewer people remember the collection, with still fewer people recommending the collection for research. This, in turn, results in the collection appearing less often in the research literature, leading to even fewer people remembering it. Furthermore, the research papers themselves can become dated over time (Davis 2013; Nicholas et al. 2005). This causes a chain reaction that culminates in the collection no longer being used for research. The data collected for this research suggests this cycle takes approximately 70 years. This may not hold true for national museums, or well-known collections. However, for smaller provincial museums this life-span is something to consider.

Another factor that may contribute to the concentration of research among more recently-excavated collections is reporting. In recent years there has been an emphasis on the production of publishable post-excavation reports and also contractors making their grey-literature reports available online. These documents provide researchers with essential contextual information (APABE 2017 pp. 8-9), which older reports may not have included. Furthermore, development in excavation strategies as well as recording techniques ensures more information is recorded, thus making the more-recent skeletal collections more attractive for research. Therefore, the pattern found in the data gathered in this research, with collections being accessed less over time, may relate to the increased standards of reporting. However, the two proposed explanations are not mutually exclusive; instead, both may have an effect on the researchers' selection of collections for their study. These theories must be interpreted with caution, however, as this study does not provide enough data to confirm them. Further investigations would be required to determine whether this pattern is consistently found across a wider cross-section of collections curated by museums.

If the patterns observed in this research are found throughout UK museums, steps need to be taken to prevent these older collections from being forgotten. One idea proposed by Roberts and Mays (2011) is the creation of a national skeletal database. This has been employed to great effect in other specialties, such as the historic art world (Atkinson 2011; Kendall 2014). This would not only prevent collections from being forgotten, but also better share the use burden of research on skeletal remains among a number of collections, decreasing the deterioration of any one collection. It should be noted that not all collections follow this pattern of decreased use with time. Certain collections with large numbers of burials or specific conditions, such as coffin plates providing identifying information or pathological collections associated with hospitals, are often used for research. Therefore, these collections are unlikely to fade from academic memory. One such example is the collection excavated from the crypt of Christ Church, Spitalfields (London). This collection includes over 900 individuals from the 17th to the 19th centuries, 400 of whom were associated with coffin plates providing names, ages, and dates of death (Molleson and Cox, 1993). A collection such as this, with such a wealth of contextual information, is exceptional and therefore is always likely to be represented in the literature.

5.3.2 Access vs. Time Period

The time period was described as the approximate date the skeletal remains were buried. Similarly-dated skeletal remains were grouped together into distinct time periods such as "Roman" or "medieval" (see Chapter 4 for a full breakdown). The time period was compared to the number of times the collection had been accessed. Theoretically, as all periods should have the same intrinsic research value, it was predicted that collections from one particular period would not experience higher access than another, suggesting no correlation was expected. However, in practice trends in archaeology may influence research foci; for instance, research on tuberculosis requires skeletons from individuals who experienced this disease, found more commonly from the medieval period onwards in Europe (Clarkson 1975; Roberts and Buikstra 2003).

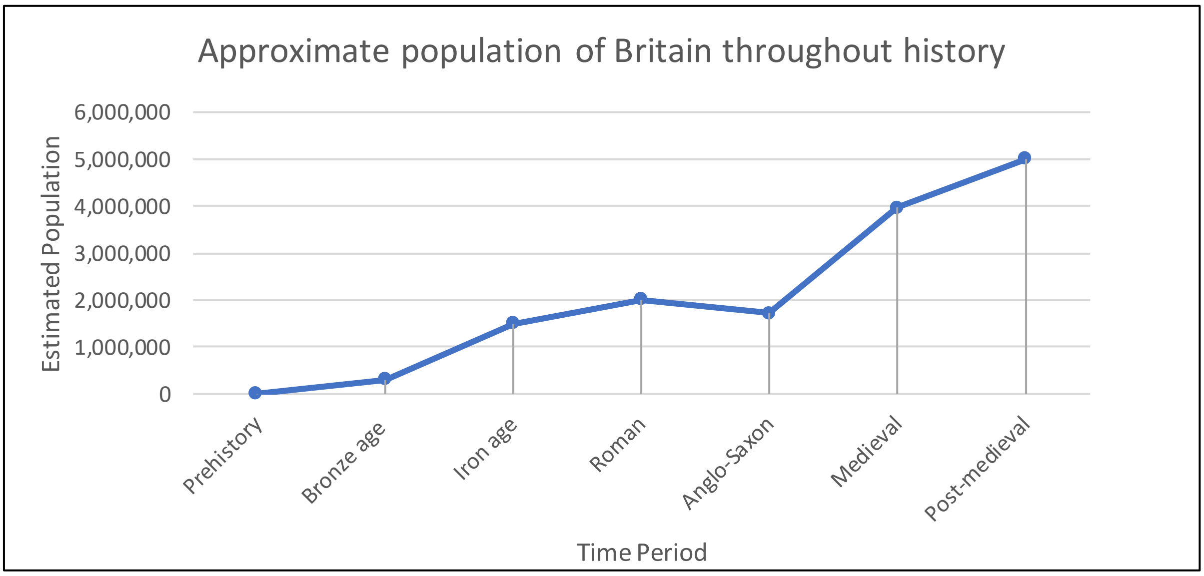


Figure 5.2: The approximate population of Britain, at key points throughout history. Numbers taken from Pryor (2004); Broadberry and colleagues (2015 p. 205); Wrigley and Schofield (1981 p. 208).

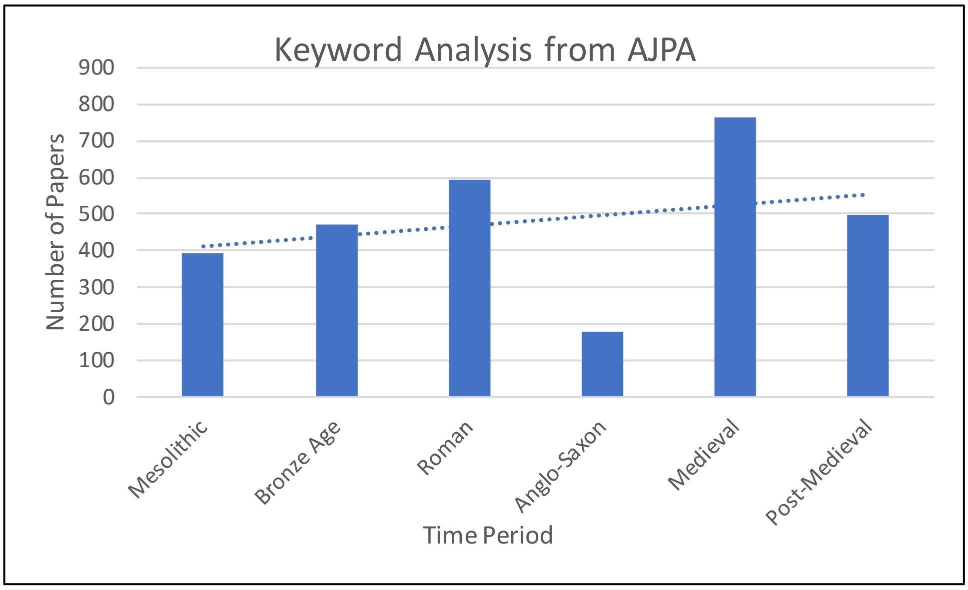


Figure 5.3: Results of a keyword analysis search conducted using the above time periods as criteria. The results show the number of articles matching each time period from the AJBA (American Journal of Biological Anthropology). Trendline value (r^2) = 0.0733

The data presented in Chapter 4 showed that there was a medium strength positive correlation (r= 0.387) between time period of the skeletal remains and the number of times they had been accessed. This was not in line with the prediction. Whilst in theory all periods should be researched equally, in practice it is not that simple. Some periods are in fact more popular: either because more human remains exist for those periods (see Fig 5.2), more comparative data already exists for those periods, or more historical documentation survives to provide context (including modern reproductions or translations of original sources). It should be noted that Figure 5.2 does not indicate what skeletal remains have been excavated or that are available to study; instead, it shows the general trends in historical populations and therefore which periods should have statistically more skeletal remains. The results presented in this study showed that the more recent periods (medieval and post-medieval) were the most popular periods for research. This is supported by a sample keyword analysis of *American Journal of Biological Anthropology* articles (AJBA), for each of the given time periods (Fig 5.3), which shows the trend in research favours the more recent periods.

This pattern can be explained by two factors. Firstly, as the medieval and post-medieval periods in the UK are the most recent of the periods linked to the skeletal collections used in this study, there should theoretically be more skeletal remains surviving. This can be attributed to the increase in population at that time (Roberts and Cox 2003 p. 293), compared to the previous 1000 years (see Fig 5.2). Consequently, a greater number of individuals are buried and therefore more are obtainable through excavation. This suggests more skeletal remains potentially should be available from these periods. The medieval period has provided many collections that are available for study; however, despite having had a larger population, there are fewer skeletal collections available for the post-medieval period (Roberts and Cox 2003 p.391). This relates to patterns in excavation, which in the UK at least are somewhat random, and usually found through pre-construction archaeology, meaning archaeologists do not get to choose which period the skeletal remains come from. Secondly, as the post-medieval period is more recent in time, comparatively more historical literature exists (Roberts and Cox 2003 p.287); for instance, the London Bills of Mortality, which recorded the cause of death for all individuals living within the city (Bill of Mortality 1665; Roberts and Cox 2003 p.287). Documentation such as this allows more detailed research questions to be asked, investigated, and compared against historical evidence (Powers et al. 2013; Wilson et al. 2013).

5.3.3 Access vs. Start Preservation

Start preservation (defined in Section 3.1.2 (i)) was predicted to have an impact on research access. Better-preserved remains would potentially hold more information, which would therefore be more desirable for researchers. Consequently, a negative correlation was expected.

The data collected in this study showed a weak positive correlation ($r = 0.148$) between the start preservation and amount of access. This answer was not in line with the prediction. The statistical significance testing returned a p-value of 0.034, which falls below the alpha value of 0.05, although only just.

Two explanations may explain the pattern. Firstly, the statistical significance of the data falls just below the needed alpha value of 0.05, suggesting there is a higher chance that the pattern found in this comparison was caused randomly. Secondly, this comparison was one of the lowest strength correlations found in this research, just crossing the boundary between no correlation and a weak correlation, once again bringing the validity of this comparison into question.

Prior to access, a researcher may not have information about the state of preservation of a collection as depending on the age of the available site report or publication information, this may not have been recorded or included in the publication due to editing decisions. Thus, they would not be able to select a collection based on its preservation. Furthermore, as discovered whilst collecting the data for this research, many museums in England do not have a baseline condition assessment available for human skeletal remains (as recommended by Janaway et al 2001), or a current “state of preservation” value. Thus, even if a researcher did enquire as to the state of preservation of a collection, in many cases a meaningful answer would not be available. In addition to demonstrating a problem with this comparison, this lack of information highlights the need for baseline condition assessments of skeletal collections, information that would be an essential part of a database of skeletal remains.

5.3.4 Access vs. Museum Type

Three types of museums were visited for this research: council-run, "shared" university (Newcastle University and Newcastle City Council), and other. The latter was a hybrid institution where collections were owned by an independent charitable trust but (jointly) funded and run by the local council. The museums used in this study were also split into three size categories: small, medium, and large – depending on the approximate area they covered (estimated whilst visiting the museums) and number of staff (provided by the curator).

It was predicted that the university-run museums would be accessed most because these institutions should encourage research. It was also predicted that the larger museums would be better able to encourage and facilitate access and research. Therefore, it was expected that the "shared" university and large museums would be accessed the most.

The data collected in this study showed that the highest average access was found in the council-run museums, followed by shared university museums, and finally "other". The size of the museum, however, seemed to have very little impact on amount of access, with all sized institutions having approximately the same amount of access. This was not as predicted.

This pattern may have less to do with the data collected and more to do with the sample of museums accessed – more council-run museums were used in this study (3) than shared university museums (1). Whilst this would not affect primary data comparisons, it is possible it created some bias for this comparison. Despite this, the data collected showed that the "type" of museum does not limit access, and funding does not appear to influence access to any great degree. Council-run museums, funded by local government that have had their funding cut in recent years, would arguably be less willing or able to encourage research (Kalia 2019; Kendall 2018a; Kendall 2018b; Steel 2018). However, the data collected here appear to refute this. This could be because museums, whatever the "type", understand that accessibility of their collections is one of the most important roles of a museum (ICOM 2007). However, to fully understand the relationship between the type of funding and the amount of access a more detailed analysis of the dates of research visits is needed to deduce if the research took place before or after the funding cuts that significantly impacted the budgets of the council-run museums (see Section 2.1.2 iii).

5.3.5 Summary

In general, many of the patterns found regarding access were unexpected. This highlights how poorly understood access and the factors impacting the preservation of human remains are, and demonstrates the pressing need for greater research in this area.

5.4 Research Outcomes

The primary aim of this research was to identify links between research through access of a skeletal collection and the change in the state of preservation of the remains. The strength of this relationship was analysed and evaluated to see if access for use was the primary cause of the deterioration found in the collections observed, as identified by Caffell and colleagues (2001) for a university. The data collected demonstrated that there was a link between access and deterioration. However, the magnitude of this interaction was lower than other factors evaluated in this research. Therefore, access was not the primary cause of deterioration in the condition of skeletal remains found in the English museums in this study.

This does not mean that controlling access would not reduce deterioration; controlling access could reduce deterioration to some degree but reducing access would probably have very little impact. We must also consider other consequences of limiting access; if skeletal collections are not accessed for research then what is the purpose of curating these collections?

5.4.1 What was the Primary Cause of Deterioration of Curated Skeletal Remains?

The highest correlation found within the data in relation to deterioration was the start preservation of the skeletal collections. However, the start preservation is out of the control of the archaeologist, curator, or collections care specialist; it is what it is. This creates some difficulty for the professions of both archaeology and museum heritage. We know that remains that have a poor start preservation will deteriorate faster, according to the data collected in this research. In theory, removal (reburial) of these poorly-preserved collections would reduce the deterioration observed in the remaining collection by improving the overall average state of preservation of the collection as a whole. In practice, not retaining the poorly-preserved skeletal remains would be impractical and inhibit research. Instead, the skeletal remains should be reviewed comprehensively. State of preservation should be considered, but other factors must also be explored, including: research potential, rarity of the remains (e.g., funerary context), and time period. This research signifies the need for museums to understand the state of preservation of their collections as a starting point for managing them. Those collections that are poorly preserved at the point of observation need extra consideration with regard to conservation, whether they have deteriorated during curation, or were excavated in that condition. This implies extra cost. Whilst a few museums might be able to absorb this cost, other museums, particularly smaller ones, are unlikely to be able to do so. Therefore, when a museum is considering accepting responsibility for a skeletal collection, the state of preservation must be appraised.

Museum storage conditions when compared with change in preservation of human remains showed the next highest correlation ($r=-0.341$). The storage quality value showed how well the individual storage locations followed the extant guidance (Cassman and Odegaard 2006 pp. 49-75; Clegg 2020; 72-76; Collections Trust 2020a; DCMS 2005; Garland et al. 1988; Janaway et al. 2001; Wakinson and Neal 1998). Importantly, storage quality can be controlled by the museum, enabling aspects of storage to be changed or improved to help reduce deterioration. The data collected in this study demonstrate the potential impact storage conditions can have on the preservation of skeletal collections and highlight the need for museums to invest in better storage facilities; poor storage facilities can be described as the primary cause of deterioration in human remains that can be controlled by a museum.

Trying to determine a single primary cause of deterioration is, at best, oversimplifying a complex problem. The data collected in this research show that, rather than a single over-riding cause for deterioration in preservation, a multitude of overlapping and interconnected factors contribute to the condition of human remains in storage. However, the impact of these factors is not equal. The impacts of museum storage and start preservation, as explained above, were greater than the amount of access the remains experienced. Nevertheless, many of the factors that influence deterioration are out of the control of museums. If controlling and preventing deterioration of curated collections is the aim of museums, a focus on the factors museums can control is needed. Start preservation, the age of remains, soil pH, and time out of the ground, are all intrinsic factors that affect deterioration. These factors will have a bearing on levels of conservation required on the remains that are accessioned by museums, but ultimately they cannot be changed. Other factors such as the quality of museum storage can be influenced or controlled. Below a study describes the cost of the various museum storage factors, with an emphasis on cost-effectiveness.

5.4.2 Human Remains Storage: Cost Estimation Study.

The components that were used in this study to calculate the quality of museum storage for human remains were outlined and explained in Section 3.1.2 (i) and recorded in Appendix 12 and 13. No specific weight was assigned to each component, and therefore for the purposes of this research, all were considered equal. It should be noted that not all of the components were directly linked to preservation; some components were related to security, whilst others were related to ease of access by researchers. Nevertheless, all factored into quantifying the overall quality of the storage of human remains. The cost to achieve each of these components, however, varied greatly. Below a breakdown is provided of the museum storage components that could affect preservation alongside their approximate costings. Costs were estimated for a 100-skeleton collection. (Note, labour costs were not calculated because this would be region-specific).

Table 5.1 provides more detail regarding each storage factor component and shows both the initial set-up cost of a component, as well as the yearly cost thereafter.

Storage Factor Component.	Details	Initial Cost (Approx.)	Yearly Cost (after initial)
Sturdy storage (includes: secure storage, dedicated storage, no stacking, and 10cm from ground)	Simple shelving can be relatively cheap. However, for more extensive space-saving shelving, such as roller racking, the cost can increase considerably. Furthermore, shelving must be able to accommodate the large boxes recommended below. [£500 per shelf; capacity approximately 15 boxes] (Preservation Equipment Ltd. PEL 2019; PEL 2019a)	Standard Shelves £3500 Roller Rack £6900	N/A
No sunlight	Generally, storage buildings should be created without windows for security reasons. If a building has been converted, this is not always possible. In these cases, it is suggested that blinds or shutters be used. [£15-£90 per window] (IKEA 2019)	£200	N/A
Suitably-sized box	Any box that is suitably large (comfortably fitting the largest bone, adult femur) and made from conservation grade materials can be used to store skeletal remains. A box with individual compartments is preferred to ensure damage is minimised. [£10.83 per box] (Bowron 2003) **Note: this price is for non-archival grade cardboard; archival-grade cardboard would be significantly more costly. Furthermore, the cost would be higher as inflation has not been calculated.*	£1083*	N/A
Packing material	Placing packaging around the bones within boxes helps to protect them further. Suitable packaging includes acid-free tissue paper and/or plastic bags [£4.15 per box] (Bowron 2003; Cassman et al. 2006 pp. 109-112). Tyvek labels can also be added to assist in organisation, without compromising the skeletal remains, although this will have an added cost (Antoine and Taylor 2014).	£415	N/A
Specialist staff member (includes: Packing order and no consolidants)	A human bioarchaeologist or collections care manager can help maintain a collection day to day. This includes enforcing best practice, keeping the skeletal collections packed in the right order and coordinating access. However, hiring additional staff members can be very expensive.	N/A	£15,269 + (*minimum wage 2018)*
Pest free	Pests can infest storage areas, damaging both the skeletal remains themselves and the storage boxes and packing material. Infestations can be stopped easily, if caught quickly, with sticky pest traps or rodent traps. However, any trap is temporary and will need replacing periodically. [£6.75 for 10 full traps] [£7.95 for 30 tester traps] (PEL 2019b; PEL 2019c)	£7.95	£31.80 [based on replacing traps every 3 months]
Humidity (includes: mould free)	Excessively dry or damp conditions can affect the structure of the bone and dampness can encourage mould to grow. As the UK is a humid country, humidifiers are most likely unnecessary. However, dehumidifiers may need to be implemented if humidity exceeds 50%. Operational dehumidifiers should be checked regularly and relative humidity should be monitored. [One dehumidifier (£100) per 15m^2] (MEACO 2019a; MEACO 2019b)	£500	£545 [*based on 12.9p per kwh* (UKpower 2019)]
Temperature	The temperature of the storage area should stay stable between 16°C and 25°C. If a staff member is working in the building, the temperature would be required to conform to the HSE (Health and Safety Executive) approved code of practice	£115	£657 *[based on 12.9p per kwh* (UKpower 2019)]

	(1992). Therefore, meeting this component is simply complying with legal requirements. (HeatersUK 2019)		

Table 5.1: Museum storage study which shows storage factor components, and their initial and yearly costs

Sturdy storage has a high upfront cost. This increases if space-saving options, such as roller racking, are considered (Bottomly 1992; PEL 2019a; Tate and Skinner 1992). It should be noted that the cost used in Table 5.1 is for installing roller racks on the ground floor in a modern building. This cost can increase considerably if the roller rack needs to be installed on an upper floor. In some older buildings it may be impossible or impractical to use roller racks. After this initial cost, the yearly maintenance cost is minimal and shelves should last for a long time, provided they are cared for and not overloaded.

As mentioned in Table 5.1 above, a secure storage facility should not have accessible windows; however, in some converted buildings (buildings not specifically designed as storage facilities) this may not be possible. Sunlight can damage bone if exposed directly, which should never be the case as human remains should always be stored in boxes (DCMS 2005). Sunlight can also cause fluctuations in temperature within the building. Simple metal blinds can be easily installed and used with a low cost per unit. The total cost of this component depends on the number of windows and, therefore, the number of blinds needed.

Suitably-sized boxes can be any box that can hold a whole skeleton without the bones touching or scraping against the sides (Bowron 2003 p.100). Whilst the Bowron box discussed in Chapter 2 is the preferred box design, because it offers excellent protection and ease of access to specific bones, the size and cost of the box does create difficulties for mass storage when compared to standard boxes (McKinley 2013 pp.138-139). Also, the Bowron boxes are made from non-archival grade corrugated cardboard, which is not typically accepted by museums. However, the design of this box is ideal for minimising damage; therefore, a similarly-designed box made with archival grade material would be the best solution. This would dramatically increase the cost per box from £10.83 to approximately £60-70 (Bowron 2003 pg. 102). As with secure storage components, suitable boxes are usually an infrequent purchase. Provided the remains are kept in appropriate conditions the boxes can last upwards of 15 years (estimated from boxes currently still in use in the Department of Archaeology, Durham University). However, if the boxes are damaged by water, pests, or similar attrition they should be replaced immediately for the protection of the collection. Overall, effective storage boxes can be cost-effective.

How the skeletal remains are held within the box needs to be considered. Bags and packing material can be considered more important than the boxes themselves. The SMA recommends that a skeleton be bagged in clear strong plastic bags (minimum 500 gauge thickness) separated according to body area (e.g., left hand, right hand) (Redfern and Bekvalac 2017 p.374; SMA 2020). The quality of the bags can have a significant impact on the preservation of the skeletal remains. Unnecessary handling of the human remains can be prevented when remains are well packaged and clearly labelled. This reduces the chance of breakage of skeletal elements. Sealed bags with Tyvek® labels will also prevent these remains from becoming mixed or lost and can help prevent pests from interacting with the remains (SMA 2020). Furthermore, the bags are cheaper than the boxes themselves; therefore, if a museum cannot afford Bowron boxes (especially if an adapted design using archival grade material is used), investing in good quality bags and more affordable boxes may be a suitable option. How the human remains are bagged can also have an impact, such as whether the whole torso should be stored in a single large bag, or many separate bags for the vertebrae, ribs, and scapulae. This is important as this can impact how the remains are handled and how frequently, depending on which areas are used for research. To protect the skeletal remains, care must be taken in the order in which the remains are packed. The heaviest and most robust elements, such as femora and humeri, should be packed at the bottom and lighter, more delicate elements, such as carpals and tarsals, should be packed in higher layers. Cranial and mandibular elements should be packed on top, and any loose teeth should be packaged separately to prevent these small elements being lost (see Mary Lewis's diagram in Roberts 2018 p. 91). To ensure that the packing of human remains follows best practice guidelines the museum will need to train staff that deal with human remains and provide guidance for visiting researchers. This guidance will ensure that when human remains are re-packed, they are packed to a suitable standard. In practical terms, however, these decisions reflect the budget of the commercial archaeological company or museum as more bags entail greater costs. Bags, and how they are packed, could have been a comparison in and of itself. However, due to time constraints, this factor had to be simplified to "suitable packaging" and included in the wider storage factor components; this allowed a brief, but more holistic view of storage to be evaluated. Going forward, it would be wise to evaluate this storage component separately. Suitable packing material should be acid-free and offer protection to the bones should they be moved. In this study, however, acid-free tissue paper, acid-free pads, or plastic bags were all considered good examples of suitable packing material (Collections Trust 2020a p.28; Redfern and Bekvalac 2017 p. 374; SMA 2020). This packaging would prevent contact with the box or with other bones which can cause damage, protecting the remains from sudden trauma, improper stacking or carelessness, all of which can cause breakages. This packaging can also prevent gentle rubbing of bone against bone which can damage and erode the bone surfaces. Similar to an appropriate box, once purchased, packing material should last for a lengthy period of time. Labels should be included in the bags or packaging, to allow easy identification of the bone and prevent mixing of the skeletal remains. Labels should include the site designation from which the remains were excavated, the number assigned to the individual and/or their burial feature, the skeletal elements that are contained in the bag, and if they are paired elements, whether they are left or right (Roberts 2018 p.90). Tyvek® labels are ideal for this, as unlike most paper they are acid-free and will not damage the bone. Furthermore, these labels are robust, durable and if a permanent marker is used, they are resistant to fading; as such these labels will last and retain pertinent information longer than paper labels (Antoine and Taylor 2014).

Specialist staff (defined as anyone who had education or training in the care and handling of human remains or the wider field of human bioarchaeology) are able to make more precise and informed decisions about the care of collections. As introduced in Section 2.1.1. (iii), collections care specialists are individuals who are trained in collections care and conservation. Their experience is vital to a museum's ability to properly care for their collections (British Museum 2021; ICON 2020). Collections care specialists are trained in the conservation and protection of different materials but cannot be experts in all materials. The museum should focus on training their staff to protect the materials that are housed in its store; if this includes human remains, training in human bioarchaeology should be pursued. With this specialist training the staff would be able to conduct regular condition assessments of the human remains in their care, identifying potential causes of damage. These specialists would also be able to provide guidelines and supervision for the appropriate handling of these remains. Training in human bioarchaeology may be necessary to evaluate whether proposed research is appropriate, especially research involving destructive analysis. Finally, specialists are often members of specialist networks and therefore have contacts throughout the field allowing for cooperation and collaboration with other institutions. However, even at a minimum wage (which should not be the case for a specialist), this is by far the most expensive of the components related to storage and care of human remains discussed here. A specialist could take care of many collections which would spread the cost. However, unless the museum hold tens or hundreds of collections, a specialist is not a cost-effective option for a single museum. This could become more cost-effective if the specialist is shared amongst several museums, perhaps regionally. Alternatively, if the museum already has a conservation or collections care specialist, who is not trained in the care and handling of human remains, the museum should consider the "continuing professional development" courses offered by Historic England, professional networks (e.g. SSNs) or other institutions. These courses can be invaluable in expanding the skill set of the museum staff, for relatively little cost. To help understand and quantify the required expertise needed by museum specialists or staff, the Chartered Institute for Archaeologists (CIfA) competency matrices can be used. The stages in these matrices are based upon CIfA's progression pathways (Practitioner, Associate and Member). For the purposes of this research two matrices stand out, museum archaeology and human osteology. Both matrices focus on a progression from a "good working knowledge" of an area, through to an "authoritative" knowledge. Individuals develop from working under direct supervision to full responsibility for multiple aspects of human osteology/museum archaeology, and from a single simple project to multiple complex projects. The matrices also require the individual to have awareness and understanding of ethical and legal guidelines for their specific field (CIfA 2016; CIfA 2019). The museum archaeology matrix covers direct care of collections including acquisition, identification, documentation, packing, organising storage, curation, condition assessments, and monitoring the store. Additionally, it includes writing reports, creating displays, outreach projects, and ensuring museum standards are followed (CIfA 2019). The depth of knowledge and range of skills expected from an individual increase as they progress through the stages laid out by CIfA. The human osteology matrix covers the excavation, recovery, processing, and analysis of human remains, as well as an understanding of scientific techniques that can be applied to them (CIfA 2016). Again, as an individual progresses their depth of knowledge increases. They are expected to continually develop their skills to ensure they are at the forefront of modern scientific techniques. Full breakdowns of these and other competency matrices can be found on the CIfA website (www.archaeologists.net/matrices).

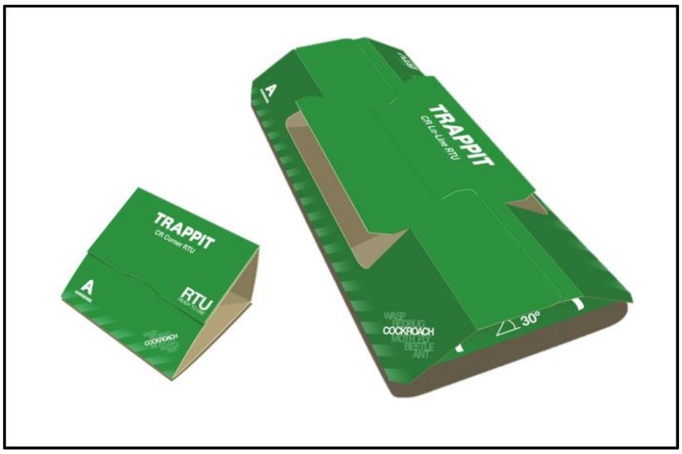


Figure 5.4: Pest control solutions: both the tester trap (left) and the full trap (right) – images are not to scale. After PEL 2019b; PEL 2019c

Pests can damage bone, boxes, packaging materials, and other objects within a museum's collections (Pinniger and Winsor 2004). Once a pest infestation has taken hold, eradicating the problem can be costly and time consuming (Dennis 1992; Hillyer and Blyth 1994; Museum pest.org 2016; Quek et al. 1990). Instead, it is better to have a proactive preventive system in place. Sticky traps (PEL 2019b) and sticky trap indicators (PEL 2019c) – smaller more mobile traps – can show if pests are gaining access to the storage facility (see Fig 5.4). If deployed efficiently, the traps can take care of small groups of pests. Provided these traps are checked regularly and replaced every few months, infestations should be prevented. Furthermore, the museum should have protocols in place to check all incoming objects (including the boxes and packing material), to ensure no pests can enter the store that way.

Excessively high humidity can precipitate mould growth on the bone surface, whilst low humidity can lead to cracking of the bone surface (Garland et al. 1988). Therefore, it is important to have systems in place that can measure and control humidity. Properly sealed buildings should not be an issue for humidity, either excessively high or low. In countries with wet climates, such as the UK, low humidity is unlikely to be a problem. However, if high humidity does become a problem, dehumidifiers can be a costly, but necessary, solution. Small dehumidifiers can be purchased from domestic retail outlets, but these will only function effectively over a small area ($15m^2$). For a large store, several dehumidifiers are needed. Industrial-sized machines can be purchased or rented, but both the cost and energy supply needed is considerably greater than for domestic machines.

As noted in Table 5.1 above, if a staff member or volunteer is working in the storage facility, the temperature, by law, needs to be kept above 16°C. A stable temperature is also necessary to prevent damage to the skeletal collection (Janaway et al. 2001). Installing heating can be costly and there is also a yearly energy cost. This brief study does not take into account seasonal fluctuations, as the specifics would vary between museums. Instead, a base rate was used to estimate the cost of electricity associated with maintaining a stable temperature (UKpower 2019).

The storage factor components discussed above can be divided into three main groups. The first group includes the one-time or infrequent purchases (shelving, boxes, packaging, and blinds). Once purchased, no further purchase is needed for a considerable length of time. Therefore, these storage-related components are investments. Generally, the more that is spent on these components initially, the longer they will last, and thus the more cost-effective they become. However, smaller museums may not be able to afford these upfront costs, as opposed to a larger cost that is spread out throughout the year. In these situations, museum grants and funding bodies should be approached. The second group includes purchases that require an annual operating cost, either in the case of a wage or fee for the specialist or a yearly energy bill in the case of the heating. Heating can be seen as a necessity due to workplace standards. Therefore, if the storage facility is regularly occupied, compliance is simply following the law and an obligation the museum must meet. To hire a specialist, or any staff member, is a costly option. The museum must balance the benefit of having the extra knowledge and skills against the somewhat considerable costs. However, if each of the staff members at the museum have training and experience in various fields, this can mitigate the cost of individual specialists and minimise the total number of staff members needed. As mentioned above, the breakdown of what skills these specialists should have can be found in CIfA's competency matrices. Each of these matrices stress the importance of continuing professional development (CPD). The final group covers the remaining components (pests and humidity) which can both be described as "situational". The associated costs only arise if there is a problem. While safeguards should be implemented to monitor whether there is a problem and prevent one occurring, this cost should be small. Not all museums will benefit from implementing these situational storage components, and only those that are required should be used if or when they are needed. This implies a situational cost-effectiveness.

Some components discussed above will have wider implications for the museum collection as a whole. Temperature, humidity, pests, and sunlight can all affect other museum collections. Therefore, the cost of improvements to these storage components should be shared across other types of collections; although this might not be easy to achieve, it could show cost-effectiveness. It is not possible to say that there is a single cost-effective solution to effective museum storage of human remains. Instead, effective storage must adapt to the individual situation of the museum. A museum must consider the level of resources and funding they have available, and whether this funding will continue or if it is a one-off sum (Museums Association 2017a; Sullivan 2017a). Cost-effectiveness needs to be balanced with the museum's obligations to their staff as well as to their collections. Temperature, humidity, and pests should be controlled regardless of the cost because these can have a significant effect on museum collections and staff working in the museum. Suitable boxes and packaging are important because these are the primary protection for skeletal remains. Once these basics are covered, the remaining storage factor components (e.g., blinds or shutters) are only needed if the storage facility is lacking them. If some, or preferably all, of the museum storage components could be improved the rate of deterioration would decline.

5.4.3 An Unconventional Mean

In order to evaluate the relationship between access and deterioration in preservation of skeletal remains, an average preservation needed to be calculated to represent the change in the state of preservation in the skeletal remains of each individual. This, however, presented a number of problems. The data collected in this study – based on the preservation scale described in Chapter 3 – was ordinal. It is unusual, although not incorrect, to use parametric testing for ordinal data. Examples of parametric tests commonly used in archaeology (Drennan 2007) include the T-test (StatisticsHowTo 2019a), ANOVA (StatisticsHowTo 2019b), and Pearson's correlation coefficient (Neyman and Pearson 1933). Conventionally, the mode would be used to represent the statistical average of ordinal data, but for this study the mean was used as the statistical average. This unconventional choice was made to increase the precision of the average values. The mode average did not provide sufficient detail in the results relating to change in preservation. Instead, the mean average was used, following a similar rationale used for a Likert scale in psychology (Carifio and Perla 2008; Likert 1932). Furthermore, parametric tests were applied to evaluate the correlations created in this study, and the most appropriate test for the majority of the comparisons was Pearson's correlation coefficient.

The use of parametric tests on ordinal data is the subject of a debate that has continued for a considerable amount of time. For example, for Kuzon and colleagues (1996 pg. 265) it forms the basis of Sin 1 in their article "Seven deadly sins of statistical analysis". The predominant argument against the use of parametric tests on ordinal data is that such tests assume, and therefore require, normally distributed data – see Figure 5.5. However, with ordinal data normality cannot be assumed. This increases the chance of a researcher interpreting the data incorrectly, leading to potentially erroneous or inaccurate conclusions.

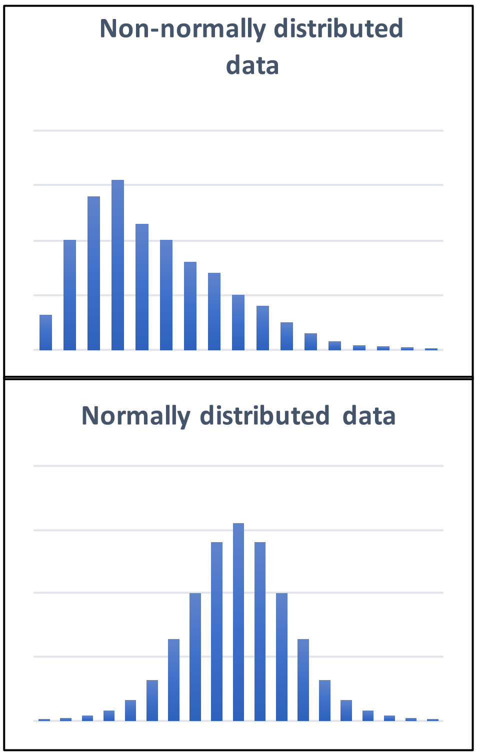


Figure 5.5: Comparison of normal and non-normal distributions of data, created from a random sample.

There might be cases where it is acceptable to use parametric testing for non-normalised data. Norman (2010) argues that the issue is not whether the data are normally distributed, but whether the statistical tests used can cope with non-normalised data – whether the tests are robust. Robustness is defined as "the extent to which a statistical test will give the correct answer, even after the assumptions have been violated" (Norman 2010 p. 627). Norman (2010) argues that if a test, scale or data set is deemed robust this could negate the problems associated with non-normalised data. This would allow the use of parametric tests on ordinal data. Pearson's correlation coefficient, in particular, has been shown to be robust to non-normality through over 80 years of research (Dunlap 1931; Havlicek and Peterson 1976; Pearson 1931, 1932a, 1932b). This wealth of research demonstrates the legitimacy of using parametric tests on ordinal data, especially Pearson's correlation coefficient. Arguments to the contrary effectively ignore the many studies of robustness conducted throughout the years, and the abundant research from other disciplines, most notably education, health, and quality of life assessment (Norman 2010 p.627).

Non-parametric tests can be used without testing for robustness. Yet parametric tests are versatile and comprehensive, allowing a whole range of aspects of data to be investigated (Norman 2010), whereas non-parametric tests, which are rarely used, can be described as being both outdated and limited. They allow only the interpretation of the simplest of interactions. Parametric tests allow more specific conclusions, theories, and knowledge to be tested (Norman 2010).

Parametric tests were implemented throughout this study as the optimum means by which to test the aims presented in Chapter 1 (specifically Aim 2: To assess the relationship between research, through access, and changes in the preservation of the skeletal remains; and Aim 3: To evaluate other potential causes of deterioration, to establish if any had a greater impact than researcher access). In spite of the issues of using parametric tests on ordinal data, as long as the data are robust (proven for the data in this study: Chapter 4), they can be used.

5.5 Wider Implications of the Research

Following the discussion of the results of this research presented above, the next step is to understand the wider implications of these results for the fields of museum curation, archaeology, and human bioarchaeology. The best methods to protect human skeletal remains stored in museums will be discussed below, alongside cost-effective methods for implementing protection strategies. The funding problems that museums face in relation to storage of human remains are also discussed to evaluate potential solutions. Finally, the problems commercial archaeology companies are facing in relation to the storage of human remains are considered, as well as how these problems might be mitigated, because they also care for human remains and are having issues with their storage (McKinley 2013).

5.5.1 What Can be Done to Protect Human Remains Curated in Museums?

Having discussed the effect various factors can have on preservation and deterioration of human remains, it is important to fully understand what can be done to protect human skeletal remains stored in museums. Despite the fact that only English museums were evaluated, methods discussed here could also apply to human remains curated globally. Beyond the UK, different regions and continents will have specific challenges relevant to those areas (e.g., climatic and pest-related problems will vary by region), but many of the risk factors facing effective curation highlighted in this study are also applicable to other parts of the world. An outline of best practice for curation was discussed in Chapter 2 based on the DCMS publications (DCMS 2003;2004;2005), which included information on accessioning and deaccessioning skeletal remains, their display, and other aspects. To effectively protect curated skeletal remains from damage each museum should also create its own policies that are tailored to the individual museum, including well-defined access policies.

It is important that a museum encourages research on their collections; research produces new information and broadens knowledge, and it is a key tenet of the role of a museum (Bassett 1992; ICOM 2007; Simmons 2010). However, whilst a museum should encourage research, it also needs to have a controlled and managed access process in place, and specifically a procedure for granting or denying access to a skeletal collection. The museum needs to balance granting access and generating new knowledge with protecting a collection for the future by restricting access. Some universities already restrict access to their collections to prevent overuse: an example of this is the University of Bradford, which restricts outside access to their collections to PhD students and practicing biological anthropologists (University of Bradford 2018). The research in this thesis showed that, although the strength of the correlation was weak, there was still a link between access and deterioration or change in preservation.

Museums have a number of options to balance access and protection. Firstly, the museum could limit access only to trained people, whether they are established researchers or students, with bona fide research (MEG 1994 p.23). In addition, only those with the relevant qualifications should be allowed to handle skeletal remains. This would hopefully ensure that the remains are handled properly, limiting any potential damage. However, it is believed that many museums already follow this policy and do not allow untrained individuals to access their collections, as recommended by BABAO (2019a pg. 13). As an example, all of the museums used in this research required information on the researcher's background, prior to allowing access to the skeletal collections.

Secondly, the museum should ensure the research question related to an access request is appropriate (a question that is focused and precise), can be answered though access to the collection, and is worthwhile (will further archaeological knowledge). Ideally, the museum would have a specialist (in a related field) able to consider these requests, including having knowledge of the viability of the research proposed. However, this is not always the case. Museums curate collections that can cover a variety of disciplines and cannot employ specialists in every field of archaeology, as the cost would be too great. For example, the Verulamium Museum, used in this research, covers the Roman archaeology found at the site of the same name (St Albans Museum 2018). Yet, even in this museum which covers a single time period, there are: human remains, coins, pottery, mosaics, and many other objects. This would theoretically require several specialists. This is for a museum which only covers a single time period; museums which cover a local area often cover multiple periods (Museums Association 2020). Having a specialist available to cover each area is not practical. Instead, greater cooperation among museums, universities, and subject specialist networks (such as the Society for Museum Archaeologists) could support museums in this process. Collaborations could enable reciprocal arrangements that benefit both parties in research, and also in teaching and learning. To some extent this is the arrangement at the Great North Museum, where the collection is partly cared for by Newcastle University. Such partnerships could be beneficial for both sides and potentially reduce the costs to both.

Finally, the museum could better document the history of access to any one skeletal collection by scholars and researchers. Although some museums keep accurate and current documentation, this is not a universal practice (as was noted whilst contacting museums at the start of this research). By recording exactly what research has taken place and by whom, and exactly what was or was not found (records of publications), the museum could prevent duplication of research; that is, unless the research focus is a corroboration of past research. Museums must ensure that all data collected and stored in this way conforms to the Data Protection Act (Gov.uk 2018) and the General Data Protection Regulation (GDPR – ICO 2021). Such legislation can have an impact on what information or data the museum is allowed to share. If a researcher requests access to conduct a study which repeats a previous project, the museum could provide the means to obtaining information relating to it. If the findings have been published, providing the location of the paper is straightforward. However, if the research has not been published, the intellectual property remains with the individual or university that conducted it. In these situations, the museum must obtain permission from the author or university before the information can be shared. If the museum is able to provide the relevant information, this would enable the new researcher to incorporate the data into their own study without accessing the collection and causing further damage or might lead them to find a different collection to work with. This of course depends on those who access collections providing the museum with the publications resulting from their research.

Museums have a difficult choice to make between encouraging research and protecting the skeletal collections they curate. Provided the museum has an adequate access process in place, preventing untrained individuals from accessing the collections and ensuring all access is for a relevant reason, any potential damage or deterioration to the collections should be minimised.

5.5.2 Cost-saving Strategies for the Protection of Human Remains

The preservation of skeletal remains curated in English museums is influenced by several factors. However, some of the factors cannot be controlled by the museum, whereas others are extremely expensive to mitigate, and as a result, smaller museums are unlikely to be able to address them adequately. In Section 5.4.2 above, various components related to storage were evaluated alongside their initial and annual costs. However, this only explored the costs associated with following the guidelines proposed by Roberts (2009; after Bowron 2003 p.100; Cassman and Odegaard 2006 pp. 49-75; Garland et al. 1988; Janaway et al. 2001; Wakinson and Neal 1998). Below, several cost-effective strategies are proposed that cover the museum as a whole, rather than only focusing on storage. These strategies may be implemented by any size or type of museum, and whilst not all strategies directly concern protection of human remains, they do all contribute indirectly to care of the skeletal remains in the long-term.

i. Charging for Research Space or Access

One idea, already implemented by some museums (one censured example is the London Natural History Museum 2019), is to charge researchers and visitors for access to the collections. This may be a flat rate for the whole research period or, more commonly in larger museums, charging for research space by the day/week. The idea is that this cost covers the opening of the storage facility, as well as the supervision required.

There are benefits to implementing this strategy but also potential issues. The primary benefit is the extra income for the museum. While this might be only a small amount, it could offset having to open up a storage facility for the researcher or help cover the cost of having a staff member present for the research period. Earning even a small amount of money would help the museum to fund the protection and conservation of their collections, assuming the money is used for this purpose. The second benefit is that a small charge will likely discourage unnecessary research, or research for the sake of research (conducting research because we can), as opposed to research that has a specific question in mind that can be applied to a particular skeletal collection. This could reduce the pressure on a collection and help to protect it in the long-term. Currently only a handful of museums charge, but with funding being slashed, others may follow.

Despite these benefits, there are risks. Firstly, these charges may discourage legitimate researchers who have modest, limited, or no resources. Self-funded university students, in particular, may struggle to pay even a nominal fee per day, especially for extended research projects. Discouraging students is a risky path to take as they are, by definition, the future of the discipline. The museum should also be aware of how much this sort of policy is disliked within the research community. Several societies have expressed their concerns over the increasing number of museums that are charging researchers for access. Most notably, the Prehistoric Society argued against this trend in 2015 – describing it as ethically wrong by the Museums Association (MA) standards (Prehistoric Society 2015). The MA retorted that its Code of Ethics did not and does not explicitly forbid charging, neither did it encourage it. Rather, the MA simply encouraged greater public access, yet made clear it understood the difficult financial position some museums are facing (Atkinson 2015; Clark 2015).

Charging for research space is a potential strategy for a museum to recoup some of the operating costs associated with curating a skeletal collection (or any archaeological material) and facilitating research. However, as discussed above, the museum needs to understand that this strategy could cause reputational damage, potentially alienate many of the groups with which the museum works closely. Therefore, if implemented, the museum should be prepared for this outcome (Atkinson 2015; Brown 2015b).

ii. Baseline Condition Assessment of Skeletons at Accession

For long-term protection of a skeletal collection, identifying and understanding the change in preservation of that collection is important. Therefore, having a baseline condition assessment of a collection is vital for a museum (Dollery 1994; Keene 1991; Keene 1996; Kingsley and Payton 1994; Taylor and Stevenson 1999). Baseline condition assessments are now part of common procedures during the accession of artefacts, as outlined by Spectrum. The method followed during condition assessments varies among museums. However, Spectrum provides an outline of the procedure that is recommended. Spectrum suggests recording a description of the object, alongside a condition and technical assessment (Collections Trust 2017d). The description should cover what the object is, where it was acquired from and how the object should be used (restrictions on access for research) (Collections Trust 2017d). An assessment of the condition of the artefact should include both completeness and an assessment of the artefact's preservation. Both of these are rated first as a single standard term for ease of reference and are accompanied by a description to provide further detail. Spectrum suggests using general terms for rating preservation, such as 'poor' and 'fair' (Collections Trust 2017e); however, the author suggests a more specific terminology is used such as that proposed in the preservation scale used in this thesis. The technical assessment should follow the condition assessments and note any actions that are required to help protect the artefact. These assessments should be followed by a conservation treatment priority assessment to determine how urgently the artefact requires intervention. The assessment should also include an evaluation of any hazards so that steps can be taken to minimise the risk to those who work on the collection, as well as the risk to other collections from the new acquisition (Collections Trust 2017e).

As mentioned in Section 2.3, some institutions are shifting to a digital archive for skeletal remains and other artefacts; by 3D scanning these artefacts any deterioration that occurs between successive scans can be evaluated quantitatively (Errickson et al. 2017; Loe 2017). This method is more detailed and objective than traditional descriptive methods.

The primary focus of these assessments should be recording the condition of the bones, but the packaging and boxes should also be evaluated to ensure they meet current standards and that the skeletal remains have been packed appropriately (Collections Trust 2017d). For example, checking that the remains are stored in appropriately-sized boxes with suitable packing material, or checking that all soil has been removed from the bones, or at least as much as possible, and that the bones are dry. Both soil and water can cause problems in the future. Soil can become detached from the bone surface as it dries, damaging the surface of the bone in the process, whilst damp bone provides a substrate for mould growth (Historic England 2016b). Mould can damage the bones, in particular those used for histological analysis (Garland et al. 1988; Janaway et al. 2001 p.205). Mould can also spread to nearby collections. By checking for these types of issues when a skeletal collection arrives at the museum, they can be resolved before any significant damage occurs.

Having this baseline assessment allows the museum to re-evaluate the collection periodically, comparing a new assessment with the baseline assessment taken during accession. If unexpected deterioration is found, the museum has the potential to resolve it before any further damage occurs, thus protecting and preserving the skeletal remains for future use. If the Spectrum standard is used, this would fall under the technical assessment. A baseline condition assessment will not protect the remains on its own. The value of the assessment becomes clear only when it is used alongside periodic condition assessments. Without these additional assessments, the baseline assessment can offer little additional information, only that the remains were accessioned in a suitable condition.

It should be noted that the baseline condition assessment requires the knowledge and skills of a specialist in human remains. The time required to create this baseline, and therefore the cost of the assessment, would vary according to a number of factors, primarily the size of the collection(s) and the experience of the specialists producing the assessment. Most museums do not have, and cannot afford, such a specialist; as described above, the specialist does not need to be a member of staff or even have a permanent contract with the museum. Thus, a potential solution to this problem is for a number of museums to share a specialist. As mentioned above, collections need to be revisited periodically. The frequency of evaluations should be determined by the risk factor (e.g., high or low soil pH), state of preservation, and the frequency of access, as well as the funding the museum has available. Sharing a conservator with training in the handling and identification of human remains, is a practical solution. Yet, as mentioned in Section 2.2, many of these specialists are centred around London or universities (J. Bekvalac pers. comm. 2021). Thus, more distant institutions whose local university lacks a bioarchaeology or conservation department may struggle to find a conservator specialising in human remains.

In summary, a baseline condition assessment can help a museum better understand the condition of their skeletal collections, allowing them to better allocate resources to protect them in the long-term. Preferably, this baseline assessment would be conducted during accession, as is currently common practice for new accessions (Collections Trust 2017d). The obstacle is the need for a specialist to accurately create baseline condition assessments and the regular assessments for comparison thereafter. A practical solution is for several museums to collaborate and share the cost and expertise of a specialist, creating a cost-effective strategy for the long-term protection of the skeletal remains held in the museums.

iii. Accurate Documentation

Another practical strategy that can be implemented by a museum is to ensure they have accurate up-to-date documentation for each of their skeletal collections (British Standards Institution 2009; Cooper and Losch 2013; Hillhouse 2009; Janaway et al. 2001; Redfern and Bekvalac 2017). This will not directly stop the deterioration of skeletal remains, or save money directly, but it would help to protect the collections by allowing the museum to track use patterns and potentially save resources in the long-term.

In order for a museum to know what research has already been conducted on their collections, they require accurate and complete documentation for each collection, even if this research was conducted before the skeletal remains were accessioned into the museum. This would prevent unnecessary repetition of the same research by different researchers, which is especially important when samples for destructive analyses are being taken, or where specific collections/skeletons are particularly rare. In recent years, there has been a push by Fox and Hawks (2019) to better track use and success rates of destructive sampling – primarily for aDNA and stable isotope analysis – on ancient remains, both modern human and near human (hominines). They argue that these remains are finite and in the last ten years destructive analysis has almost quadrupled (Fox and Hawks 2019). There is no comprehensive record of how much damage has been done to remains in museums across the world for the sake of these analyses, although currently some projects such as "Code Narrative History" by Stockholm University or the online database of Scottish aDNA results being collated by the National Museum of Scotland are endeavouring to create such records (Conahi 2021; Sheridan et al. 2019). Similar concerns have been raised by BABAO, and guidance has been added to their Code of Practice and Code of Ethics to help prevent this damage (BABAO 2019a p.16-17; BABAO 2019c p.7). With the growing use of aDNA and other destructive analysis in human bioarchaeology, it is easy to see how this could become a significant problem, especially for rarer and older collections. As technology and methods evolve in the future, these skeletal resources may become limited. The accurate documentation described in this section, if shared, could help to minimise this problem.

Accurate records could also be used to detect and prevent overuse of a particular collection. Preferably, each time a collection is accessed, the reason for the access should be recorded. Therefore, the museum should have a clear indication of how many times each of its collections had been accessed and for what reason. If one collection is being used significantly more than another, to the point of overuse, steps can be taken to limit access, offering some protection to that collection. Finally, this strategy has the added benefit for the museum that information about their collections is more readily available for any researcher that enquires about them. This would benefit not only the potential researcher but also the museum staff.

Despite the benefits, there are some downsides and costs that may be associated with this recommendation. Firstly, a staff member or trained volunteers would need to update the records regularly, though this individual would not need to be a specialist (Skeates 2017 pp.9-10). This would involve recording all access to the collections, as well as any published and unpublished research produced. Ideally, any further research produced as a result of the initial access would also be recorded. However, this would require the researcher to keep the museum informed. Although further research would not increase the amount of access, a record of it is still useful to have to make the documentation complete. Collating these data and contacting researchers could take time out of any one curator's or collections care specialist's year, especially for museums that have several collections. Thus, this would be a cost for the museum. Finally, having accurate records for each collection is a continuous process. For a particularly popular collection, if this is neglected, information may be missed and the benefits of having the documentation would be lost, along with the ability to use it to implement effective protection for the collections (Merriman and Swain 2017 pp. 77-92; Skeates 2017 pp.3-5).

In summary, accurate baseline assessments and other records for any skeletal collection can help to protect it. If museums can understand what research has already been conducted on their collections, they can prevent unnecessary repetitions of the same research and overuse of collections (Caffell et al. 2001), saving resources in the long-term. Although this strategy can be cost-effective, it is dependent on the overall popularity of the collection. The more popular the collection, the more work is required to keep the documentation up to date, and therefore the less cost-effective this strategy would be. Less popular collections would require less work in this process; therefore, this recommendation may be better suited for smaller museums.

iv. Catalogue or Database of Collections

Following baseline condition assessments, creating detailed catalogues and databases of skeletal collections curated by a museum could contribute to protection strategies (Collections Trust 2017a; Ericksen and Unger 2009; Morris 2007). A catalogue is a systematic record used in the management of museum collections that can be cross-referenced to other records maintained by the museum. A database is a detailed record of the human remains within a collection that is designed to facilitate research. The catalogue and the database would allow museums to better understand their collection as a whole, and be in a better position to protect the collection from potential damage. Furthermore, any collection that has a detailed database would be more appealing to potential researchers.

Collections management systems (CMS) are computer programmes that can be used to support the cataloguing procedure. CMS recommended by Spectrum include Modes, Mimsy (Axiell), and EMu amongst many others; a full list can be found on the Collections Trust website (https://collectionstrust.org.uk/software/).

Ideally, catalogues should cover all of the skeletal remains and any other artefacts curated by the museum. The catalogue should contain the museum identification number (or object number) which should be clearly written on the box, object name, number of boxes (per individual), box(es) location (as well as any reference name or numbers, which should also be clearly marked on the box), whether held on or off site, current authority (or for other museum objects, the owner), brief description of the remains, and the accurate documentation, as discussed above – Section 5.5.2 (iii) (Brickley 2004; Brickley and McKinley 2004; Clegg 2020 p.69; Mays et al. 2002). The catalogue should have the functionality to be cross-referenced easily to other records including any media or photographs, records of exhibitions that featured the remains, previous loans of the remains, and should also be linked to any human osteological databases. The database should contain a skeletal inventory and any osteobiographical information such as age, sex, stature, and pathology for each skeleton. Any information about the site from which the remains were recovered should be included, such as location, time period, burial context, and related finds. Finally, the database should also include any condition assessments, both baseline and periodic.

With this information the museum would be better equipped to guide researchers to the appropriate sites, skeletons, area of the museum/room, shelves, and boxes, saving time in finding the desired skeletal remains. For example, if a researcher only wanted to evaluate non-adult skeletal remains, they could search through the database to find suitable individuals and use the catalogue to find out where they are held and go directly to the correct boxes. Without these detailed records, the researcher may have to search through many boxes, disturbing and handling human remains that are extraneous to the research question, potentially causing unnecessary damage. Furthermore, by spending less time searching through boxes that are eventually of no interest, a researcher would be able to gather their data more quickly; this could reduce the resources expended by the museum to supervise the researcher, and the researcher would incur less costs for their visit. Therefore, not only would a detailed catalogue and linked database help to reduce overall damage to the skeletal collections, but it would also reduce the amount of time researchers need to spend at the museum and reduce the time it would take the museum staff to assist them. This could allow resources in the museum to be reallocated for preservation and conservation efforts.

The difficulty with this strategy is its inception. Creating the catalogue requires an understanding of the museum layout and the storage system used by the museum, while creating the database requires an understanding of skeletal remains, their interpretation, and their curation. Although initially time-consuming, these systems have the benefit of requiring little maintenance, unless the storage system or location is modified. If a museum is considering undertaking a storage refurbishment, it should consider updating its catalogue as part of the overall cost and include it in any funding or grant applications.

Museums need to understand the scope and function required from both the catalogue and the database in order to design them appropriately, including determining which type of CMS the museum intends to use. This would require an upfront investment to organise, collate, and enter the data. By considering these details from the outset the museum can save confusion in the future. For instance, the Museum of London (MoL) and the Museum of London Archaeology (MoLA) have a system that grew and was adapted organically over time to suit their collections. The Wellcome Osteological Research Database (WORD – https://www.museumoflondon.org.uk/collections/other-collection-databases-and-libraries/centre-human-bioarchaeology/osteological-database) used by the contract human osteologists at MoLA and Curator of Human Osteology at MoL records osteological information, site codes, context numbers, sampling history, and a record of associated images. The system was designed as a human osteological database, not a collection management catalogue, but has been adapted to serve some of the functions of a catalogue as well. MoL also utilises a CMS (Mimsy) that can be accessed by collections care and conservation staff, as well as programme managers and other curators; this provides the location information for human remains that have been on display or are featured in exhibitions, or that have been accessioned by the museum. Due to the size of the collection, those remains accessioned to the archive are not entered into the CMS. As such, human remains acquired from non-MoLA contractors are not included in the system and the management of these collections is an ongoing issue (R. Redfern pers. comm. 2021). MoL is attempting to address this issue; however, due to the size of these collections and how entangled the systems are, the cost of resolving the information technology problems and online content management problems will be significant (R. Redfern pers. comm. 2021). The system used by MoLA and MoL is functional but complicated; adapting a system to fit the museum's evolving needs is possible but can lead to unforeseen issues. As the museum collection grows, more issues may arise. In designing their catalogue and database systems, museums should consider not only their current collections but the pace at which they are growing.

In summary, there is a high initial cost and labour investment associated with creating both a catalogue and a database for skeletal collections. Once a database is created, there should be limited maintenance costs, although as new collections are accessioned they will need to be entered into the database. A catalogue will need to be updated continually to ensure all information is correct, resulting in maintenance costs. The database would allow researchers to determine whether there are suitable remains for their research at the museum; the catalogue would allow the researcher to locate them without disturbing other skeletal remains. The prevention of unnecessary handling of human remains is a significant contribution to their protection. Finally, using a digital database and catalogue together can reduce the amount of time a visiting researcher needs to complete their research and reduce the time spent by museum staff in supervising or assisting the research.

v. Display and Public Tours

One final strategy a museum can implement is the display of their skeletal remains. Whilst this may seem counterintuitive as a method to protect and conserve the collections, display (as will be discussed below) can offer several benefits that can help protect collections.

Countless studies have looked at the ethics and popularity of viewing human remains in museums (e.g. Barbian and Berndt 2001; Barham and Lang 2001; Kilmister 2003; Page 2011; Rumsey 2001; Sledzik and Barbian 2001; Swain 2016). The results overwhelmingly conclude that the majority of visitors enjoy, want and even expect to see human remains in museum displays. Therefore, by placing human remains on display, the museum can potentially attract more visitors (Connor 2007). Furthermore, when skeletal remains are placed on display, their condition can be easily assessed, and any changes would be detected quickly and, if possible, resolved. Furthermore, display cases are often environmentally controlled and monitored closely (Tinytag 2020). This would not necessarily be the case if the remains were kept in storage. It is, however, unlikely and impractical to think that all human remains the museum curates would or could be put on display.

Although it may be true that displaying human remains can help to attract visitors to the museum, it is certainly true that creating a display has considerable associated cost – some estimates from an American museum put the cost at between $75-$550 (£60-£440) per square foot (Walhimer 2011). Not only are there costs for additional display cases and extra security (if these are not already in place), people must also be paid to research and design the display. The display needs to be created with a sense of purpose, be educational, contain relevant information and be well researched; displaying human remains for the sake of novelty is ethically questionable (Fletcher 2014; Swain 2002). Moreover, design and layout are vitally important, as emphasised by the DCMS (2005 p.20). This guidance also stipulates that visitors should not be taken by surprise by coming across the human remains unexpectedly. Following this guidance requires both careful design and detailed planning, which may be more challenging in smaller facilities due to lack of staff and resources. It should be noted that there is a distinction between permanent and temporary exhibitions. Whilst human remains are commonly found in both (Biers 2020 p.241), there are differences in the development and management of these types of exhibits. Temporary exhibitions allow the museum to showcase different areas of the collections that are not normally on display, encouraging previous visitors to return. Permanent exhibitions require significantly more planning, as the space they occupy cannot be used for other purposes. Permanent exhibitions may also fail to attract repeat visitors. Additionally, museums which do not charge admission to the museum's permanent galleries will be unable to charge for any new permanent exhibitions. For instance, the Brighton Museum is free to Brighton and Hove residents; therefore, when the Elaine Evans Archaeology Gallery was opened in 2019, they were unable to charge admission to local residents for this new permanent exhibition (Brighton Museum 2021). However, currently there is an admission charge for all visitors to the Brighton Museum's temporary exhibition (Brighton Museum 2021). Therefore, if museums decide to display human remains from their collections, they must also consider whether a temporary or permanent exhibition is most appropriate.

In recent years, some museums and larger historic bodies (e.g., Historic England) have decided to open their storage facilities for public tours accompanied by a staff member through collections not on display. (Gardener 2007; Keene 2008; Museum Practice 2002). This is an interesting idea, especially as museum storage locations may hold up to 90% of the museum's entire collection (Hart 2018), as is true of the Science Museum in London (Caesar 2007; Gammon and Mazda 2004). This 90% is never seen by the public unless special tours are arranged, which would increase the accessibility of the museum collection.

Currently, Historic England (HE) runs monthly tours of some of its storage facilities, which are free to all HE members (English Heritage 2019) but, due to their popularity, booking one of the limited number of places on the tour can be difficult. Rather than a shortcoming, this instead shows the potential for the programme. Even without a charge, these tours could increase public engagement and lift the profile of the museum. Although this may not impact human skeletal remains directly, these tours would help visitors to understand the scope of the museum's collection and how much work is required to maintain the collection.

The downside to this idea is that staff will be required to be present at all times and would not only need to lead the tour itself, but also provide security for the collections against accidental damage or theft. The internal security of the storage facility would not be as dependable as that of the museum proper, which normally has alarmed cases and other security measures. Security should be considered when setting the maximum size of the groups for the tour. Despite these issues, opening up the storage facility to the public can clearly have significant benefits. Not only would the public enjoy the tour and collections, the museum would also be given a chance to show parts of their collections that, for whatever reason, are not normally displayed (English Heritage 2019; Gardener 2007; Keene 2008; Museum Practice 2002). The staff hours required for these tours represent a significant investment, one that is unlikely to be recovered financially (from donations or admissions). However, the museum benefits in other ways, as mentioned above.

Although costly, both display of collections and opening storage facilities for tours can benefit the museum and the collections curated therein. Both strategies have the ability to attract new visitors to the museum, as well as encouraging repeat visits by past visitors, thereby encouraging accessibility. However, both strategies have a cost associated with them. When displaying skeletal remains, the museum must factor in the cost of designing, researching, and creating the display. After this initial cost, however, the yearly cost is relatively low, unless the display needs to be updated or changed – excluding museum operating costs as a whole. Opening the storage facility requires one or more staff members to run the tour, which can represent a significant time investment. Yet, if executed properly, the increase in popularity of and publicity for the museum, will generate public interest and public engagement.

vi. Summary

Many of the cost-saving strategies discussed above are designed to either save, or to generate, resources for the museum. However, not all of the resources saved through applying these strategies will go directly into the protection and conservation of the human remains, or even the museum collection as a whole. This is because there would be many areas in need of additional funding and resources. However, even if only a fraction of what is saved goes towards care of the collections, then implementing these strategies would be worthwhile. Furthermore, the strategies discussed are only those that became apparent throughout the course of this research. Undoubtedly there are other cost-saving initiatives that might be more suitable for certain museums.

Finally, many strategies discussed above, particularly those in Section 5.4.2, can be better understood as an investment by a museum. Several involve a large upfront cost followed by a low annual cost. Therefore, museums may find it necessary to acquire grants, loans, or other additional funding to implement these strategies (Museums Association 2008 pp.7-8; Museums Association 2017b). However, the museum should consider the words of the well-loved author Terry Pratchett before deciding on how much or how little to invest. In one of Pratchett's books (Men at Arms 1993) a character describes his theory on why rich people are rich, known in the book as Vimes' theory of socio-economic unfairness. Vimes explains that "The reason that the rich were so rich...was because they managed to spend less money" (Pratchett 1993 p. 35). He then goes on to describe the so-called "boots theory", which has been used and repeated by economists and others for years (e.g., Mellor 2014). The theory goes:

> *An affordable pair of boots cost about ten dollars, whilst a really good pair of leather boots cost fifty dollars. However, the affordable boots only lasted a season or two, whilst the good boots lasted for years. Meaning whilst the rich person who could afford the investment spent only fifty dollars on boots, the poor man who could only afford cheap boots would have spent a hundred dollars on boots.*
> (Paraphrased from Pratchett 1993 p. 35)

Similarly, a museum must decide whether it is able to invest in the "good boots" and therefore save money in the long-term (Kendall 2011; Museums Association 2009). Alternatively, museums may spend less on the "affordable boots" now and end up spending a greater amount in the long-term, as well as having "wet feet", which in this example is a higher level of deterioration in their collections (Museums Association 2017b). Although this example does come from a fantasy book, it describes precisely what happens in the real world. The more that a museum invests in protection and preservation of its collections now, the less they will have to spend overall in the long-term (Museums Association 2008 pp.7-8).

5.5.3 Problems Facing Museums

Museums are currently facing a multitude of problems; some of the key issues were described in the Section 2.1.2. It is clear from this research that the factors affecting the preservation of human remains within museums are amplified by these issues. The key problems identified were the filling up of museum storage, the "brain drain" currently being experienced by Britain, and a lack of funding and income in museums, all of which could exacerbate problems relating to the care of collections.

Museum storage was shown to be one of the most important factors when looking at what causes deterioration in human skeletal remains (Section 4.3.3). Yet, the filling and overfilling of museums' storage was one of the key problems discussed in Section 2.1.2 (i). To protect the human skeletal remains curated in our museums something must be done. DeepStore was one option discussed in the Background Chapter (Section 2.1.2 i). Storage facilities such as DeepStore could store the material long-term, then transport the archaeological materials to the museum if requested by a researcher. This would mean the museum could focus more on displays and research, rather than storage, which would potentially change the function of museums in the future. The cost of DeepStore was explored in Section 2.1.2 (i) and over a ten-year period was approximately £762.80 for 1 m^3 of storage (Tsang 2017). There are additional costs involved in accessing boxes from storage and returning them; whether the museum shoulders this cost or passes it on to researchers may complicate future research. Creative solutions such as this are becoming increasingly necessary. For example, at one of the museums visited for this project a staff member remarked that the storage facility had already reached the capacity it had been designed for, but that more artefacts could be "squeezed in" (Anonymous pers. comm. 2018). Yet, this is merely delaying the problem, and overcrowded storage facilities can have long-lasting effects on the preservation of the collections, by increasing the likelihood of accidental damage (Bowron 2003; McKinley 2013). Deaccessioning of a collection was the other option that was discussed to help relieve the museum storage burden. Whilst many documents and rules regulate what can be deaccessioned, when possible it does give the museum an option to rationalise their collections. This will be discussed in more detail below, alongside other options that may make it more palatable (Section 5.5.4).

The "Brain Drain" currently being experienced in Britain was outlined as one of the many major problems facing museums (Section 2.1.2 ii). Wages throughout the heritage sector in the UK are stagnating, and this results in specialists either moving to heritage jobs in other countries or leaving the heritage sector altogether. Specialists (not only human bioarchaeologists) help to protect collections by conducting regular condition assessments. Without these specialists, deterioration in these collections could go unnoticed, leading to significant damage and a loss of knowledge. Therefore, something must be done about this "Brain Drain" out of the British Heritage sector.

A lack of funding and income as discussed in Section 2.1.2 (iii) is probably one of the most significant problems faced by museums. With enough money, arguably all the other problems discussed could be solved or at the very least mitigated. There is no doubt that a lack of funding in museums will have an impact on preservation; without the necessary funding museums will not be able to improve or maintain their storage facility to the best possible standard. As shown in this research, this can have a negative impact on any collections stored there (Section 4.3.3). It is clear that something needs to be done to help museums; whilst some options were discussed above, greater action is needed.

5.5.4 Deaccessioning as a Possible Solution to the Storage Crisis

The thought of deaccessioning any museum collections, not least human remains, may seem like a negative concept, but there can be benefits to reducing the size of a museum's collection. While this is a controversial topic, before discussing the strengths and limitations of deaccessioning, it is important to understand how the process should be done, or if it is even possible for the museum. For the purpose of this section, British archaeologically-derived human skeletal remains will be the focus of the deaccessioning discussion, in relation to releasing storage space. Other types of museum collections can be deaccessioned, although the rules and processes can differ significantly (see Chapter 2).

As outlined in the Background Chapter, there are many issues associated with deaccessioning. To address these concerns the DCMS published guidance on the subject as part of their 2005 publication – Section 1.1 (p.12) and Section 2.5 (p.18). First, the museum that wishes to deaccession an artefact or collection must ensure they have the legal right to do so (Ladin 2004; Lewis 2004). Determining the legal right would depend on the type of museum and the conditions that were set out when the museum was originally created, as well as what was written on the original burial licence required for excavation. As discussed in Chapter 2, these burial licences will preclude deaccessioning and reburial, or will require reburial (in which case deaccessioning will not be required as the remains would not have been accessioned). If the former is the case, the museum can appeal to the Ministry of Justice to change the licence and allow reburial; however, each appeal is conducted on a case-by-case basis and the outcome is never certain. Some museums, such as The British Museum, function under the British Museum Act of 1963 which prevents them from deaccessioning any of their curated materials, except in special circumstances such as repatriation (Collections Trust 2017b; Museums Association 2014). Smaller museums that were set up by a trust or charity may also find themselves in difficulty if they wish to deaccession, if it is forbidden by the museum's charter. Donated or bequeathed material can also be problematic to deaccession, if not impossible. The museum would need to establish whether it has the legal authority to deaccession the "object", and this would depend upon the specific wording of the bequest or donation. It should be noted, however, that human remains do not normally fall into this category; bequeathing human remains is, to say the least, unorthodox and of questionable legality (BABAO 2017).

Museums in the UK attempting to deaccession any curated material from their collections should consider the ethical, moral, and reputational damage, and implications of the loss of the material. However, especially when considering human remains, these moral implications can fall on both sides of the argument (Evans 2006). Visitors and patrons may be concerned that the museum is essentially "throwing away" their history, despite potential benefits for the museum as a whole. This may be attributed to the poorly-understood nature of deaccessioning (Verjee 2018; Wijsmuller 2017). Alternatively, some may find comfort in knowing that the skeletal remains are being reinterred. Special interest groups, including Honouring the Ancient Dead (HAD 2018), are particularly known for advocating the reburial of prehistoric human remains in Britain.

The museum should understand the potential financial costs of deaccessioning. In the case of human remains these costs are related to reburial, which is the most common outcome of their deaccessioning. The costs of reburial include: a suitable location, an appropriate ceremony, the actual casket or container for the remains, and the time spent organising reburial and the necessary debate/discussion to come to a decision. Alternatively, there is the potential for human remains to be deaccessioned and transferred to another museum or university. The transfer of human remains between institutions, however, does present some challenges as part of the process involves a transfer of authority over the remains. In the UK, legal ownership does not apply to human remains, unless they have been altered with skill; therefore, authority rather than ownership must be determined (DCMS 2005 p. 12). Furthermore, the burial or faculty licence issued prior to excavation would determine where the remains should be stored; if this is to be a permanent change (rather than a loan), an application must be made to vary the original licence.

The DCMS (2005) set out a number of conditions for determining whether deaccessioning is acceptable or not. The guidance outlines the steps that should be taken in deaccessioning material and who should be consulted beforehand. This has been defined in Chapter 2. Recognising the different reasons for deaccessioning human remains is important (APABE 2017; Garratt-Frost 1992). The focus of this section is the potential of creating more storage space in museums by deaccessioning collections of human skeletal remains. The strategy presented here is to deaccession skeletal remains that have rarely been accessed, or whose provenance is unknown, implying their use in archaeological research is limited. The specific collections to be deaccessioned would need to be decided by an advisory panel. Ultimately, this could relieve the financial and physical burden on storage space in museums to some extent.

Another reason for deaccessioning skeletal remains is for the purposes of repatriation, though this does not apply to most remains excavated in the UK (Gilyeat 2019; Kendall 2019b; Knowles 2018).

Deaccessioning human skeletal remains excavated in the UK can be difficult, but, once all the criteria for deaccessioning have been met, it can proceed. The main option for deaccessioned human skeletal remains is reburial. However, finding the right place to rebury the deaccessioned skeletons can be fraught with ethical and logistical challenges. The APABE (2017) guidance dictates that all Christian remains (7th-19th centuries) should be reburied in consecrated burial grounds. However, for the purpose of this guidance, “Christian” remains were defined as those related to the Church of England; post-reformation Catholic burials and non-conformist Christian burials were not covered. Human remains that fall outside this remit are not explicitly protected by the guidance. For post-reformation Catholic remains, finding a suitable Catholic burial ground may not be difficult, as many Catholic burial grounds are still in use. However, for other non-conformist denominations and for non-Christian remains, this presents a significant ethical challenge, as finding an appropriate burial ground may not be possible. Often these human remains are buried in non-denominational council-run burial grounds. APABE (2017) guidance also states that the reburial location should be as close as possible to the original excavation site. However, in major cities this can involve logistical problems as often nearby burial grounds are full or it is too expensive to obtain space there. Therefore, in some cases the human remains are reburied considerable distances away. A recent example of this is the 3300 skeletal remains found during the 2015 Crossrail excavations in London. As all the nearby burial grounds were full or it would be too expensive to rebury the large number of excavated human remains, a location was chosen in Essex, more than 30 miles away from the original site (Burrows 2016). To find a suitable burial location, it is suggested that the museum consult experts in the relevant field, so that the chosen burial ground and the burial itself can be conducted in the most ethical way.

i. Benefits of Deaccessioning

As mentioned in Section 2.2.1 the burial or faculty licence obtained to permit the excavation of human remains will determine whether they are retained indefinitely or reburied following a period of study (APABE 2017). If the licence requires that the remains be reburied, this must occur, although researchers may apply for an extension to the period allowed for analysis of the remains. If the licence requires that the remains are retained, they will be stored in a designated museum or other appropriate institution (APABE 2017). If the museum wishes to alter the initial terms of the burial licence, either to retain human remains intended for reburial or to deaccession remains intended to be held, they must apply to the MoJ or the Christian Church to vary the burial or faculty licence respectively (APABE 2017). However, prior to starting the arduous process of varying the burial licence, the museum should convene a panel of experts (see Section 2.1.1 vi) to evaluate the remains and any associated artefacts or documentation. This evaluation will ensure that the selected remains or collections are appropriate for deaccessioning. Should the panel determine that the remains can be deaccessioned there are several potential benefits to the museum.

Curation is expensive. An appropriate storage facility must be found, either bought or rented, secured, and equipped to house a multitude of artefacts, materials, human and animal remains. When storing human skeletal remains large boxes are required to properly protect the remains (SMA 2020). Thus, even a small human skeletal collection may require a substantial area for storage. If the museum follows the dedicated guidelines, this would include additional costs relating to packing materials, environmental controls, and other costs more specific to the museum (Cassman et al. 2006; Clegg 2020 pp. 136-137; Collections Trust 2020a; Garland et al. 1988; Janaway et al. 2001). Additionally, the care and assessment of these human remains requires expertise that would impart further costs. Consequently, a substantial part of a museum’s budget may be dedicated to the care and protection of their collections. Rationalising the museum’s collection, by deaccessioning appropriate human remains, can help to limit these costs.

When deaccessioning human skeletal remains the most common option is reburial. However, for some remains, particularly disarticulated or un-stratified remains that are in a good condition, there is the option of moving them to a teaching and/or handling collection. This was the case with the Museum of London disarticulated human remains that were deaccessioned in the early 2000s. The remains were evaluated, with a selection of the well-preserved ones being retained and the remainder reburied (J. Bekvalac pers. comm. 2021). This process made available significant space.

If the whole collection is well-preserved and has appropriate documentation and information, but the museum can no longer provide for its curation, either due to a lack of available space or funding, the museum could consider transferring the collection to a university with a relevant department, to be used in teaching human bioarchaeology students (Redfern and Clegg 2017). As this process would involve changing the designated institution responsible for the human remains an application to vary the burial licence would be required (APABE 2017). BABAO offers to facilitate this process by helping museums find institutions that are willing to accept human remains collections; their website includes a list of possible institutions (www.babao.org.uk/assets/Uploads/Receiving-Skeletal-Collections2.pdf). Any institution that accepts human skeletal remains through BABAO must meet all the relevant storage requirements and must follow the current best practice guidance for curating human remains (BABAO 2021b). An example of this in practice is the University of Reading Archaeology Department which, with the help of Professor Mary Lewis, acquired two collections from museums. The first was the Hulton Abbey collection which was received from the Staffordshire Museum in 2004. The second collection was St Oswald's Priory which was obtained from the Gloucester Museum circa 2013 (M. Lewis pers. comm. 2021). These collections are used in research and teaching at the University of Reading. This transfer has provided a valuable opportunity for education and research while creating space in museum stores.

Numerous groups, such as HAD, COBDO, and other neopagan or Druidic groups, advocate for the reburial of ancient human remains – a minority viewpoint. While these groups hold a variety of opinions regarding human skeletal remains, of particular concern to several of these groups are collections of ancient human remains that are curated indefinitely in "ignoble storerooms" without being researched (Wallis 2015 p. 136). By deaccessioning human remains that are not being researched and by involving these groups in the dialogue surrounding decisions regarding reburial, museums may foster friendly relationships with these groups. Though at this time, due to the lack of cultural continuity or genetic relationship with ancient remains, the advocacy of these groups for their reburial does not meet the criteria established by DCMS (2005) guidelines. Therefore, museums should not give undue credence to their requests.

When human remains are accompanied by good documentation and are in good condition, they represent a valuable opportunity for research. However, there are many collections that do not have documentation (Redfern and Clegg 2017). Without the context and historical background provided by documentation these skeletal collections have a limited use in research. Furthermore, skeletal remains that were recovered in poor condition or have since deteriorated to poor conditions may be of limited scientific value. In these cases, according to the DCMS guidelines (2005), it is acceptable to deaccession the skeletal remains.

By rationalising their collection, the museum can reduce the space required for storage and the expenditure of resources used in its care (Baxter et al. 2018). Thus, resources can be redistributed among the remaining collection. In some cases, this may allow a museum under threat to remain open, as when museums close, their entire collection may no longer be accessible to researchers or to the public.

ii. Issues with Deaccessioning

Deaccessioning human remains can, however, be detrimental, due to the loss of scientific knowledge that might be gained in the future. When a skeletal collection is deaccessioned and reburied, any potential knowledge still "contained" within the skeleton is lost (Clegg 2020 pp. 136-137; Pearson et al. 2011; Ubelaker and Grant 1989). Reburied remains will once again start to decay in the ground and will eventually be lost completely. Moreover, as technology and archaeological methods develop, the chance of implementing new techniques on reburied remains is lost. Therefore, loss of knowledge is twofold. A secondary outcome of deaccessioning skeletal remains is the negative impact on the museum's image. Researchers and the public may disagree with the museum's policy of deaccessioning the skeletal remains. For instance, in 2006 there was a request to rebury prehistoric remains from the Avebury Museum. This request was rejected after several years of consultation, in part due to the perceived scientific value of the remains; see Section 2.2.3 for detailed discussion of the "Avebury Request". While COBDO and Paul Davies (who filed the request) were unhappy with this decision (Wallis 2015; Wallis and Blain 2011), the scientific community supported the decision, as did the majority of the respondents to public surveys (Thackray and Payne 2008; 2009; 2010). Reactions cannot be predicted in every case, but it is not unreasonable to assume some individuals and groups will be distressed by any decision, whether remains are deaccessioned and reburied or retained. Neopagans feel a cultural and spiritual connection to pre-Christian remains and may find their retention objectionable, particularly when the remains are not being used for research (Wallis 2015). Neopagans may advocate for the reburial of these pre-Christian remains under modern adaptations of ancient traditions, but these adaptations may differ significantly from the original rituals (Clegg 2020 p.137; Fforde 2004; Historic England 2009). Neopagans are also not a single unified group and dissent may arise among groups regarding the treatment of pre-Christian remains (Wallis 2015). Furthermore, as shown by the "Avebury Request", there is no demonstrable cultural or genetic continuity between modern neopagans and these pre-Christian groups that would lend them preferential status regarding the treatment of these remains (Brace et al. 2019; Thackray and Payne 2010). Thus, despite best intentions, finding solutions that respect the cultural sensitivities of the various groups can be difficult, if not impossible.

The financial costs of deaccessioning can vary significantly according to the size of the collection and the method of reburial (Cubillo 2010; MEG 1994). As demonstrated in Section 5.5.4, these factors can make it difficult to adhere to the best practice guidance to rebury the remains as close to the excavation site as possible, particularly when other requirements, such as location and ritual appropriate for the religious denomination of the remains, also need to be met (Burrows 2016). These factors may be an issue if the museum is struggling for resources, as this cost would compound the problem. Yet even with these issues, we should not shy away from the ethical and financial benefits of deaccessioning.

iii. Summary

To deaccession skeletal remains from a museum's collection, the museum must first make sure it has the legal right, as well as the ability, to do so. Once this is confirmed, the museum should discuss its decision with other institutions, as well as specialists in the area of human bioarchaeology, to ensure it is making a decision which meets their needs. Once these criteria have been met a suitable location needs to be found for the remains as well as the funding for the reburial process. Despite the issues and challenges associated with deaccessioning skeletal remains, there are benefits – allowing the museum to reallocate space and resources, improving the care of remaining skeletal collections and other objects still curated by the museum.

In the literature and throughout the museum discussion, there appears to be a stigma around the term "deaccession" (Baxter et al. 2018). Many academics and the public are uncomfortable with the idea of deaccessioning and its connotations. However, there has been a new push to replace the term "deaccession" with "rationalise", emphasising greater efficiency within a museum by reducing the size of the collection (Baxter et al. 2018). With this change in terminology, it appears the negative connotations of deaccessioning may be removed, whilst progress can still be made (Baxter et al. 2018). Museums may find it advantageous to consider deaccessioning other archaeological materials, but this project focused only on human remains. A discussion of the pros and cons of deaccessioning other artefacts would require expertise in those specific areas, an expertise the author does not claim to possess.

The loss of knowledge with deaccession is a significant problem, and the next section will endeavour to look at a number of options that may help to reduce this loss, thus making the decision to deaccession more acceptable.

5.5.5 Can Technology Help to Limit the Loss of Scientific Knowledge from Deaccessioning?

Technology is evolving at an ever-increasing pace, enabling archaeologists to have more and more potential methods to use for research (Graham 2017). Therefore, it is reasonable to expect that technology could hold the solution to the negative issues of deaccessioning, most notably the loss of knowledge. The solution to this loss of knowledge, from the author's perspective, is 3D digital scanning of bones, as outlined in Errickson (2017). This could be conducted prior to deaccessioning at first, but eventually it is hoped that 3D scanning will become part of standard recording practices, resulting in all skeletal remains being scanned. Whilst this is a colossal task, complicated by issues such as intellectual property rights, it is still something we, as archaeologists, should strive towards.

i. 3D Scanning

A 3D surface scanner uses visible light to measure objects and create 3D models. The two most common techniques are active scanners and passive scanners. Active scanning uses lasers or structured light to map the surface of an object. Laser scanning involves passing a calibrated wave-length of light over the surface of an object; the reflection of the laser is monitored by a sensor and the distance is computed to build up a mesh of data points (Errickson et al. 2017). Structured light systems project patterns of light onto the object and measure the dimensions of the object through distortions in the pattern of the light (Errickson et al. 2017; Friess 2012). By taking a multitude of measurements of the object through different angles, then aligning these measurements through matching points and eliminating any redundant (duplicated) points, the scanner creates a point cloud of the object (Friess 2012; Gomes et al. 2014). This point cloud can then be used to create a 3D Computer-Aided Design (CAD) model. The more "points" used to create the point cloud, the clearer and more detailed the CAD model will be. This CAD model would be an exact digital replica of the surface of the scanned object, but the colour of the scanned object is not replicated in this process. To reproduce the colour of the object, a 360° high-resolution photo must also be taken and combined with the CAD model (Gomes et al. 2014). Alternatively, colour data can be measured at multiple points along the object and then integrated into the final model (Gomes et al. 2014). Some higher-end laser scanners have this function built in, such as the Artec Eva (Artec3D 2019). Passive scanning such as photogrammetry creates a mesh of an object from a collection of images taken from different angles and under different illuminations. These images are calibrated through a reference object included in each image (Gomes et al. 2014). The images are then stitched together using computer software to create a 3D model of the object. This method, as opposed to the methods discussed above, does record the colour of the object and the final product will be a photorealistic model (Gomes et al. 2014).

Different types of 3D scans have different benefits and weaknesses, meaning some of the scans are better suited to one type of research than are others. Photogrammetry has been in use for approximately 60 years in archaeology, the longest of any of the methods discussed here (Fries 2012). Despite this, it offers the lowest resolution of the three surface-scanning methods discussed and may have issues with scale and size (White et al. 2018). The method requires a laboratory setting to closely control the light levels for proper application (Gomes et al. 2014). However, this is the only method that produces colour models which makes it well suited to 3D printing (K. Badreshany pers. comm. 2021). 3D laser scanning provides sub-millimetre resolution, though the specific resolution depends on the angle of diffraction and the wavelength of the laser (Gomes et al. 2014). Laser scanners, unlike those needed for photogrammetry, are portable. This method specifically has problems with deep narrow structures, such as the interior of the nasal aperture (Freiss 2012). Other issues occur when scanning materials that are dark, translucent, or reflective. Enamel, for instance, is difficult to scan using this method. This can be mitigated by using blue light instead of white light (Errickson et al. 2017), by using a mattifying agent (alcohol and chalk) on the surface (Collings and Brown 2020), or by scanning a cast of the teeth (Errickson et al. 2017). Laser scanning is the most commonly used method of active scanning in archaeology; however, this is most likely due to the relative availability of the scanners (Errickson et al. 2017). Laser scans tend to experience less size and shape distortions than photogrammetric scans, meaning laser scanning is ideal for morphometric applications (White et al. 2018). While laser scanning does not offer the best reproduction of surface detail it has been proven sufficient for observational studies, such as those estimating age-at-death and sex from the *os coxa* (Kotěrová et al. 2019). Structured light scanning provides the highest resolution of these three methods, with relatively affordable scanners offering precision of 0.05mm, versus a comparably-priced laser scanner offering 0.1mm precision (Kotěrová et al. 2019). These scanners are also portable; however, they are sensitive to ambient light especially daylight (Gomes et al. 2014). These scanners, similar to laser scanners, also have problems with dark, translucent, or reflective surfaces, though this issue can be mitigated in the same manner as discussed above. Structured light scanning is increasingly being used in archaeology, as the scanners become both more available and affordable (Kotěrová et al. 2019). The high-resolution scans produced with this method can be used for the applications discussed above for the laser scans, as well as for research that requires the microtopography of the bone (K. Badreshany pers. comm. 2021).

Many other methods exist to create 3D scans, many more than can reasonably be listed and described in this thesis. However, as with the methods discussed above, each has benefits and weaknesses that can preclude certain areas of research (see White et al. 2018). Volume scanning, the broad term that includes Computed Tomography (CT), Synchrotron (X-ray range), Magnetic Resonance Imaging (MRI), Terahertz, and Infra-red scanning, can offer images of the internal structure of the object as well as the surface (Friess 2012). Specialised scanners such as µCT devices can provide resolution of up to 25µm (0.025mm) (Collings and Brown 2020). These methods, however, are not commonly used in archaeology. All of these scanning methods may damage any preserved ancient DNA (Friess 2012). The cost of these devices is also prohibitive; for example, the µCT scanner costs in excess of £1 million in comparison to a midrange structured light scanner's cost of approximately £5000 (Collings and Brown 2020).

Regardless of the type of scan that is used, the applications for these scans are numerous. These scans can be used in teaching to provide better demonstrations of anatomy, normal variation, and pathology than 2D images (Errickson et al. 2017) although arguably these scans are not as good as actual human bone. If these scans are available on an open platform students will be able to study the human remains outside of the laboratory (Errickson et al. 2017). Furthermore, unique examples of pathology or fossil hominids could be shared between institutions (Friess 2012). 3D scans can be used as reference records, prior to destructive analysis (Errikson et al. 2017). The portable methods of scanning can record fragile material *in situ* that cannot be removed without damage (Errickson et al. 2017). Morphometric studies can be conducted without damaging the bone through measurement contact. There are several variables that are more easily obtained from a 3D scan than from the physical remains, including volume, radius, perimeter lengths, vertices, areas, and curvatures (Errickson et al. 2017). For research similar to that in this thesis, scans can be used in longitudinal preservation studies, allowing deterioration to be recorded in detail and 3D (Errickson et al. 2017). As mentioned in Section 2.3, some institutions, for example Oxford Archaeology, have already started to record their collections digitally (Loe 2017).

A number of aspects must be considered when determining which type of 3D scanner is appropriate for the specific institution. Parameters include measurement volume/field of view, resolution, accuracy, portability, acquisition speed, environmental sensitivity, data size, and cost (Errickson et al. 2017; Friess 2012; Gomes et al. 2014). The institution needs to evaluate which parameters are most important for their needs and the type of research they intend to pursue.

Scanning every bone in every skeleton in every museum is a huge task, one that would take decades to complete, and with more skeletons being continuously excavated, this may make the task seem impossible. Therefore, it is more appropriate to begin with any human remains that are to be deaccessioned or reburied, where there is an immediate threat of loss of information and knowledge

(Smith and Hirst 2020 p.332). This should help to limit the loss of potential information. Furthermore, if 3D scanning becomes part of the routine process of recording skeletal remains that are excavated, more skeletal collections would be recorded digitally. Understandably, this will increase the time required to properly complete the post-excavation analysis of a collection, but the author believes this would be worthwhile. A question does need to be asked on how to deal with fragmentary remains, in particular how small of a fragment is practical to scan. The answer to this question should be determined by how many remains are being scanned, as well as the time and resources available. Fragments must be scanned individually and take approximately the same time as a complete bone (K. Badreshany pers. comm. 2021). Very small fragments may require specialised equipment, such as the µCT, which would drastically increase the cost of the scanning process (Collings and Brown 2020; Kotěrová et al. 2019).

If every skeleton that is deaccessioned is scanned, alongside newly-excavated skeletons, within a few years there would be the beginnings of a digital database, a database that would contain not only information about the skeletons themselves, but also photorealistic 3D images, or high-resolution 3D models, of the skeletons. This idea builds on the database proposed by Roberts and Mays (2011), who have long advocated for a country-wide database of human remains. The database could be created with additional functionality, allowing query searching to find bones and skeletons with specific diseases, ages, or sex, and of a specific period or geographical location. This database would be an invaluable resource for researchers and would certainly help to limit the loss of knowledge through deaccessioning and reburial. A similar database has already been created for zooarchaeology. The Virtual Zooarchaeology of the Arctic Project contains a large comparative assemblage of the skeletal remains of northern vertebrates for use in archaeo-faunal analysis (Betts et al. 2011).

Figure 5.6: An example of a 3D scan of an ulna from the Digitised Diseases database. Available at: "Digitised Diseases" http://www.digitiseddiseases.org/mrn.php?mrn=156

Three-dimensional scanning and the creation of a digital database have numerous benefits. Firstly, if the digital database can be accessed online, it could be accessed from all over the world (Smith and Hirst 2020 pp. 334-337). This could increase what we know about the skeletal collections by enabling comparisons between sets of data, thus increasing archaeological knowledge (Errickson 2017 p. 100). This research would be limited to: observational studies – macro analyses (Metcalfe 2007); geometric-morphometric studies – mathematical modelling of shape (Errickson 2017 pp. 93-101; Webster and Sheets 2010); and demographic studies – population analyses (Chamberlain 2006; Hassan 1978). However, the potential research and the knowledge we could gain from these studies is extensive. Secondly, with a database of 3D scans stored digitally, there is no issue of compromised preservation, provided the database is curated properly. A "digital bone" cannot be damaged and does not degrade over time. Some care should be taken to future-proof the database by ensuring the file formats are compatible with future software versions and computers, and to make sure the hardware is replaced every 3-5 years to prevent data loss (Corrado and Moulaison 2014; Morgan 2019). If the data are stored online, the risk of loss due to incompatibility will be very low (Moulaison and Corrado 2015).

The final, and possibly most important, benefit of 3D scanning is the physical space requirements for the database itself, and the resources that it would save, when compared to the physical space required to store the skeletal remains. Estimating the cost of physical space is difficult (we must factor in boxes, shelving, building cost, and other costs), but the cost of space alone is high and is an annual cost. Some museums charge a one-off payment for commercial archaeology companies to store objects and archaeological material, but this charge differs from museum to museum (J. McKinley pers. comm. 2019; McKinley 2013 p. 139). One facility that was interviewed for this research charged a one-off fee of £800 (R. Nicholson pers. comm. 2019) for the storage of any archaeological material (not only human remains). Estimating the cost of digital space is considerably less complicated. Using the Digitised Diseases Database, an open-access resource created by the University of Bradford, Biological Anthropology Research Centre and the Centre for Visual Computing (Digitised Diseases 2020), it is possible to estimate the file sizes of certain bones. The database contains a number of examples of scanned pathological archaeological bones created by using a 3D laser scanner, similar to the method discussed above. Using this method, they created a number of high-quality, photorealistic digital replicas of pathological bones – for an example see Figure 5.6. In relation to the information in the database on the size of the files for the scans, estimates for full skeletons and skeletal collections can be made. A high-resolution scan of an ulna, used in this estimate for its average size, from the Digitised Diseases website (http://www.digitiseddiseases.org/alpha/) was approximately 31 megabytes (MB). Different-sized bones would result in different-sized files; for example, a scan of a femur would be larger than that of an ulna but, equally, the file size of a cuneiform bone of the foot would be much smaller. Therefore, the file sizes noted here are estimates. An adult skeleton with the full complement of 206 bones, mostly intact, would require approximately 6.4 Gigabytes (GB), although only rarely are all 206 bones recovered for each skeleton excavated. A collection of 20 skeletons would amount to just under 128 GB of data storage. Figure 5.7 shows this breakdown by bones, by skeleton and by collection. The preferred method of data storage, cloud storage, typically requires a subscription and, therefore, imparts an ongoing cost of a few pounds per month (approximately £3 for 2TB [≈2000GB] TechRadar 2021). However, the benefit of this storage method is that the data can be accessed anywhere and at any time and is considered secure. Alternatively, external hard drives may be used, and the data can be stored on site. One TB (≈1000GB) of data on an external hard drive costs approximately £40 (taken from a consumer website – Currys 2019a) although it should be noted that these external hard drives should be replaced every 3-5 years (Morgan 2019). Thus, over a three-year period the data storage cost for 160 skeletons (≈1TB of data) stored on the cloud would cost £54, whereas external hard drive storage for these same data would cost approximately £40 every three years. It should be noted that external hard drives are normally only used as a last resort or back up; cloud storage is safer and more widely used (Zamora 2018). Regardless of the method of data storage, the cost incurred is considerably less than the cost of boxing and storing the physical remains: although an exact figure of the cost of the long-term storage is difficult to estimate, the boxing costs alone would be in the range of £200- £1200 (Bowron 2003).

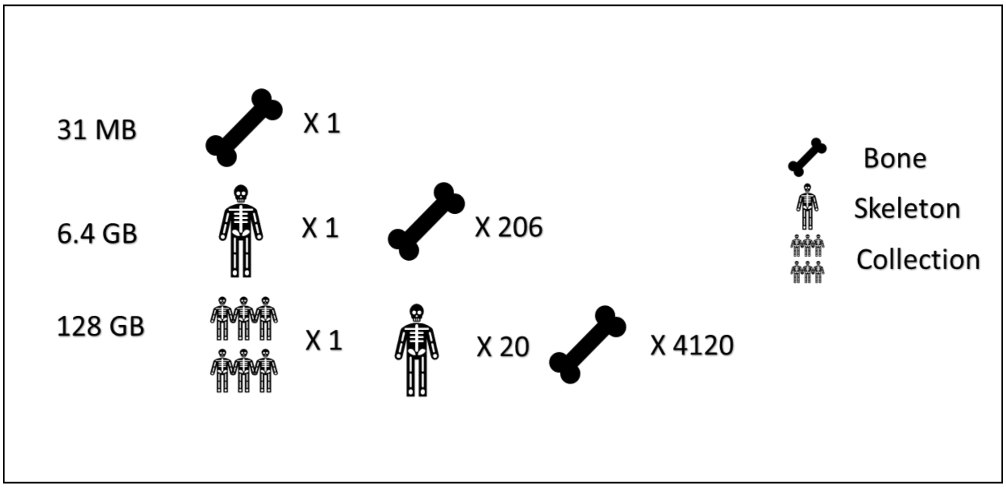


Figure 5.7: Breakdown of digital memory needed per bone, skeleton, and collection. Created from estimations taken from Digitised Diseases.

There are, of course, downsides to 3D scanning skeletal remains. Firstly, the 3D scanning machine itself can be quite costly, with a basic laser scanner costing £2500 (All3DP 2019). Larger, better-quality machines will cost more. Furthermore, to scan the number of bones indicated in Figure 5.7 many machines would be needed. The training needed to set up and calibrate the machine and to troubleshoot any problems that arise would require an expert; this imparts further costs. Thus, the initial cost entails thousands of pounds for a single machine. This high cost is impractical if every museum would expect to own one. However, many larger institutions and universities already own the necessary equipment and employ individuals trained to use them. Furthermore, as with all technology, novelty is expensive; as time passes, prices fall. It is anticipated therefore, that in the future the equipment costs will be reduced.

Secondly, the value of the 3D scans is entirely based upon their resolution, which is dependent on the number of "dots" used to create the point cloud. If the scans have poor resolution, fewer details would be visible – Fig 5.8 shows this difference. Without sufficient detail, observational studies could not be conducted. Thus, scans of high resolution should be taken for the database. To achieve high-resolution scans more points must be used, and this increases the amount of time needed to perform each scan. Even with these high-resolution scans, many argue that these scans are still insufficent and can never replace real human bone (Errickson 2017). A further issue is the fact that you cannot scan what you cannot see; internal structures such as the cranial vault can be difficult, if not impossible, to record in complete or unfragmented remains (K. Badreshany pers. comm. 2021).

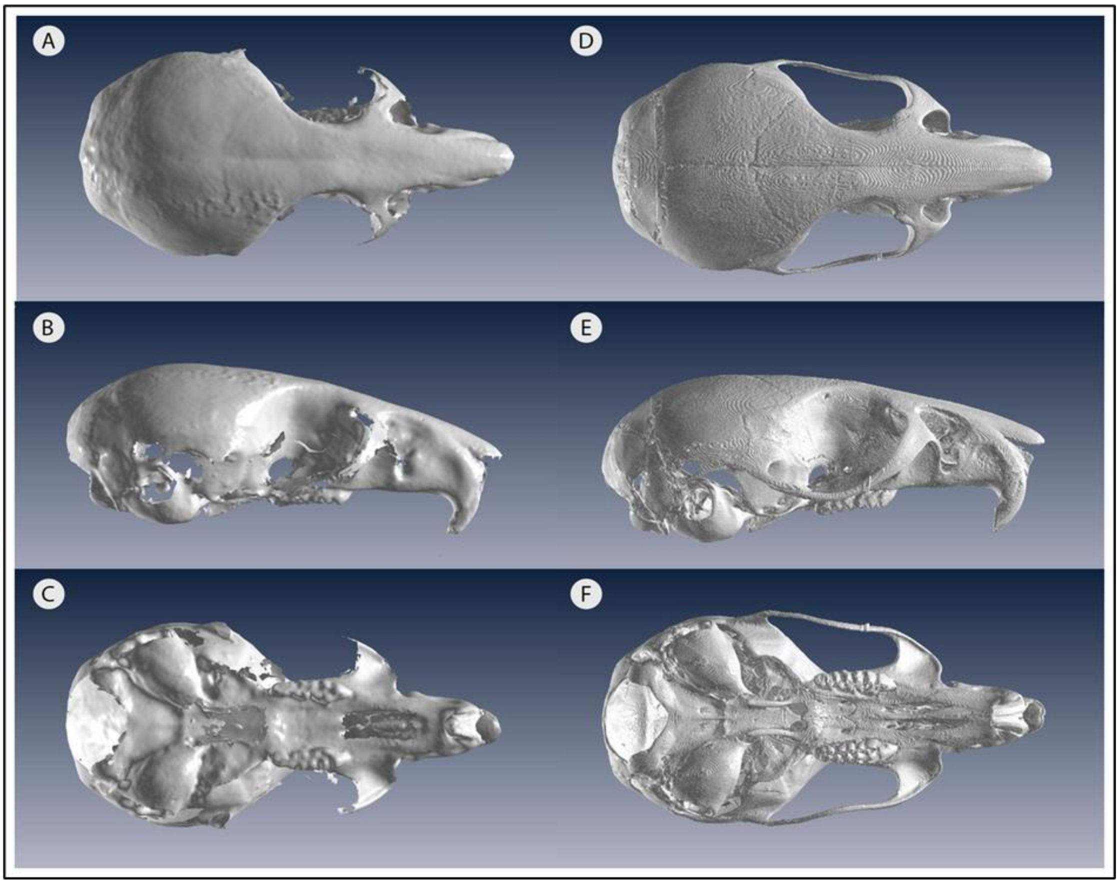


Figure 5.8: Comparison of a high-quality 3D scan (right) and a low-quality 3D scan (left). A and D superior view, B and E view from the right, C and F inferior view – all scans were completed on the same mouse skull (Pseudomys delicatulus). After: Marcey et al. 2018, Figure 1.

Another issue with 3D scanning relates to biomolecular, radiographic, histological, and dental calculus analyses, as such analyses requires a physical sample, which a scan cannot provide. If the skeletal remains have already been reburied, these data cannot be obtained from the scan alone. This is the most significant limitation of the digital scans. This does not mean that with 3D scans potential biomolecular data are lost, but extra steps are needed to collect those data, prior to deaccessioning or reburial. Sampling will be discussed in more detail below in Section 5.5.5 (iv).

A major issue with any digital data is that of intellectual property rights and copyright. Before beginning to scan their collections, museums should ensure they fully understand how to manage and protect the intellectual property they are creating. The issues of copyright and intellectual property rights are discussed further below, in Section 5.5.5 (v).

Museums need to understand the benefits and limitations of each of these types of scans and choose one that best fits their collections. The benefits of 3D scanning are myriad. The potential to save storage space and resources in museums may be the most significant. However, for the best results the process can be expensive and time-consuming, especially for larger collections. Each scanned object takes approximately one hour to complete; in terms of human remains this would be the time scale needed per bone or fragment (K. Badreshany pers. comm. 2021). Therefore, whether each fragment of a skeleton can be scanned depends upon how much time can be allotted to each set of human remains; with highly fragmentary remains the time required may be prohibitive. The methodology of 3D scanning has been somewhat simplified in this research and in practice unforeseen problems can arise. Therefore, an expert or specialist in 3D scanning should be consulted by museums or institutions seeking to employ this method to fully understand the practical limitations involved. Thus, as with several of the potential solutions suggested in this research, 3D scanning can best be understood as an investment. In this section, only remains to be deaccessioned and newly-excavated remains were considered. Whilst these should remain the priority, there are many thousands of skeletal remains that are curated in museums that are unlikely to be deaccessioned. Ideally, these remains should also be scanned, enabling researchers from all over the world to have access to them, but this is an enormous and time-consuming task (Smith and Hirst 2020 pp.334-337). Therefore, scanning of these remains should be done on a case-by-case basis, if or when, the museum wants them scanned and, when or if, the resources become available. These scans should also then be added to the digital database when established.

ii. 3D Printing

Once a digital database of 3D scans has been established, these CAD models can be utilised in a variety of ways. The images can easily be viewed and manipulated on a computer screen, but this has the limitation of displaying a 3D image on a 2D screen. These 2D images can be difficult for some people to mentally interpret, especially if the resolution of the screen is low (such as on a mobile device) (R. Gowland pers. comm. 2020). A potential technological resolution to this issue is 3D printing. It may seem contradictory to suggest creating a new physical model of a skeleton or bone, especially after a museum has gone through the whole process of deaccessioning it. However, 3D printing can be carried out by any researcher anywhere around the world. Any 3D scan, printed models, or related data should only be shared in line with BABAO's Digital Code of Practice, to avoid crossing ethical boundaries (BABAO 2019b) as well as legal boundaries, such as copyright discussed further in Section 5.5.5 (v). Below, the positive uses and drawbacks of 3D printing will be discussed.

First, it is important to understand what 3D printing actually is and how it works. A 3D printer is a machine that takes any 3D digital file and creates a physical 3D model. The materials used to create these models will be discussed in more detail below. A standard 3D printing machine can cost anywhere from £300 to £1,000 but more advanced machines can cost in excess of £10,000 (Grames 2019). Many factors must be considered when choosing a printer, including speed, quality, functionality (colour printing), and materials used in the print. 3D printers can use a range of materials from resin to ceramic and even metal, the most common being polymer or plastic-based materials (Ngo et al. 2018). The three most common and popular plastics are ABS (Acrylonitrile Butadiene Styrene), a petroleum-based plastic used to make toys such as Lego; PLA (Polylactic Acid), a plant starch-based bioplastic, which is nontoxic and better for the environment; and PVA (Polyvinyl Alcohol), a water-soluble plastic, also made from petroleum (3D Printing for Beginners 2019). All these materials have pros and cons associated with them, and each may be better suited to a certain situation than another. Therefore, research is required to establish the best material for museum and archaeological purposes.

Some mediums may need to be treated before being subjected to handling. Annealing, as it is known in metallurgy, is one method of treatment. This is the process of heating a material to just below its melting point then allowing it to cool slowly back to room temperature. Due to similar mechanics, the same name has been given to the process for strengthening polymers. This process changes the structure of the material in polymers such as those used in 3D printing; annealing makes the material stronger, stiffer, and more resistant to handling (Tyson 2017). Other treatments involve coating the print in a superglue solution that, when dried, hardens the surface making it stronger and stiffer. This process was used to harden the 3D replica skeleton used in the Bodies of Evidence exhibition, discussed in Section 2.2.1 (Durham University: Department of Archaeology 2019).

The benefits of 3D printing replicas of human bone are that they are just that, replicas. They will not degrade or deteriorate to the same extent as real human bone (Wilson et al. 2017a p. 131), although they can still become damaged. If they do degrade or become damaged a new replica can be printed at a minimal cost, because the printing media are inexpensive when compared to the printer itself. The printed bone will likely be stronger and more durable than human bone, making it better for museum displays where the object may be handled and there is concern about damaging the original bone, or for teaching introductory anatomy courses (Lozova 2017; Smith and Hirst 2020 p. 328). A rarely-discussed benefit of 3D printed models is the ability to include visually-impaired persons in osteological research (Evelyn-Wright et al. 2020). Another benefit, briefly mentioned above, is that the replica bone does not need to be printed by the institution that originally curated the skeletal remains. The model could be printed anywhere in the world by any number of researchers (Lozova 2017; Smith and Hirst 2020 pp. 334-337) provided the researchers meet the ethical standards set by BABAO – see the Digital Code of Practice (2019a; 2019b). This ability to share 3D scans and create 3D replicas throughout the world would allow many more researchers from different backgrounds to study bones from many collections. This could greatly further knowledge. It should also be mentioned that HAD promotes the idea of using replicas in place of real human bone (Levitt 2016).

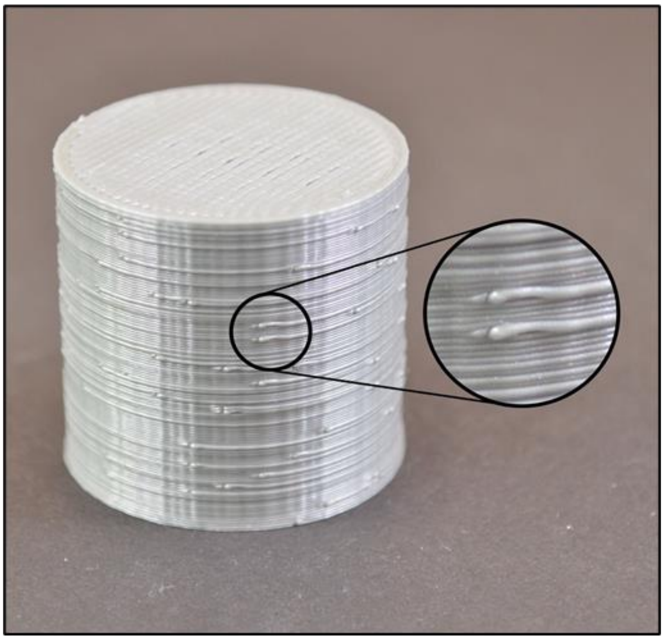


Figure 5.9: An example of a low-quality 3D print. Note the streaking that can occur when filament is laid down incorrectly. After: https://www.simplify3d.com/preventing-blobs-on-3d-print/.

As with any new technology, there are problems with 3D printing. The primary issue is the price of the 3D printer itself. The cost of the filament, essentially the 3D ink, and the wage of a trained individual to set up and run the machine, also factor into this expense. Another issue is the required storage space, not only for the printer itself, but also for the replica bones created. Although the replica bones are more stable than real bone, they take up as much space (which is why it is impractical to 3D print all of the bones we scan). However, if environmentally-friendly or biodegradable polymers are used, disposing of the replica bones will be considerably easier than disposing of real human bone. The 3D prints are also heavier and denser than real human bone; therefore, it is impossible to get a sense of the fragility or lightness of the bone. This prevents certain conditions such as rickets or osteoporosis from being observed in

3D prints, which impacts the usefulness of the prints in certain types of research. The time taken to print a 3D model can also be an issue. Although printing times have decreased over the last few years, a large high-quality print can still take several hours (Grieser 2016; Ultimaker 2019). Thus, 3D printing a whole collection is impractical. The final issue is that of resolution and detail. Although current models are much better than the first-generation printers, issues with the resolution still remain. Primarily, lines or streaks on the printed models can be present and are caused by faults in the model design or printing when the layers of polymer are placed down – printed (AmeraLabs 2018). With the newer printers the streaks are becoming less common and less noticeable, yet these streaks still obscure detail on the surface of the bone model when they occur (see Fig 5.9). This, therefore, limits the use of these 3D models in research, as it would prevent observation of landmarks or pathologies on the bone surface. Additionally, it should be noted that there are copyright and intellectual property right issues with scanning and printing replicas of human remains, as once a scan is created it can be owned; this issue will be discussed in more detail below (Section 5.5.5 v).

3D printing is still a relatively new technology. All the issues and limitations have yet to be identified or mitigated. However, 3D replicas can be useful in certain situations. 3D replicas are ideal for use in museum displays, and when visitors are allowed to handle replicas (Smith and Hirst 2020 p.328). A replica 3D skeleton was used in the Bodies of Evidence exhibition (discussed in Section 2.2.1) presented by Durham University (Durham University: Department of Archaeology 2019). The replica skeleton of one of the "Scottish soldiers" was produced for the exhibition due to the emotive circumstances surrounding the historical events presented, and because the skeletal remains were to be reburied before the exhibition began. Whilst this exhibition did not involve handling the remains, replica remains were considered the most practical and ethical choice. A real skeleton was included in the exhibition; however, these skeletal remains came from the Coach Lane collection (c. A.D. 1711-1857) excavated from North Shields and held at the Durham University Department of Archaeology. The exhibition itself was well received by both the archaeological community and the public (Marchini 2018). Surveys conducted by Durham University showed that 98% of visitors rated the exhibition positively (excellent or very good) (Biddlecombe-Brown et al. 2019). A peer review of the exhibition by Quigley (2018) praised the sensitivity and respect shown to the human remains presented (Biddlecombe-Brown et al. 2019). Quigley (2018) discusses the benefits of using 3D printed skeletal remains for display in cases where the context of the remains is highly emotive. In the free text feedback from visitors where the use of a 3D replica was mentioned, all of the comments were positive (K. Braithwaite pers. comm. 2021). Other comments from this feedback demonstrate that visitors either did not realise or were unconcerned that the remains displayed were replicas (K. Braithwaite pers. comm. 2021). The display of both human remains and 3D replicas were well received in this exhibition.

3D printing is useful when the scanned bone is considered too fragile, valuable, or important to be handled regularly; in these cases, using a replica bone can help to preserve the original (BABAO 2019b pp. 7-8; Beath 2019; Wilson et al. 2017b). This is particularly true of hominin bones where few examples have been excavated/preserved and models are used widely to teach human evolution (Friess 2012). Nevertheless, due to the issues of quality and detail, the replica bones are currently not at an adequate standard for most research, the one exception being morphometric analysis which can be conducted on 3D scans of bones (Marcy et al. 2018; Webster and Sheets 2010). The quality of the prints also limits their use in teaching of human bioarchaeology courses. They may, however, be suitable for introductory anatomy courses. New printers with better quality prints are being developed all the time. New generations of printers are using lasers and light to create replicas of objects (Greguric 2018). These new 3D printers produce the most metrically accurate prints, and are widely considered the best for printing bones. However, these "selective laser sintering" 3D printers cost anywhere from £3800 to £135,000 (Collings and Brown 2020).

iii. Future Technology

As we look into the future of 3D printing, we can see how quickly the technology is developing. New technologies are being introduced all of the time. Archaeologists must consider how to implement this new technology. One example of a technology that has the potential to be very useful to archaeologists is virtual reality, or VR.

VR is a technology that uses computers to create a digital simulated environment. It places the user inside a generated three-dimensional space, allowing them to interact and move around in a 360° area, rather than viewing a flat two-dimensional image as would be the case on a regular computer screen (Carson 2016). Currently, the technology is being developed for entertainment-based gaming systems. However, it has great potential in many other areas, some of which will be discussed below. VR requires the user to wear a head mounted display (HMD) that is connected to a suitably-powerful computer, one that can send a video feed to the HMD (Carson 2016). Two types of HMD exist. The first is a dedicated HMD device that has been solely created for VR. These are usually equipped with hand controls, allowing the user to manipulate whatever they are viewing in VR. This setup offers the best resolution and has the best functionality. However, dedicated devices are very expensive – a single HMD can cost anywhere from £100 – £800, depending on make and model (from a consumer website: Currys 2019b; Greenwald 2019). Therefore, owning several of these dedicated devices would be impractical for most institutions. The second option for VR – HMD is a simple plastic or cardboard frame that has two lenses (see Google Cardboard Viewer – Figure 5.10). These HMDs require only a smart phone to produce VR images and videos. The user simply inserts their smart phone into the frame and runs a VR application. This option is much more affordable than the dedicated HMD if the user owns a smart phone or has access to one. The cost of the frame is between £6 and £60 (from a consumer website: Amazon 2019; Noble 2019). However, with this option there is no capacity to manipulate the 3D image or object. Additionally, the resolution of the image depends on the PPI (pixels per inch) of the smartphone, which is typically less than that of a dedicated HMD.

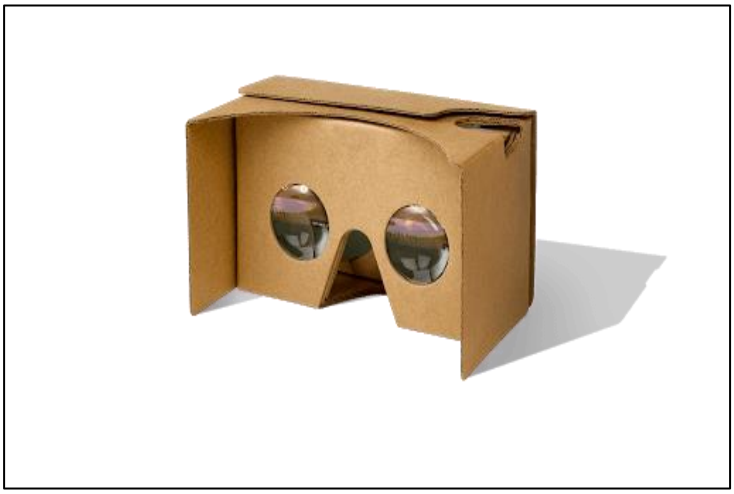


Figure 5.10: Example of a Google Cardboard Viewer for use with a smart phone. After: https://store.google.com/product/google_cardboard.

VR will become an invaluable tool for teaching, and it has already been used with great success in some classrooms and in some archaeological projects (Bestock 2019; Ellenberger 2017). In VR lessons, students can visit and experience the world without leaving the classroom. One example of this has featured on the BBC programme *Ancient Invisible Cities* in which an historic building, such as the Hagia Sophia, was scanned. A 3D model and a VR tour of the building were created. (The VR tour is accessible online: BBC 2018). There is no reason this technology cannot be applied to teach human bioarchaeology in the future. For optimum functionality, the instructor should have a dedicated HMD with the ability to move and manipulate the area, with the students having the simpler smartphone holders to view the area or object. This would allow the teacher to focus in on key areas of the digital image, location, or object. In teaching human bioarchaeology this could be: bone landmarks, signs of disease, or any other bone abnormalities. This digital "hands-on" approach would be beneficial for new human bioarchaeology students and for those who do not have access to physical remains. Furthermore, students from less well-resourced universities that may have limited, or no, skeletal collections could use this technology to view rare pathological bones and other examples. The digital database (discussed above) would allow for a wealth of skeletal remains to be accessed in this way. The possibilities for VR to augment teaching and education are endless (Class VR 2019).

This technology, at least for human bioarchaeology, is still for the future. A dedicated application (app) would be required, and one has not yet been created for human bioarchaeology. This is an opportunity for human bioarchaeologists to design the app with specifically-tailored functionality for human bioarchaeology. To create such an app would require individuals with technological expertise as well as familiarity with human bioarchaeology, or perhaps a collaboration of individuals with the required expertise.

As discussed above, the greatest potential for VR is its use in teaching. However, there are further benefits. If the VR technology is combined with online digital database technology (discussed above – Section 5.5.5. i), the proposed VR teaching could be expanded, potentially taking place globally, and hypothetically through the platform of Massive Open Online Courses (MOOCs 2019). This would be especially helpful in those places that are limited by a lack of skeletal collections. This combined technology could also benefit places where the use and study of ancient skeletal remains is controversial or limited, such as in the USA, Canada, Australia, and New Zealand (Errickson 2017 p.94), as less controversial remains from other countries, such as the UK, could be used. Another benefit is the long-term cost. Although the initial cost to purchase the required technology is substantial (several thousand pounds), so too is the cost of caring for a skeletal collection. Purchasing several HMDs and using an online database of skeletons and pathological bones to provide most of the examples needed for teaching is a practical solution in many cases. Despite the high initial cost, the annual cost is fairly low in comparison to the cost of caring for a physical skeletal collection.

As with all new technology there are drawbacks. The first is an issue that arises in the way that VR creates a three-dimensional image. Some people experience dizziness and, in some cases, mild nausea when using VR (Kim 2019). This does not affect everyone, but some people do seem more susceptible to it. Most who are susceptible will only experience these effects when using VR for extended periods (Kim 2019). The second issue is the current expense of a dedicated HMD, as well as a computer with sufficient specifications to run the high-resolution videos required. Both of these technologies can be very expensive, but the prices are beginning to come down. Whilst a smart phone and a head-mounted frame could be used as a cheaper alternative, this setup is limited by the resolution of the phone. If the resolution of the phone screen is too low, details cannot be seen, and images may appear pixelated. Resolution issues may render the user unable to properly view and interpret the image in 3D (R. Gowland, pers. comm. 2020). Finally, the lack of a dedicated application which is needed to fully utilise VR in human bioarchaeology is another key issue. Although an application can be developed, this will take both time and money. Therefore, as it currently stands, VR cannot be used to its full potential for human bioarchaeology.

VR is an amazing technology, and has many applications within numerous disciplines, including archaeology. In education, it is likely to become a vital tool for teaching, although currently the technology is too expensive for the dedicated HMD and the resolution is too low in the smartphone display. Therefore, the utility of VR for teaching human bioarchaeology is currently limited. Nevertheless, VR technology has great potential and will definitely become more useful in the future. Some will argue that technology, including VR, can never be a substitute for real bone and hands-on experience (Roberts 2013 p.129). However, in cases where access to physical remains is not possible, VR produced from photorealistic digital scans can be a suitable alternative.

iv. Chemical Analysis Problems

While 3D scanning retains the image and proportions of human remains for future research, and 3D prints or VR allow these scans to be viewed and manipulated, none of these strategies allow for chemical analyses. Instead, samples of bone or teeth must be kept to allow for these analyses. Retaining a small sample of the skeletal remains after a collection has been reburied is not an uncommon practice. One recent example relates to the skeletons of the Scottish soldiers from the Battle of Dunbar found in Durham (Annis 2015). The skeletal remains were reburied in May 2018, in accordance with the burial licence; however, provisions were made within the licence to allow a number of teeth and rib fragments to be retained for future research as new techniques become available (Durham University: Department of Archaeology 2019). Similar practices may, hopefully, be applied in future to skeletal remains that are deaccessioned from museums and subsequently reburied.

As discussed throughout this thesis, the museum should ensure it has the right to retain any samples; this information is determined by what was written in the original burial licence. This licence can be changed to allow retainment of a sample, and this decision is made on a case-by-case basis. If this option is available to museums, it has the potential to be useful. The museum should ensure any data that comes from the analysis of those samples (or any samples taken from the museum) still belongs to the museum. Without special agreements, this may not be the case. Although ownership of human remains is impossible, any raw data produced from the remains can be owned. The raw data, without any agreements, would belong to the institution or researcher that conducted the analysis, rather than belonging to the museum that curates the remains. This would mean that, although the museum still holds the remains, they would not have any ownership of or access to the data produced (Holst 2017; Redfern and Clegg 2017; Smith and Hirst 2020). There are options for the museum to avoid this. A memorandum of agreement could be created, showing that the museum would still own the data, although this is not legally enforceable. This option has been used with great success by the International Ancient Egyptian Mummy Tissue Bank at the Manchester Museum (Elliot 2009), where both the Bank and the depositors agree to share ownership of the data. The depositors must prove that they have the legal "ownership" of the remains and can legally make the decisions for what happens to the remains. Once this has been established, the museum agrees that any samples still belong to the original depositor, and in return, the depositor agrees that the museum can use the samples for analysis. The agreement goes on to state:

> "If commercially useful developments result from any use of the sample(s) of mummy tissue in the Bank, the Parties agree to notify each other promptly and negotiate on fair and reasonable terms and conditions independent of this Agreement."
> (Elliot 2009; taken from The Manchester Museum Reports and Policies 2004)

If similar memorandums or contracts can be implemented between researchers and museums, or the analytical institutions and museums, this would allow the museum to share the data with any researcher, meaning more research can be conducted without further degradation of the skeletal remains, or without infringing on copyright laws. Museums are encouraged to create their own copyright policy; The Collections Trust and Spectrum have created resources to help with this (Clegg 2020 p. 68; Korn and McKenna 2017).

Retaining a small sample of the skeletal remains, while reburying the majority of a collection, means the remains are available for use in biomolecular analysis should the need arise. Storage of these samples would require significantly less space than storing the entire skeleton and, therefore, would use fewer museum resources. The obvious problem with this method is that a single study has the potential to consume the entirety of the retained sample. Therefore, efforts should be made to ensure that the analysis is appropriate, useful, and that all data collected are owned by the museum, so that they can share the data with future researchers (Holst 2017). Accurate records of the data generated from the original recording of the skeleton would be necessary as the skeleton could not be used to verify osteobiographical information for the sample.

These small samples would require a minimal amount of space and could be retained by the museum or stored in one or more centralised locations. The idea of a biobank specifically for UK archaeological human remains was originally proposed by Wilson and colleagues in 2013. It is possible that universities could be used as potential centralised storage locations. Biobanks already exist in some museums and universities; notable examples include the Natural History Museum (Emery et al. 2012) and the Manchester Museum's International Ancient Egyptian Mummy Tissue Bank (Elliot 2009). The Natural History Museum curates three biobanks: CryoArks, an archive of frozen zoological specimens; the United Kingdom Insect Pollinators Initiative, a collection of pollinator specimens with their gut contents and parasites; and the Schistosomiasis Collection, a repository of schistosome parasites and host specimens gathered from around the world (Natural History Museum 2021b). The Ancient Egyptian Mummy Tissue Bank consists of 1496 samples of skin, muscle, internal organs, bone, hair, insects, resin, and other materials from 614 mummified individuals or the materials used to preserve and pack their bodies (University of Manchester 2021). The Ancient Egyptian Mummy Tissue Bank is one of the only biobanks in the world that holds primarily archaeological material (University of Manchester 2021). If similar biobanks were created to house samples from archaeological human remains excavated in the UK, this could help alleviate the issue of knowledge lost when skeletal collections are reburied. An archaeological human remains biobank facility should follow the guidance documents for the storage and treatment of human remains created by BABAO and CIfA, as these are the professional bodies for human bioarchaeologists and archaeologists in the UK.

Whilst biobanks have many negative connotations in medicine, this primarily relates to the issue of informed consent (Widdows and Cordell 2011). In archaeology, any remains that are less than 100 years old fall under the Human Tissue Act (HTA), which requires additional documentation during the process of sampling and tracking what each sample is used for, as well as informed consent before the samples are taken (Wilson et al. 2013 pp.153-155). However, this 100-year threshold seems arbitrary, as it is a timescale that is always shifting; remains that were once covered by this Act will fall out of its protection (Wilson et al. 2013 p.153). For those remains that are older than 100 years, informed consent can be impossible. Yet, in archaeology there is less of an issue of consent – as rightly or wrongly – it can never be given by the deceased, which is why human bioarchaeologists deal with so many ethical issues.

Having one facility that stores the samples of human remains can be beneficial. The facility can ensure these samples are stored in optimal conditions. It can also ensure they are equipped to deal with the problem of informed consent and, if this is not possible, they can ensure the remains are treated in an ethical manner which should always be at the core of any research (Squires et al. 2020b). Storing only a small amount of osteological or dental remains is less invasive than storing the entire individual; for some groups – such as descendants of the deceased, this may be a suitable compromise between reburial and curation. Storing only a small sample also has the benefit of using significantly less space within the storage facility.

The question then becomes which element(s) should be sampled and stored. This is not a simple question, as some skeletal elements are better suited to certain analyses than others. The samples that are selected can sometimes preclude certain methods of research. The bone, tooth or parts thereof that are chosen need to be considered carefully, to maximise the possibility that these samples can be used in future research. When conducting isotope analysis, for instance, dental tissues can be used to reflect childhood values while samples from bone will reflect an average value reflecting the last years of an individual's life (Beaumont et al. 2015). Bone samples will not produce uniform values as different bones remodel at different rates; thus, femoral bone samples will reflect a longer-term average than samples of rib bone (Hedges et al. 2007). However, predicting which elements are going to be useful, and which elements will be needed for future research, is problematic and challenging. Instead, we must look at trends in the research and evaluate which bones commonly contain the information we need. Traditionally, dental samples (often from premolars) were used to examine isotope values from childhood; however, recently analyses of the third molar have been used to examine values reflecting the period of adolescence (8 years – 23 years) (Kancle et al. 2018). As this type of analysis has only recently been applied to this period of development, samples of the third molar were not necessarily selected for storage when a collection was reburied. Kancle and colleagues were only able to proceed with their project, researching dietary changes in adolescence at two medieval friaries, due to the third molars from these reburied collections having been retained by chance (L. Kancle pers. comm. 2021). Another issue is whether the samples that have been chosen for retention are viable, which is difficult to determine prior to analysis. For example, the petrous part of the temporal bone is considered the best part of the skeleton for aDNA analysis (Charlton et al. 2019) but is not guaranteed to contain aDNA (Campos et al. 2012; Charlton et al. 2019). Whilst it is possible to test for aDNA preservation before the sample is selected, it is unlikely that the funding and resources would be available to do this. Therefore, any bone that is selected for storage would be selected "blind" (Campos et al. 2012). Furthermore, aDNA may degrade in storage, although this is dependent on the storage conditions (Mitchell et al. 2005). Thus, even if the appropriate bone or dental samples are retained there is no guarantee that analyses conducted on these samples will be successful.

v. Copyright and Intellectual Property Issues

Copyright and other intellectual property rights are important issues when dealing with scans and 3D printed replicas. Intellectual property has been discussed briefly with regards to data created from samples held in biobanks; this section focuses on imaging and printing rather than research data. BABAO, The Collections Trust, and Spectrum have all created guidance, guidelines, or other resources outlining the recommended practice for dealing with 2D and 3D imaging and printing of human remains (BABAO 2019b; Clegg 2020 p. 68; Korn and McKenna 2017). Spectrum and The Collections Trust also suggest a process to help museums create their own copyright policy (Clegg 2020 p. 68; Korn and McKenna 2017).

Museums and other institutions considering scanning or printing parts of their collections should consider issues of copyright and intellectual property rights before beginning the process. BABAO recommends that 3D prints are only made if there is a scientific reason, and a physical replica should only be used where research, education, or public knowledge can be enhanced (BABAO 2019b). Furthermore, the museum should ensure it has permission to create the 3D scan or 3D print, as without this, they may be liable for copyright infringement themselves, or may face other legal repercussions (Taylor and Wessing 2013).

Even with this guidance ethical concerns remain (Smith and Hirst 2020 p.330), primarily over the use of the images and scans in the public domain (social media) and the issue of consent. The issue of consent is inextricable from the study of human bioarchaeology as the dead cannot provide consent. This issue also applies to any 3D scans or prints made from human remains. While consent cannot be obtained, human bioarchaeologists must ensure that these scans or prints are used respectfully. However, once a scan or print (including photos of the 3D print) has been created it can be difficult to control how or where it is used (BABAO 2019b; BABAO 2019c). Errickson and Thompson (2019 p.309) outline some instances of 3D scans being used and manipulated into household objects such as candleholders. The responsibility to prevent this type of misuse belongs with the holder of the copyright and they should endeavour to ensure the scans are treated with respect, no matter where they are shared and with whom (Errickson and Thompson 2019 p.310). The holder of the scans should strive to ensure that they are not exploited, manipulated, nor sold for profit in any way by other individuals, companies, or institutions.

Human skeletal remains cannot be owned, whereas the same is not true for scans or prints made from those skeletal remains (BABAO 2019b). As the scans have had agency applied, the copyright belongs to the creator. This can mean that although the museum curates and holds authority over the skeleton and the collection, they would not own or have the rights to the scans or 3D prints created by others and would have no control over how or where they were used. This can lead to further ethical concerns, depending on who created the scans. Thus, museums should ensure they own the copyrights to any scans, 3D prints or data created from skeletal remains. This would allow the museum to better prevent the scans from being used inappropriately, such as for commercial purposes. If the scans or 3D prints are used inappropriately, constituting copyright infringement, legal action should be taken. Institutions should remember that these scans are of real human remains and should be treated and protected as such (Errickson 2017). However, if someone is determined to flout copyright laws, realistically there is little the museum can do, beyond precautionary measures, to prevent this. Furthermore, once the images or data have been reproduced and distributed it is impossible to stop further misappropriation. Therefore, it is important for the owner of the scan or data to be determined before creation, to ensure the copyright stays with the owner/curator of the original skeletal remains. Whoever curates the scans gains the responsibility of enforcing and protecting the copyright, ensuring the scans are used only for suitable purposes, such as research. There should always be a justification for sharing images of the scans online or printing the scans, such as research or museum display, but never for personal use nor for profit (Errickson and Thompson 2019 p.309).

One suggestion outlined above was that universities could help museums to scan or print their collections, as the 3D scanner and 3D printer can be costly to own and use. However, in these cases assurances must be sought regarding who would own the copyrights. This should be agreed before the work commences.

If the museum intends to hold digital collections (not only of human remains) they need to ensure that they are prepared for the new added area of security and copyright protection. As with any data held online, there are greater and different security concerns. Whilst some copyright and intellectual property problems have been discussed, these are just outlines. Museums should consult a legal expert on the matter to ensure they are conforming to and protecting their intellectual property and copyright claims.

vi. Summary

In this section, present and potential future technologies that could help museums and other institutions manage loss of knowledge associated with deaccessioning skeletal remains have been discussed. Deaccessioning is a difficult and controversial decision. However, in some cases, it can be the correct decision. It is hoped that the technologies discussed above can help to mitigate the negative scientific impact of deaccessioning, namely the loss of scientific knowledge. By taking 3D scans of skeletons and retaining a small sample of bone or tooth, research can continue even after the skeleton has been deaccessioned and reburied. 3D scans can be used for observational or morphometric research and they can be used to create 3D printed replicas of bones. In the future the 3D scans can potentially be used in virtual teaching. If deaccessioning of skeletal remains becomes more prevalent, archaeologists will need to turn to technology to help limit the loss of knowledge. Therefore, familiarity with this technology is advisable.

5.5.6 Commercial Archaeology Companies and the Storage Crisis

One of the main focuses of this chapter has been on museums and the issues they are currently facing, and particular attention has been paid to the storage and preservation of human remains and to a lesser extent other archaeological material. However, as mentioned in Section 2.1.2 (i. a), museums are not the only organisations in the heritage sector facing storage problems. Commercial archaeology companies are also facing the struggle of storing excavated material, arising from the increase in archaeological excavations, the filling up of museum storage, and changes to planning guidance. This results in these companies having to resort to expensive and occasionally improper temporary storage.

Commercial archaeology companies do not choose when or where to excavate; rather they respond to decisions made by construction companies and contractors. Yet, commercial archaeology companies bear the brunt of storage costs from these excavations. If we return to the original motivation of PPG 16, founded on the "polluter pays" principle, then the burden of storage should rest with the construction firms and contractors. Currently, following the National Planning Policy Framework and Historic Environment Good Practice Advice, all excavation and processing work is covered by construction companies; these costs are often factored into the cost of the land or, at the very least, budgeted for when planning the construction project. Long-term storage costs are not typically included in these budget estimates or are included only as a one-time cost (R. Nicholson pers. comm. 2019). Yet, these costs factor into the post-processing expenses of an excavation, and therefore, it is neither unjust nor unfair to ask the construction companies to contribute more toward these expenses.

The competitive nature of obtaining archaeological contracts makes it difficult for a single commercial archaeology company to add this additional cost to their proposal. Even now, the issue of cost-cutting in excavation in order to adhere to strict development schedules is faced by commercial archaeology. For example, in the excavation of St Pancras, London, burial ground in 2002-2003, developers felt that the excavation was taking too long delaying construction, and turned to an exhumation company to expedite the removal of burials, with the loss of archaeological recording (Loe and Clough 2020 p.164). Although this decision was later reversed due to both public and professional backlash, this example shows that, from a construction stand-point, archaeology may be viewed as an unnecessary and expensive delay. Thus, commercial archaeology companies will not be able to remain competitive if they begin adding further costs, such as those for long-term storage, to their bids for projects.

While development companies may dislike or contest the cost of archaeological excavation, the original documentation of PPG 16, the precursor to all the current policies, was to discourage construction on archaeologically-important sites. The intention of the policy was to make development excessively expensive at these sites, thus preserving the finite resource of archaeology (Loe and Clough 2020 p.159; McKinley 2013 p. 135; PPG 16 1990 p.5). Therefore, applying the cost of storage would only further this goal. Furthermore, as outlined in PPG 16 (paragraphs 12 and 13), leaving archaeological material *in situ* was the primary desired outcome, with excavation being the secondary alternative (PPG 16 1990 p. 6). If the objective continues to be the protection of archaeological sites *in situ*, then charging construction companies for the indefinite storage of excavated material seems a logical means by which to achieve it. Costs would increase with each excavation as more material would need to be stored.

Developers would not welcome this increased cost. Many have strict profit margins, and any delays or increase in costs can cause the company to be unable to cover costs, and possibly become insolvent or bankrupt. This is a risk not only to development projects, but to developer-funded archaeology, as any archaeological excavation would be left unfinished and undocumented (Loe and Clough 2020). There are some public relations benefits to development-funded archaeology and, increasingly, development companies are aware of these benefits and encourage outreach opportunities that arise from their association with excavations (Loe and Clough 2020). Development companies could gain similar public relations benefits from helping museums survive, by contributing to long-term storage costs for archaeological materials or archaeological human remains.

To achieve this change in funding structure a government policy would be required. Commercial archaeology companies cannot begin adding long-term storage costs to their bids for projects individually as they will be under-cut by other companies that do not add this cost. Development companies will not be willing to pay these extra costs unless they are legislated.

Unfortunately, recent policy changes that plan to allow bypassing of the planning permissions, threaten the current allocation of funding for archaeological excavation (Lennox 2020). Increasingly, it is clear that archaeology is seen, by the current government, as inconvenient "red tape" that prevents and impedes development. The proposed relaxation of the planning regulations in England would remove safeguards which may threaten archaeology through the loss and damage of archaeological sites (CIfA 2020b)[5]. Furthermore, the proposed relaxation in planning policies shows the government apathy towards the plight of archaeologists, emphasising how difficult, if not impossible, it would be to pass the needed legislation that adds long-term storage costs onto development. Nevertheless, a planning policy that incorporates the cost of storage into excavation costs that is paid by construction companies, however unlikely, would be welcomed by museums and commercial archaeology companies alike.

5.6 Summary

In this chapter, the original hypothesis that research, as measured through access to human remains, would impact the state of their preservation in English museums, was discussed. As expected, the

[5] Recent news suggests that the relaxation of the planning policy may not go ahead due to significant backlash unrelated to archaeological concerns (Skopeliti 2021).

research showed that access did have an effect on skeletal preservation. However, this was not the primary cause for deterioration; instead, the data showed that "start preservation" was the most significant factor in determining deterioration in preservation. Start preservation cannot be controlled. Good storage, another significant factor and one that can be controlled, was determined to be integral in limiting deterioration. The costs of preventing and controlling deterioration, as well as ways to mitigate and offset these costs, were also outlined. Problems facing museums were considered, of which financial pressures and storage issues were found to be the most pressing. Deaccessioning human remains was proposed as one potential solution to the storage crisis in museums, enabling museums to conserve money and other resources. Further to this, 3D technologies – scanning, printing, and virtual reality – were discussed in relation to how they could be used to limit loss of scientific knowledge from deaccessioning skeletal remains. Finally, the issues facing commercial archaeology companies, as related to storage, were discussed. The idea of a shift in planning policy by the government was proposed, which would allow museums and commercial archaeological companies to charge construction companies a yearly fee for the long-term storage of any excavated archaeological material.

In the final chapter, conclusions that can be drawn from this research are outlined. The research outcomes and the limitations of this project will be further explored. The potential for future projects that could build on this research will be discussed. Finally, the need for change in certain areas of archaeology, as highlighted in this thesis, will be reviewed and recommendations presented.

Chapter 6: Conclusion

6.1 Overview of Research and Findings

The key research question, as outlined in Chapter 1, was to assess the change in preservation of human remains stored in English museums and to evaluate if research, as observed through access, was the primary cause of deterioration, and if not, what primarily causes this deterioration. A secondary question asked whether there are any cost-saving methods that can help resolve or mitigate these causes.

To answer these research questions, several aims were outlined and described in Chapter 1:

> Aim One: To create, develop, and test a new preservation scale for human remains that recorded not only surface damage, but also the completeness of the bone.
>
> Aim Two: To assess the relationship between research – through access – and deterioration in preservation, using the newly-developed scale.
>
> Aim Three: To evaluate other potential causes of deterioration to establish if any had a greater impact than researcher access.
>
> Aim Four: Using the information gathered as a result of achieving the other three aims, evaluate what might be done by museums to lessen deterioration, as well as any limiting factors.

6.1.1 What was Expected?

Access was expected to have some impact on deterioration in preservation and past research supported this expectation. However, the degree of this impact needed to be better quantified. Additionally, other potential factors that could have caused the deterioration needed to be discussed and evaluated. The results largely supported the predictions that were made for the factors observed in this study. As predicted, access did impact deterioration, but so did many of the other factors evaluated in this study. In particular, start preservation (estimated via a retrospective baseline assessment) and museum storage were found to have a correlation with deterioration.

Although not a primary aim, factors that impacted access were also evaluated. The data required for this analysis had already been collected during the course of investigating the primary aim. Therefore, it seemed logical to investigate how the factors observed for this research impacted the amount of access. These results were not as reliable as the results found for the primary aim; this was due to the data collection method favouring the data required for the primary comparison – see Chapter 1, Section 1.6.1. Whilst the results for these comparisons were interesting, the predictions made for these data sets were less consistent with the results found.

6.1.2 To What Extent Were the Aims of This Study Achieved?

The first aim of creating a preservation scale was discussed in Section 3.1.1. In that section the method of creating and developing the new preservation scale was outlined, as well as the improvements that were made. In Section 3.1.1 (i) the inter- and intra-observer error testing of the scale was presented and discussed. The results showed that the scale had relatively high levels of inter- and intra-observer agreement within the groups who took part. The scale was, therefore, determined to have low levels of subjectivity. As the scale passed testing and was deemed fit for purpose, it could be used to evaluate preservation of the skeletal remains in the next stage of the research. The preservation scale, however, was assessed for use on actual human remains and met the criteria outlined in Chapter 1. Yet, limitations exist when using this scale alongside the methodology outlined in Section 3.1.2 to create a retrospective baseline assessment from documentation. These limitations are discussed in Section 6.1.3 and 6.1.4. Future research to assess the reliability and accuracy of the methodology used to estimate the retrospective baseline condition is proposed in Section 6.4.

Section 4.2 addressed the second aim, an evaluation of the relationship between access and deterioration. The results showed that there was a weak correlation (r=0.17646) between access and deterioration. Whilst this showed that there was some influence of access on deterioration, the correlation was not as strong as one might have expected. This led to the conclusion that concerns over the preservation of human remains should not prevent responsible research, provided the funding is available to do so.

Section 4.3 addressed the third aim: evaluating other factors that could influence the level of deterioration observed in the skeletal collections. The results showed that the factors with the strongest correlation with deterioration in preservation were the start preservation of the skeletal remains (r=0.37604) and the museum storage rating (-0.34095). These two factors were shown to be the most important when considering how to control deterioration in skeletal remains. However, only the museum storage ratings could fully be controlled by the museum; start preservation, as a "natural" factor, could not. This research, therefore, focused on improving storage conditions. Discovering a singular causative factor for the deterioration in preservation of human skeletal remains is unrealistic; instead, deterioration is caused by a number of interconnected and related factors. Nevertheless, in this research factors were evaluated individually, to determine which most influenced deterioration, so that steps could be taken to address them.

The final aim was to suggest actions to lower or mitigate the level of deterioration observed in skeletal collections held in museums. Firstly, in Section 5.4.2, museum storage improvements and the associated costs were discussed. Some improvements were seen as investments, such as boxes or shelving, with a high upfront cost, but a low annual cost. Other actions, such as hiring a human remains specialist, had no upfront cost but had an annual cost. This hiring cost could be out of reach for individual museums, but the cost may be mitigated by sharing the specialist, both their expertise and their salary, among several institutions. Secondly, methods designed to help museums apply their limited resources were discussed, the savings of which could be put back into conserving the collections. The methods were discussed fully in Section 5.5.2. These methods included: producing better and more complete documentation for all collections; producing a detailed use history of the collections; and displaying human remains to increase visitor numbers. Together, these sections cover a wide range of methods that could be beneficial to museums of all sizes. Not all of these methods would be applicable to every museum in England, or the world. However, each of these methods if implemented, even individually, could help to ease the deterioration of our skeletal collections.

i. Supplementary Findings

As a supplement to the primary aims, factors affecting access were also investigated. The impact of time out of the ground, time period, start preservation, and museum type/size on the amount of research access experienced by a collection were evaluated. One of the most surprising results was access compared to time out of the ground. It was assumed that, the longer a collection had spent out of the ground the more it would have experienced research on it. Therefore, skeletal collections that had spent longer out of the ground were expected to have had a greater amount of access. Yet, the results shown in Section 4.4.1 showed the opposite: the longer a collection spent out of the ground, the less likely it was to be accessed. A possible explanation for this is that skeletal collections in curation have an effective 'life-span' for when they are accessed for research (Section 5.3.1).

The incorrect predictions made regarding factors influencing access, as shown above, demonstrates the dearth of understanding in this area. This emphasises the need for a greater amount of research into this field, which in turn would enable museums and other institutions to better facilitate and control responsible access.

6.1.3 How Effective was the Methodology?

Creating a retrospective baseline assessment was a methodology devised specifically for this project, as no existing methodology could be found that would allow the key research question to be answered fully and in the time available. It is hoped that because of its usefulness, as demonstrated in this project, it may, after further testing to determine whether the preservation scale can be used to obtain an accurate reflection of preservation from documentation alone, be implemented and used elsewhere.

A means by which to chart the change in preservation in human skeletal remains was required. The standard method of a longitudinal study involves taking a series of recordings at intervals over many years. However, the time-scale of several decades that would be necessary to observe these changes directly was impractical for this thesis. Therefore, a method for a retrospective baseline preservation assessment was created. Furthermore, it is not realistic to start a longitudinal study anew and wait for several years. Action is needed now to protect curated human remains, not only for the present, but also for the future.

The method of creating a retrospective baseline preservation assessment, referred to throughout this research as the "start preservation", used any available documentation such as: photographs, skeletal reports, excavation reports, or site reports – alongside the created preservation recording scale. The need for high quality and detailed documentation became the limiting factor when choosing the collections observed for this research, and this will undoubtedly limit its widespread application in the future. As the human remains used were excavated during the 19th and 20th centuries, many museums simply do not have the required detailed documentation to create an adequate estimate of the baseline preservation.

Once the baseline preservation had been recorded, an observational study was conducted on the skeletal remains, providing both a current preservation estimate and a retrospective baseline estimate. These two values could be used to calculate an estimate for the change in preservation. These data were analysed statistically. The statistical methods used were not typical for the type of data collected. Section 5.4.3 puts forward an argument for the legitimacy and necessity of using these statistical methods; Section 4.1 shows why they worked for the data collected in this study. Hopefully, following the evidence presented in this thesis, these statistical methods will be used more liberally in archaeology – where and when they are applicable.

Some difficulties were encountered during the process of reconstructing the baseline preservation assessment; these have been discussed in Sections 3.1.2 (i) and 5.2.1. Despite these difficulties, this research has produced some interesting correlations, particularly between the change in preservation and museum storage conditions. Whilst these correlations need to be verified by further research, they do suggest that the best way to protect the human skeletal remains stored in museums is to improve storage conditions. If further analysis is to be conducted, the issues faced with this methodology will need to be overcome. One problem that was faced was a lack of clarity in some of the photographs used to create the preservation estimation. Although photographs were the preferred method for creating the retrospective baseline, the quality of the photographs varied. Photographs that were taken *in situ* caused some difficulty, as often the bones were obscured by soil meaning a full preservation assessment was not possible. In these cases, the specific elements had to be discounted from the study as a reliable retrospective baseline could not be created. Another potential issue is the damage that can occur between the taking of photographs *in situ* and the accessioning of skeletal remains into a museum collection. As mentioned in Section 3.1.2 (i), skeletal elements may appear whole *in situ* but when lifted from the ground and cleaned, the bones may be shown to be fragmentary. Distinguishing between fragmentation that occurs in the burial environment and later during curation is discussed in Section 3.1.2 (i); this methodology should be employed where this issue occurs. However, it should be recognised that there will be breaks that occur after the *in situ* photographs are taken and before the human remains are accessioned by a museum. Human remains are handled during lifting, washing, drying, packing, transport, initial assessment, and full analysis. Breaks that occur during these processes will not be stained and therefore will appear fresh during later analysis. Further damage may occur whilst the human remains are waiting to enter the museum; as discussed in Section 5.5.6, the length of time human remains are held by commercial companies prior to accession is increasing. Thus, evaluating all unstained breaks as having occurred since accession will result in an overestimation of the damage that occurs during curation. This issue highlights the difficulty in retrospectively estimating the condition of human remains from documentation, further indicating the importance of conducting baseline condition assessments at accession. The final difficulty was one that was expected, namely the written descriptions of the skeletal remains in the collections which were used alongside the photographs; these descriptions varied significantly in quality and usefulness. The discussion in Section 5.2.1 showed how valuable descriptions can be when sufficiently detailed (as shown in Figure 3.7), but also mentioned how limiting they can be if confined to a single word or phrase (referred to as the "traffic light system" in Section 2.3.1(iv)).

The use of a retrospective baseline condition assessment to estimate the change in preservation of curated human skeletal remains was deemed to be the most appropriate way to go about conducting such a study. A true longitudinal study, conducted by the same person, using the same preservation scale on the same collection, over a period of 10, 20, or 30 years would prove more useful. However, the use of retrospective baseline preservation assessments has shown the potential for this type of study, albeit with the need for further analysis of the accuracy and reliability of the methodology to confirm the findings of this research. The major limitation of this method is the need for detailed documentation, which was available for the collections used in this research but is not readily available for all skeletal collections. This limitation does prevent the methodology and analysis from being used on a wider scale. Nevertheless, where the documentation is available, and after further testing of the methodology, it should be possible to use this method on other skeletal collections.

Notably, all museums used in this thesis had excellent documentation, as well as complete human remains policies. One factor that must be considered when using documentation and photographs to create a baseline preservation assessment is the age of the documentation. As mentioned in Section 5.2.1 the quality of photographs has increased over the years as camera technology has improved; skeletal collections excavated earlier are represented by hard copy photographs or were not photographed at all, whilst more recently excavated collections, when photographed, are represented by higher quality digital photographs. Some of the oldest collections used in this study were excavated and accessioned before cameras became commonly used in archaeology, and did not have photographs taken. The Sneep collection, for example, was excavated in 1889 and accessioned in 1910; no photographs were available to create the retrospective baseline preservation assessment. This collection could be included in this study, however, due to the excellent descriptions. The more recently excavated the collection, the more likely it was to be photographed; the photographs produced would usually be of higher quality. Thus, photographs from more recently-excavated collections would be more useful for studies of changes in preservation. Furthermore, if 3D scans become more commonplace, future preservation studies could compare these images, providing detailed information of the deterioration of human remains in three dimensions. Descriptions, conversely, have not necessarily improved over time. Time pressures on those conducting post-excavation analyses may instead have limited the detail included in descriptions of human skeletal remains. Whilst excellent descriptions and detailed documentation of collections can be found, as was the case with the collections used in this study, this standard of documentation is far from universal. However, as condition assessments have become a part of the standard protocol for the accession of human remains to museums, it is hoped that in future more collections with excellent documentation will be available.

The need for excellent documentation for this research, which is not always available in the museum industry due to a lack of appropriate resources, will have introduced a bias in the results. Skeletal collections without excellent documentation could not be included, due to the fact that a retrospective baseline assessment could not be created. Furthermore, all of the skeletal collections selected for this research also had dedicated human remains policies. This must be considered when viewing the results and conclusions of this thesis. The excellent documentation and dedicated human remains policies would have had a positive impact on the preservation of the human remains stored in museums. To what extent these policies impacted preservation cannot be determined by this methodology. Instead, further investigations following alternative methodology would be required to determine this.

6.1.4 Limitations of Research

With any study, there are limitations and this study is no different. The first limitation is one that was discussed above: the need for detailed documentation to create the retrospective baseline preservation assessment, and the overall lack of availability of this documentation. This limitation unfortunately cannot be easily resolved, and instead shows the need for better and more detailed documentation across the wider museum community. Other challenges encountered during the creation of the retrospective baseline preservation assessment have already been discussed in the evaluation of the methodology used; see Section 6.1.3 above. Additionally, detailed records regarding past access to the collections were required to quantify the amount of access that was granted to each collection. These records are not universally available for all museums. The collections studied in this research were selected to satisfy this need for detailed documentation for the retrospective baseline assessment.

One significant limitation with this study is that the methodology used to create the retrospective baseline assessment from available documentation has not been thoroughly evaluated. An evaluation of this methodology was planned, but due to COVID-19 restrictions this evaluation could not be carried out. The intended evaluation was an intra-observer error test of the methodology – revisiting a collection used in this study and repeating the retrospective baseline assessment. This required a significant period of time (at least one year) between the first and second assessments, such that the second assessment could be considered independent of the first. Comparing the two assessments would allow for a determination of the reliability of this methodology, at least at the intra-observer level. An alternative evaluation of this methodology, discussed in Section 6.4, involves observations on a newly-excavated skeletal collection and analysis of the associated documents. While this methodology should be evaluated for reliability before it is used for further research, this study produced significant correlations between museum storage conditions and the change in preservation. If the data can be verified through further evaluations of the methodology, this would strengthen the arguments put forth in this thesis.

A related limitation, that was outlined in Section 3.2, was the disparity between the dates of excavation and the dates at which documentation was produced for the human skeletal remains in the museums. For example, Ad Pontem was excavated over 40 years before the condition assessment was conducted. This meant that the start preservation and change in preservation (current preservation minus start preservation) were calculated from 2008, whilst the time out of the ground was calculated from the 1960s. Whilst this would not have had an impact on most of the comparisons used in this study, it was significant in the comparison of time out of the ground versus change (Section 5.2.4). Time out of the ground was found to have no correlation with the change in preservation, perhaps as a result of this issue; however, further research should be conducted to determine this, and the current data from this comparison should be used with caution. This limitation is difficult to mitigate; accurately dated, detailed documentation is not necessarily available for skeletal collections excavated in the past. However, for research conducted on recently-excavated collections this should be less of an issue, as condition assessments should now be conducted both as part of the post-excavation evaluations of human remains and the museum accession process and recording methods (both osteological and in the field) have been standardised and professionalised in recent years.

Another associated limitation was that the highest recorded amount of access was a collection that was accessed on eleven occasions. Thus, the range of access experienced by the collections included in the study was relatively low. Well-known and high-access collections, such as Christ Church Spitalfields, or university collections experience a significantly greater amount of access. However, these high-access collections are not typical of the collections held in museums across the UK (Roberts and Mays 2011). Instead, the regional museums studied here are more representative of the overall amount of access experienced by skeletal collections in museums.

As discussed in Section 5.3.2 there was a limitation in the creation of a storage quality score, in that only current storage conditions could be quantified. Any changes in storage conditions over the period of curation would not be accounted for by this score. This will have impacted the correlation found between storage quality and change in preservation. None of the museums evaluated in this research maintained accurate records of past storage conditions, meaning it was impossible to assign these past conditions a quality score. The most information that could be obtained was either from curators who had personal experience with the past conditions, or in the strange instance that the packing material itself had acquired historical value over time (i.e., newspapers from the 1930s). This limitation is unfortunately unavoidable, as the documentation for storage conditions in the past do not exist. Going forward, perhaps maintaining detailed records of past storage conditions should become common practice in museums. However, currently, the results from this research must be interpreted with caution. Whilst it is likely that storage has a significant impact on the preservation of human skeletal remains, the full extent of this impact must be evaluated by further research.

A related limitation was that the study utilised a relatively small sample of human remains: 21 collections from five museums were recorded. The sample was restricted by the need for detailed documentation discussed above. In order to confirm the findings of this thesis, further research on a wider sample should be conducted. However, the methodology might need to change in order to accommodate collections lacking the necessary documentation. A longitudinal study of preservation would trade the requirement for detailed documentation for the requirement of a time span of several years, even decades, between assessments. One benefit of this study is that the condition assessment conducted for the current research could form the basis of a future longitudinal comparison using the same methodology.

A further limitation of this study is that all the values used to describe preservation are estimates rather than actual values. Deterioration is a gradual and inconsistent process. Therefore, ascribing a value or trying to assign a category is challenging. Deterioration in preservation does not conform to the categories we create, and therefore assigning bones to those categories has to be on a "best fit" basis rather than an exact match. Consequently, the values we ascribe are merely estimates of the preservation. Yet, realistically, there is no other way to observe and record preservation; estimates are the best we can achieve to make informed conclusions.

Another limitation is the subjective nature of preservation scales in general. All scales that require an observer to rate anything have some level of subjectivity or disagreement between observers. The scale used in this research was no different. The intra- and inter-observer testing conducted in Section 3.1.1 showed that the preservation scale developed for this project had low levels of subjectivity; however, low subjectivity does not fully eliminate the problem. This was expected, yet there is no doubt that unchecked subjectivity can impact results and conclusions of a study. Therefore, care must be taken to ensure subjectivity is kept to a minimum. As there was only one observer collecting the majority of the data in this study, subjectivity was less of an issue, as shown by the intra-observer testing conducted at the start of this study. However, repetition of these tests by another researcher may result in differences in evaluation.

The final limitation was that only the long bones of adult skeletons were evaluated for preservation and that not all long bones were present for each individual. This was primarily due to the need to evaluate a large number of skeletons within a constrained amount of time, as set by the museums. Whilst the major long bones represent a sizeable portion of each skeleton, they are relatively robust and large compared to other elements. Therefore, further research is required to determine if the same patterns of preservation can be found for other skeletal elements.

The limitations discussed above are consistent with any study that endeavours to look at preservation. Sample sizes are going to be limited by time, budget, or the scope of the project/research questions. Preservation studies will always involve some amount of estimation in calculating a preservation value or score; these values are subjective. However, the inevitability of these limitations does not excuse them from evaluation. Efforts must be made to improve estimates and reduce subjectivity. Additionally, researchers must be aware of these limitations in the analysis of data that are produced from these types of studies.

6.2 Recommendations from the Research

6.2.1 What Should be Done?

Throughout the course of this research two major issues became apparent: the need for a database of human remains curated in the UK and the growing problem of over-crowding in the storage facilities housing human remains, both of which can have an impact upon the preservation of skeletal remains. To ensure the long-term survival and protection of not just the human skeletal remains museums curate, but also other artefacts stored in museums, these issues must be addressed.

A key issue is the lack of a human skeletal database (both localised and country-wide). As mentioned in Section 5.5.2 (iv) a distinction is made between a catalogue of collections, which most museums already have in place, and human skeletal databases which are used to collate and store information about the skeletal remains from multiple collections. Without a database, collections go unstudied as researchers are unaware of the human skeletal remains that are available (Roberts and Mays 2011). This, in turn, concentrates research to a limited number of high-access, popular collections that are vulnerable to over-use. This pattern of unbalanced access demonstrates the need for a database. The form of this database and what information it should contain has yet to be decided: whether the database should simply contain a list of all the human remains currently stored in the UK and their locations, or be a more complete version containing 3D scans, full documentation, demographic information, and bone profiles. The latter has, albeit optimistically, been promoted in this study.

Another database that is desperately needed in English archaeology is one that contains the information from destructive analyses. It is recommended that this be similar to the database created by the National Museum of Scotland, an online, updatable, and open access database that allows aDNA data to be shared among researchers, avoiding the unnecessary duplication of destructive analyses (Sheridan et al. 2019). Destructive analysis of human remains has not been a focus in this study, as it unquestionably causes damage to the remains used. Yet it still needs to be controlled, along with the factors highlighted in this study, to ensure the long-term preservation of our skeletal remains for future generations. The database would need to contain information on what destructive analysis had already taken place, by which company or institution, on which collections, whether it was successful or not, and if unsuccessful the reason why, all of which is recorded in the National Museum of Scotland database (Sheridan et al. 2019). Unlike the National Museum of Scotland database, it would need to incorporate all forms of destructive analysis, not just aDNA. This database could protect human remains in two ways. First, where analysis has been successful, if the data are readily available and reliable, this would prevent unnecessary repetition of destructive analyses. Second, if information is provided regarding failed analysis, this may preclude certain analyses. For example, if the samples analysed failed to produce amplifiable human aDNA, then there would be little point in further analysis of these samples to locate aDNA of pathogens such as *Mycobacterium tuberculosis* (Donoghue et al. 2004). However, information on destructive analyses is typically only kept if the analysis was successful (Fox and Hawks 2019). Therefore, how many samples have been analysed and failed is unknown, or how many of those failed samples have been taken from the same collections. This is becoming a significant problem in the study of hominin remains, as outlined in Fox and Hawks (2019). Fox and Hawks (2019) argue that, as only successful analysis is published and failed analyses are not discussed, researchers are losing necessary information. Nobody has a record of what analysis has and has not worked, how many samples have been used or, more worryingly, how many skeletal samples are left. This is particularly alarming for the study of hominins as there are few to begin with. This information must be recorded and disseminated. Archaeologists of the past are often chastised for their approach to archaeology – excavating without care for future generations and without appropriate documentation. Arguably, this was done without knowledge of the harm being done. We, however, do have this knowledge. The archaeologists of the past could not have imagined the technology and techniques we use today – from studies in aDNA analysis to flying drones – or the information we are able to obtain. Therefore, it is logical to think that future techniques and technologies are beyond our comprehension; thus, it is our duty to ensure that there are still skeletal samples available for future archaeologists. Currently this is not a significant problem in the study of historic and prehistoric human remains, but it is not impossible for it to become one. Whilst there are considerably more historic samples than hominin samples available to study and research, the current mentality of "publish or perish" in academia, and the ever-present judgment of the Research Excellence Framework (REF 2021), push researchers and their universities to regularly publish. It is possible to see how this analysis could get out of hand.

Gathering information and making it available in a database, however, presents several difficulties. Firstly, the necessary information may not be readily available, particularly with regards to failed analyses. This data are typically not held by the curating institution and are instead held by the laboratory that conducted the analyses. The curating institution may not have been informed which analyses were successful and which ones failed, meaning they would be unable to share this information. The curating institution may be able to determine this information by comparing the resultant data to the sampling log; however, generating and sharing this information would require a significant time investment. Copyright is another issue associated with the database of destructive analyses. The curating institution may not have the rights to the data produced; this would instead belong to the person(s) who commissioned (and paid for) the analysis. For example, if the police commissioned radiocarbon (^{14}C) analysis to determine whether a set of skeletal remains were modern or archaeological, they would have the rights to any data. Archaeological human remains would then be passed to a curating institution (university or museum) along with the original report of analyses conducted. However, if further information is required by the curating institution regarding these initial analyses, the laboratory would only be able to provide this information to the police. Copyright issues relating to human remains are discussed in detail in Section 5.5.5 (v). Due to the complexity of copyright laws, it is advised that the museum consults an expert on copyright law to guarantee no issues arise in the sharing of data. Furthermore, the Collections Trust advises museums to create their own copyright policy and has resources available to assist with this (Korn and McKenna 2017). In theory, a database would be useful in preventing the unnecessary destruction of human remains. However, in practise, this database of destructive analyses would be more challenging to create and maintain than a database of human remains. Part of the difficulty is that this database would require the collation of data from multiple sources including curating institutions, laboratories, researchers, and those who commission analyses. Furthermore, the data required for this database would be subject to copyright laws. Thus, the database creator would need to obtain permissions to collate and share any data they collect.

The second key change that is needed is a solution to the storage problem; that is, the filling up and overcrowding of storage facilities. Deaccessioning is one potential solution that was discussed in Section 5.5.4. In that section, the technology that could be used to limit the potential losses of deaccessioning were discussed. Yet, even with all of this potential technology, deaccessioning is still unpalatable as, fundamentally, deaccessioning terminates access to a collection. Thus, no further research can be conducted. Deaccessioning is also unpopular with the public; museums are seen as stewards of history and heritage, removing items from their collection can be seen as contrary to this role. DeepStore was suggested in this thesis as a way to deal with the dwindling capacity of museum storage. There are two primary benefits to utilising DeepStore for museum storage. First, all material is stored underground and, therefore, is protected from fluctuations in temperature, flooding, and sunlight. Secondly, the storage area available is vast and ever-expanding; as such, the capacity of DeepStore is unlikely to be exhausted in the near future. The ease of access to collections stored in this manner will be reduced relative to traditional storage; however, DeepStore offers to transport collections upon request. Yet, a question needs to be asked over the impact transport has on the preservation, loss, and breakage of the stored artefacts. DeepStore attempts to manage the potential damage to the stored artefacts caused by transport, including loss, breakage, or deterioration in condition; however, more research is needed to understand these impacts. The full benefits and limitations of DeepStore are discussed in the Background Chapter (Section 2.1.2 i). It is this type of innovative thinking that the museum industry needs to solve the problems they face.

The second potential solution for the storage problem discussed was greater funding for storage facilities and museums in general. In Section 5.5.2, various methods were discussed that could help museums save money or raise money from the collections of human remains they curate. These resources could be used to protect and preserve the collections the museum curates. One option for the source of this funding would be the construction and development companies that often instigate the excavation of archaeological material. Although the cost of excavation and post-excavation processing may sometimes include a storage cost for the developer, this is usually a one-off fee (sometimes determined by the number of boxes; R. Nicholson pers. comm. 2019). However, this one-time storage fee is not substantial enough to cover the cost of long-term storage. The cost of long-term storage is continuous, and to offset these costs the charge should also be continuous, annually for as long as the material is stored. However, if an individual commercial archaeology company were to begin including these costs in their project bids, they would not win contracts in a competitive market (Loe and Clough 2020). Instead, as mentioned in Section 5.5.6, a change in legislation or government policy would be needed, making it clear that the long-term cost of storage is the responsibility of the developer. This idea builds upon one of the aims of PPG 16, the "polluter pays" principle, with a preference of leaving archaeological material *in situ* (McKinley 2013 p. 135; PPG 16 1990 pp.5-6). If the developer decides to leave the material *in situ*, it would remain for future generations to discover, which is arguably better than keeping it in storage. Yet, recent proposed changes to planning policy guidelines are moving in the opposite direction. The current government has proposed relaxing existing planning policies to encourage development; this political atmosphere is not conducive to further expenses being suggested for development companies (CIfA 2020b; Lennox 2020). Thus, getting any archaeologically-favourable legislation passed at this time seems extremely unlikely.

6.2.2 What Can be Done?

Realistically, the options discussed above are unlikely to be implemented in the near future, if at all. A comprehensive UK database for human remains has been proposed and advocated for ten years by human bioarchaeologists (Roberts and Mays 2011), and as yet little progress has been made other than a handful of museum-wide databases. Likewise, policy changes, such as that suggested above to improve funding for archaeological storage facilities, require considerable amounts of parliamentary lobbying and time to bring forward – and would probably not be passed (see discussion in Section 5.5.6). Therefore, we can say there is a difference between what ideally should be done and what realistically can or is likely to be done. Rather than focussing on a nationwide project, such as a change in policy or the creation of a national database, we should instead focus on individual museum-level factors. These small changes can add up to much larger improvements, if adopted by multiple museums.

The primary action a museum can take to help protect their collections is to improve their storage facility or general storage conditions. This thesis explored several ideas on how this could be achieved through a museum storage cost-analysis study, presented in Section 5.4.2. The ideas were based upon the storage quality evaluation factors used during the investigation into the relationship between storage and change in preservation, presented in Section 4.3.3. These ideas could be split into: investments – one-off or infrequent purchases with a subsequent low annual cost (such as metal shelving, sturdy boxes, or non-acidic packing material); annual charges (such as building rent, electricity, heating, or hiring a specialist); and situational charges – these being charges that only occur in certain situations, such as pest infestation. The research conducted in this study indicated that storage was a key factor in slowing or preventing the deterioration of skeletal remains stored in English museums. Therefore, any improvement to storage will help to prevent deterioration. Some of these improvements are quite expensive, but the data showed that investing in these improvements is worthwhile. Even if a museum cannot apply all of these changes, a greater understanding of the options available to the museum can help them to make informed decisions with regard to their limited resources.

When it comes to protecting their collections, museums have options other than improving their storage facilities. These other options were discussed in Section 5.5.2 and offered a more holistic or general approach to protecting museum collections. The primary option was to conduct a baseline preservation assessment, followed by periodic assessments. This would allow the museum to observe any changes in their collections and take action to resolve the problems immediately as trends of deterioration become apparent.

The second option involved creating and updating the documentation of their collections. By understanding both the state and history of their collections, the museum can make more informed decisions when it comes to the allocation of resources. Documenting access will show whether a collection has been handled extensively. When coupled with periodic condition assessments, this may reveal early signs of deterioration, and record keeping will allow the museum to implement changes in order to protect the collections.

The options discussed above as well as the museum storage factors all have one thing in common; they all cost money. Some improvements can be made with only minimal investment, while others require greater resources, but they all have a cost. This is a problem when the museum does not have funding to spare. As such, it was deemed necessary to discuss means by which museums could bolster their resources in order to protect their collections of human skeletal remains.

The first, albeit unpopular, solution is to charge researchers for access to the museum's collections. This could be a flat fee covering the entire research period, or a daily rate for the research space. The charge, in theory, would help to cover the cost of opening the storage facility to researchers, including the wage of a staff member. However, self-funded students and independent researchers that lack sufficient resources may be unable to afford this fee. Discouraging research is an extremely undesirable outcome; however, museums struggling financially may consider these charges as a potential solution.

A more widely-accepted solution for museums is to display their collections of human remains, either in temporary or permanent displays (Biers 2020 p.241). There are different considerations for each (see Section 5.5.2 v.); for example, whether or not the museum would be able to charge for entry to the exhibition, and whether or not to permanently allocate space to these displays. As mentioned in Section 2.2.1 and Section 5.5.2 (v), the display of human remains is popular with the general public. The surveys listed in Table 2.1 by Carrol (2005), Mills and Tranter (2009) and the Museum of London in both 2004 and 2008 show museum visitors find it acceptable for museums to display human remains (79%-92% of respondents) and in the majority of cases (53% of respondents) actively want or expect them to be displayed. Therefore, if a museum were to create a display featuring human remains, it could potentially attract visitors, increasing donations or if the museum charges for entry, admissions. The increased funds could be used to improve all areas of the museum, including storage conditions. Before creating the exhibition, the museum should ensure it has a human remains policy and follows this policy whilst creating the display (Collections Trust 2020a). This option is not only limited to human remains; artefacts discovered locally can also be popular, as local visitors (as well as non-local visitors) enjoy finding out about local history (D. Jones pers. comm. 2019).

A solution which follows from display, also mentioned in Section 5.5.2 (v), is the opening of the storage facility for tours. Information from Historic England shows the popularity of storage facility tours. The proportion of curated material that is stored out of the view of the public can be as high as 90% (Caesar 2007; Gammon and Mazda 2004; Hart 2018). Opening a museum's storage facility also increases the accessibility of the collections, a continual goal for museums. Yet, the museum must understand that to create these tours is a vast undertaking. As well as creating the actual tour, there are revised risk assessments, cleaning, security checks, and other preparations to make. These preparations would impart an increased cost, one that is unlikely to be regained through the tours themselves. Instead, the museum would benefit in other ways, through increased publicity and public engagement that raise the profile of the museum.

The cost-saving methods discussed in Chapter 5 are not going to solve the storage problem on their own. These methods can help mitigate the problem and delay the crisis point at which a museum can no longer accession new materials or can no longer afford to run a storage facility. None of these truly provide a solution; they are merely delaying the impending storage crisis. Realistically, a solution is needed now. As described above, the options available at this time are either: wide-scale deaccessioning to reduce the strain on storage facilities, or a change in planning law or policy to provide further funding for the storage of archaeological materials. Achieving a change in planning law in the current political climate seems improbable; the only pragmatic option is to deaccession.

Museums need to do their part, but researchers can help in a number of ways. Firstly, researchers need to be responsible with their research. This covers a number of different behaviours. Respecting the skeletal collections is the most important responsibility. This should be automatic and no researcher should be allowed access if they do not respect the skeletal remains they study; however, the need for respect is still important to state. These skeletal remains are all that is left of a once-living individual, and they should be treated and protected as such. By treating the skeletal remains with respect, we can minimise the chance of accidental damage.

Furthermore, researchers need to fully understand that research is destruction to some extent. Whilst this is obvious with destructive analysis, the research in this study showed that any and all access to a collection does have an impact on the preservation of that collection, even if this impact is slight. Although access was not the primary cause of the preservation deterioration, it did have an impact. By understanding that access can damage the remains, researchers must ask themselves if their research is worthwhile, or even necessary, or has the same information been collected elsewhere, that could be used for the analysis.

Thirdly, researchers can better communicate their data and results to others, not only through the publication of successful studies, but also by recording unsuccessful analysis. This allows other researchers to understand what collections are appropriate for answering specific research questions, and how to avoid collections that will not be practical. Data protection would, of course, be an issue. However, the sharing of all data and results would help prevent the duplication of studies, helping to protect skeletal collections for future use.

Finally, researchers should look more closely at deterioration in preservation, and its causes, building upon the work presented in this thesis. This research is one of only a handful of studies that have endeavoured to look at preservation of human remains, and there is much left to do. This project was designed as the first step – of many – on the path to fully understanding and controlling the deterioration of preservation in skeletal remains. The method of creating a retrospective baseline was designed to enable preservation studies to be implemented without the need to wait the 10 or 20 years necessary for a longitudinal study. If we can better understand the mechanism of deterioration and how it impacts skeletal collections, we would be in a much better position to control preservation and therefore protect our skeletal collections.

The methods discussed above are realistic, but their cost and effort may prevent them from being implemented. The last option is a simple one and most importantly relatively cost-free: greater communication. Communication among all areas of the museum sector: the museum staff, archaeologists, researchers, commercial archaeological companies, the government and, finally, the general public. All need to be involved, or at least informed about the problems that museums are facing, problems that may lead to the closure of some museums. The closure of museums can elicit an emotional response. In 2013, a survey conducted by BritainThinks regarding public perceptions of museums found that, when asked about the closure of museums, the majority of respondents expressed feelings of guilt or shame (BritainThinks 2013 pp.10-11). The survey was conducted at six museums across the United Kingdom and efforts were made to reflect the demographic breakdown of the United Kingdom in reference to age, gender, ethnicity, education, and occupational groupings (BritainThinks 2013, p. 8). However, the survey was conducted in 2013; undoubtably opinions will have changed over the past few years and new studies are needed to reflect this (Lans 2020). As discussed in Section 2.2.1 museums need to be aware of differing opinions regarding their collections and work to decolonise the narratives around them (Heal 2019; Singer-Baefsky 2020). Communication is needed to help museums to update their collections and to mitigate the long-standing colonial influence on museum displays and communication is needed to help the public understand how many museums are under threat of closure. Therefore, if museums and commercial archaeological companies communicate their problems not only to the government, but also to the public, the public might take notice and lobby the local and central government on the museums' behalf.

6.3 Curating Human Remains in the Future

This research has highlighted two problems. The first is the issue of preservation of collections in museum storage facilities. This was the primary line of investigation for this research. The second problem arose from the observations made while visiting the museums for data collection; this covers broader issues with storage. These broader issues include the rapidly filling museum storage facilities and the inevitable over-filling of their capacity. This will affect the preservation of all the stored archaeological material – overfilling the storage facility leads to damage, which in turn leads to conservation costs. These problems are connected. The storage crisis is a larger, overarching problem, and the issue of preservation – at least partly – stems from it. Therefore, the storage problem needs to be solved first, as addressing preservation issues alone will not be as effective. Yet these problems require vastly different solutions.

Several methods were proposed to help limit deterioration in a museum storage facility. Other methods were suggested that could help mitigate the storage problem. Yet, as discussed above, none of these methods are a solution – at least on their own – they are merely a way to delay the problem that must still be solved in the future.

Therefore, the author believes that museums and other institutions curating human remains have two paths to take if they wish to solve these problems now. Both have been discussed above. The first is a policy shift by the government that would make developers pay commercial archaeology companies and museums an annual cost for the storage of excavated materials. The second is increased deaccessioning, loaning or reburial of archaeological material and the powers required to do so. To counterbalance the loss of artefacts and human remains to those options, the increased use of technology is discussed and advocated for.

6.3.1 Change in Policy

The change in policy suggested, as explained fully in Section 5.5.6, is an addition to the current planning guidelines. The suggested provision would place the financial responsibility for the storage of excavated materials on the developer or construction company. This provision would require covering the cost of long-term storage, potentially indefinitely, as outlined in the exhumation order. Alternatively, it would make excavation prohibitively expensive, leading to a preference to leave the archaeological material in the ground, as was the aim of the original PPG 16 (McKinley 2013 p. 135; PPG 16 1990 pp.5-6).

Asking developers to contribute to the long-term storage of archaeological materials or archaeological human remains is not an unreasonable prospect as these development companies determine where they will build and consequently which archaeological sites are excavated. If the selected site contains archaeologically-important features these should be excavated and protected; part of this protection is long-term curation. However, recent policy shifts by the current government have shown that archaeology is increasingly being viewed as a hindrance to development and an inconvenience to economic growth. Thus, a policy shift that would increase the cost of development to protect archaeology is further away than ever.

6.3.2 Deaccessioning as a Solution

If a policy change is not possible, which seems to be the case in the current climate, museums need to create space within their own storage facilities. If they cannot afford to expand, this leaves only one option – that is to deaccession archaeological material. Materials that may be deaccessioned were outlined in Section 2.1.1 (iv). Deaccessioning is not a popular option but may in some situations be necessary. The deaccessioning of human remains generally involves the reburial of the remains. The collections that would be selected for this are those that are rarely, if ever, used for research, or whose provenance is unknown. Whilst this argument would currently not be sufficient to warrant reburial, it is hoped that due to the problems museums are facing, this will change. Deaccessioning for the purposes of relieving overcrowded stores is not limited to human remains; any material stored in a museum can potentially be deaccessioned. With other archaeological material, there are more deaccessioning options than reburial, such as the sale of objects, transfer of objects to a different museum, or recycling the object. One of the main considerations must be if the museum has the legal right to deaccession. As discussed throughout this thesis, the main obstacle to deaccessioning human remains are the burial licences issued for the collections when originally excavated. If the burial licence states that the human remains are to be stored in a museum, that museum could not deaccession the collection without special permission from the MoJ, which is given on a case-by-case basis only. Nor would the museum be able to transfer the collection elsewhere without permission to vary the burial licence. Whilst this does not entirely prevent deaccessioning from the museum, it does make it considerably more challenging.

Deaccessioning unused archaeological material would help to solve the storage crisis, by allowing only important, rare, or well-used material to be retained. However, the material lost equates to a loss of potential knowledge. When a museum deaccessions human remains, or other material from its collection, the museum needs to consult specialists. Typically, these consultations involve a group of external experts in relevant fields. All archaeological material – not least skeletal remains – represent value and potential knowledge, even if they are not considered rare or valuable. Options have been put forward in this thesis to help mitigate this loss of knowledge by using available technology. Although the methods discussed primarily focused on skeletal remains, there is no reason they could not be applied to other archaeological material. Arguably, certain techniques such as 3D scanning may be more effective on other archaeological objects. 3D printing can be conducted, and once a detailed scan has been made, replicas can be created and studied. Furthermore, the option of a biobank was suggested as a possible solution to the chemical analysis problem, at least for skeletal remains, although once again the burial licence will determine if this is legally possible.

Greater funding would clearly be necessary to implement most of the suggestions discussed above to limit the loss of knowledge. While this would not be necessary for the deaccessioning process, it is preferred that if we are to deaccession archaeological material, we retain as much information as possible. There would be costs associated with the technological solutions proposed to allow information to be retained from the deaccessioned material. Greater cooperation with institutions which already have the required technology, such as universities, would be useful.

Of the two paths discussed above, deaccessioning or arranging long-term loans seems the most likely and practical path to achieve and follow. Primarily this is because of the lack of political power archaeology currently has. Additionally, deaccessioning can be conducted on an individual museum basis rather than requiring national-level cooperation. Though methods have been discussed to limit the loss of information with deaccessioning, these methods are not without cost and can be time-consuming. Even without the application of these technologies, deaccessioning may be the most pragmatic means by which to resolve the storage crisis (Baxter et al. 2018). This process would allow museums to focus on improving their storage facility, and therefore better preserving and protecting the collections they retain.

Change is needed; palliative actions may suffice for a time, but eventually the problem will become overwhelming. Already museums are having to “force in” newly-excavated archaeological materials where storage facilities are over-crowded, and museums are closing due to inadequate funding, putting their entire collections at risk.

6.4 Future Research

Research often yields more questions than answers. Certain comparisons and factors observed in this study were considered only as contributing variables, evaluated to determine potential underlying bias rather than to be fully studied in their own right. Other comparisons did not return expected results and, therefore, warrant studies of their own.

The first aspect of this study that requires further investigation is the dual factors of museum type and museum size. Although this was used as a comparison for preservation in this study, it was not explored fully. In this research, only three categories of size were used. No national museums were available for this study; their size would have been much larger than the museums that were used here. This could have an impact on the resulting data. Determining the impact of the inclusion of these very large museums on the data in this project would require further study.

Another aspect of this research that needs more careful considerations are the factors that make up the “museum storage components”. Due to time constraints and the fact that this study was a preliminary attempt at evaluating preservation using the developed methodology, concessions needed to be made, meaning the storage components were summarised into a single factor, and only used for a single comparison. Yet, as was shown in this study, storage was one of the most important factors when looking at how to protect and preserve human skeletal remains. It would, therefore, be wise to take the components that made up the storage quality factor and evaluate them separately. Particular attention should be paid to the quality and size of the box, the types of packing material used, whether the skeletal remains were bagged (as well as the types of bags), and the order in which the skeletal remains were packed, to truly see the impact this has on the preservation of the skeletal remains. While all the components should be evaluated those listed above should be the primary focus.

Another aspect of this research that requires further exploration is the comparison between the "time out of the ground" and research access. The results were unexpected and interesting. The data collected in this study showed that there is effectively a "life span" for the skeletal collections of approximately 70 years. After this period a collection becomes increasingly unlikely to be accessed or studied. The explanation proposed for this was that once a collection falls out of the current literature, and out of the memory of the researchers, it is forgotten. Newly-excavated collections begin to be used instead. These results should be corroborated, as they would have a significant impact on which collections should be retained and which should be deaccessioned. A study that focused specifically on the time out of the ground and access could use many collections that were not suitable for the research conducted in this thesis. The results from such a study, focused on "time out of the ground" as a primary factor affecting access, would be much more convincing. If the results were comparable, then deaccessioning of older collections may be the preferred option. Additionally, confirmation of these results would also emphasise the need for a database to prevent skeletal collections from being forgotten.

Following from the "time out of the ground" versus access comparison, it would be sensible to evaluate the other access comparisons in this study. These comparisons were evaluated because the data needed for them had already been collected for use in the primary comparisons. Therefore, it was deemed reasonable to use these data to explore factors that could affect access. Yet, as discussed above, these results are not definitive. A more detailed study would be required to confirm the data collected here. A study that explores access as the primary factor (as opposed to this study which focused on change in preservation) could better show the nuances of factors impacting access. A more detailed study would help to confirm the results from this study – or dispute them – and could help to explain some of the unexpected results that seemed contrary to logical predictions. Furthermore, a new study would not be limited to the factors observed and presented in this study. Instead, further research should also endeavour to look at factors not considered, such as geographical location of a skeletal collection. If one thing can be taken from the access predictions made and the access data collected for this research, it is that access as a whole is poorly understood and that this needs to change.

One major issue that was flagged from the information collected in this research is the storage crisis, and the problem of overcrowding in museum storage facilities. Yet, this study did not evaluate overcrowding. As this thesis was subsequently directed at producing solutions to overcrowding in museums, it is important to know how much of an effect this actually has on skeletal collections. Presumably, overcrowding of a museum's storage facility will have a negative impact on the collections stored there, as one of the key factors affecting deterioration in preservation found in this study was the quality of storage the museum was able to provide. However, we need to fully understand to what extent overcrowding will lead to deterioration of skeletal remains and other artefacts. If overcrowding has a significant impact, we know that urgent action is needed. If, however, overcrowding only has a minimal impact on deterioration, then we can say we have more time to solve the storage problem. It should, however, be stressed that the storage crisis still needs solving, as the potential damage to artefacts is just one of the negative aspects associated with overcrowding.

As mentioned in Section 5.2.1, due to time constraints the methodology for creating a retrospective baseline assessment was not fully evaluated. In Section 6.1.4 an intended evaluation of the methodology was discussed that unfortunately could not be conducted due to COVID-19 restrictions. This evaluation would have determined the reliability (how well multiple assessments of the same bone agree) of the methodology through an intra-observer error assessment. However, this evaluation would not provide data on the accuracy (how closely the assessments reflect the actual preservation of the bone) of the methodology. In order to fully evaluate this methodology, for both reliability and accuracy, a newly-excavated and well-documented human skeletal collection would be needed. Two independent assessments of skeletal preservation would be conducted on this collection by the same person. One assessment would use the skeletal report, photographs, skeletal inventory, or any other available documentation to create a baseline preservation assessment, equivalent to the retrospective baseline assessment in this study. The second assessment would involve a direct examination of the skeletal remains to determine the state of preservation; this should be conducted without reference to the results of the first baseline assessment. This second assessment would be equivalent to the "observed levels" of preservation recorded for the skeletal collections in this study. As little or no time would have passed between these two assessments, the expectation would be that the two assessments of preservation would be consistent. By comparing these two sets of data the accuracy of the method could be evaluated. If the two assessments are the same, the methodology would be considered accurate. If this evaluation was repeated by additional researchers (inter-observer study), reliability of the methodology could also be determined. Thus, this methodology could be used to accurately create retrospective baseline assessments in future research.

Finally, a longitudinal study is needed, one that records the changing preservation of skeletal collections stored in museums. Despite this research attempting to create a methodology that allows the creation of a retrospective baseline preservation assessment for skeletal remains, a longitudinal study would still be useful. Not only would such a study be more accurate, as subsequent condition assessments could use the same methodology, it would also bypass the limitations of the methods used here. In particular, the need for detailed and accurate documentation would not be necessary, which – as discussed above – can be difficult to find. Therefore, a longitudinal study could be applied to a greater number of collections than would be possible for a retrospective study. Although arguments are made above to show that we do not have time to wait for the results of a 10-year study, that does not mean we should not start one now. In fact, the state of preservation of the collections studied here as recorded at the time of analysis (2017-2018) could form the basis for a future longitudinal study. If the changes discussed in this thesis in relation to preservation and protection were implemented, then theoretically the longitudinal study should show and track the improvements affected by these changes. The longitudinal study might then confirm that the changes were effective and show which were key in preventing the deterioration in preservation of human skeletal remains in museums.

The proposed future studies discussed above cover some of the major questions that arose from the results that were generated during the course of this research. Some of the future projects discussed are relatively small and would require minimal resources, and thus they are appropriate research projects for students. Other studies would require more specialist knowledge, such as financial studies on how museums acquire and use their funding. Finally, a longitudinal study would require considerable effort and cooperation among multiple institutions, as well as the dedication to run a study for 10 years or longer. Ideally, what is required is a greater focus on preservation studies within human bioarchaeology, to enable us to understand exactly how skeletal collections change as they are curated and used, as well as what we as researchers can do about it.

6.5 Final Remarks

The primary aim of this research was the study of preservation of human remains. Deterioration of preservation is not a single factor, but rather many intertwined and inter-related factors that are nearly impossible to separate, as all factors can influence each other. The storage factor can be affected by the time out of the ground, as well as by start preservation, which in turn can be affected by time period and soil pH levels. All the factors can be linked in some way. However, for simplicity and clarity, these factors can be separated and assessed individually, even if these comparisons are a step removed from reality. This research shows the benefits of assessing preservation as a series of individual factors, primarily by identifying where small changes, such as storage quality improvements, can potentially have a significant impact on the future preservation of a collection.

Looking at a single preservation risk factor in isolation we are able to assess the impact that each factor has, therefore, determine where the museum should focus its efforts to best prevent deterioration. By naming a primary factor responsible for deterioration, museums have a manageable problem to work towards solving. In this study, the primary factor was museum storage conditions. However, to discuss museum storage quality as a single factor is misleading. In this research museum storage quality was evaluated as 16 components, drawn from literature focused on the curation of human skeletal remains (Cassman et al. 2006; Clegg 2020 pp.72-76; DCMS 2005; Garland et al. 1988; Janaway et al. 2001). This list is not exhaustive, and there has been a lack of research into what constitutes appropriate storage for human remains. Thus, it is challenging to describe "good storage" and the factors of which it is comprised. By clarifying which storage quality factors can best protect the human skeletal remains in their care, museums can focus their limited resources.

Museums face a multitude of problems, among them caring for and protecting the collections they curate. Most, if not all, of these problems could be resolved if the museum had a greater amount of funding. Currently, however, the trend is in the opposite direction, with most government-funded museums receiving less funding (30% funding cut in real terms over the last 10 years). This shortfall has culminated in an estimated 76 museums closing since 2005 (estimate from MA website, see Figure 2.1). Furthermore, the lack of funding has also led to a "brain drain", as discussed in Section 2.1.2 (ii), with world-leading specialists choosing to leave the UK to find work abroad (Pes 2017). Finally, the effects of COVID-19 are only starting to be fully realised. The closure for at least a period of time of 95% of the world's museums has obviously impacted their financial situation; this has been compounded by the costs of reopening with social distancing measures (ICOM 2020a). The costs of plastic screens, hand sanitisers, and personal protective equipment (PPE), require a substantial upfront investment, which many museums in the current climate simply cannot afford; however, grants can be found to help cover these costs. Even with these measures in place, there are doubts as to whether the general public will come to museums when they do eventually reopen. When asked by the Art Fund, some 56% of museums responded that they are worried about the viability of their institution, potentially putting their entire collection at risk (ArtFund 2020).

The options museums have to mitigate their financial problems are limited. One option discussed in this thesis was the American approach, of soliciting monetary donations from wealthy patrons, trusts, foundations, or commercial companies. British examples of this include the Barbara Mertz Bioarchaeology Laboratory, funded by the Institute for Bioarchaeology and the Wellcome Trust (Antoine 2019 p. 44), and the Roxie Walker Galleries at the British Museum, funded by the Bioanthropology Foundation Ltd. (Leahy et al. 1999). These examples drawn from the British Museum are not unique and similar situations can be found throughout the British heritage sector. In the US, this option has been shown to raise millions of dollars for museums, allowing them to thrive and to focus on producing excellent exhibitions and caring for their collections. This approach could more than cover the shortfall in government funding. However, museums need to be wary, as discussed in Section 2.1.2 (iii. a), of culture washing by companies or individuals. This thesis used the example of the Sackler family donating to the Guggenheim Museum and the backlash the museum faced.

If a museum's funding and finances are dealt with, several of the issues raised are no longer significant. Given sufficient funding a museum could invest in high-quality storage, expand storage facilities when necessary, and employ the appropriate specialists to care for their collections, thereby allowing the museum to focus on its primary roles, such as disseminating information and encouraging research.

In Section 5.5.2, several methods of decreasing deterioration were proposed, but these methods will be ineffective if storage facilities continue to be overcrowded. When storage facilities are overfilled, any storage improvements the museum had made would be negated, thus wasting any resources used. The phrase "storage crisis", as discussed throughout this thesis, was based on observations made and conversations had whilst collecting data for this research. It is a widespread problem that has been recognised by archives and museums for years, and it is getting worse (Adams 2017; J. McKinley pers. comm. 2019; McKinley 2013). Museums cannot afford to continually expand their storage facilities; this requires money they simply do not have. Eventually, further expansion will no longer be viable.

Deaccessioning human skeletal remains or adjusting planning policies to pass the cost of storage onto developers may seem unnecessary or unwarranted to those outside of the heritage industry. Certainly, either option would have long-lasting consequences for archaeology. Yet, deaccessioning does not necessarily need to lead to reburial; the skeletal collections could be transferred to a university or another institution (Clegg 2020 p.146). As mentioned in Section 5.5.4 (i), BABAO has a process in place to assist museums looking to deaccession or loan skeletal remains and institutions seeking remains to get in contact with each other (BABAO 2021b). This benefits both parties, helping museums to relieve their overburdened storage facilities and universities to gain valuable teaching collections necessary for teaching human bioarchaeology – as was the case with the University of Reading (M. Lewis pers. comm. 2021). Reburial is final and should be a last resort. However, if deaccessioning is the only option the museum has to protect its collection, and if the museum has the legal authority to do so, it should consider deaccessioning. DeepStore was suggested as a way for museums to relieve the pressure on their own storage facility, whilst still having the collections available (DeepStore 2019). In some cases, DeepStore may be the better option and may be more financially viable, as reburial of larger collections can become very expensive, especially in metropolitan areas (Clegg 2020 p.138). Both proposals discussed in this thesis have their drawbacks. Deaccessioning precludes any future research on the remains if they are reburied but allows museums to allocate resources to the remains they retain. A planning policy that charges developers for the curation of the human remains and other artefacts, excavated from the land they intend to develop, would be unpopular but would give greater funding to museums. Such a policy would be unlikely to be approved by the current government, leaving deaccessioning as the more realistic solution. Regardless of the options available and the ethical and monetary costs, it is clear something needs to change within the heritage industry in order to protect museums and their collections. If the predictions made in this thesis are accurate then major action will be required to prevent the storage crisis becoming a catastrophe, though there are those that argue the situation has already reached catastrophic proportions (Adams 2017). The sooner we start preparations to deal with this crisis, the less damage and deterioration will occur among the collections being curated. The heritage industry, and those who work in it, ultimately must devise a solution, and implement it as quickly as possible in order to preserve archaeological collections. Nevertheless, the human skeletal remains we have stored in our museums will not deteriorate entirely overnight; it is a long gradual process. Many of the remains observed in this study were relatively well-preserved after 10 years or more in curation. However, the process of deterioration is one that cannot be reversed and the skeletal remains we excavate are a finite and precious resource. Therefore, the sooner we act to protect them the better.

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Appendices

Appendix 1: Preservation Scale – Version 1.

Research Potential Scale

Category	0	1	2	3	4	5	5+
Approximate Completeness	100%	>75%	Any	Any	Any	<25%	<25%
Characteristics of the bone surface	• Bone appears untouched and fresh • No sign of cracking or flaking	• Light and patchy surface erosion covering less than 25% of bone surface	• More extensive surface erosion than category 1, with deeper penetration	• Moderate erosion covering more than 50% of bone surface	• More extensive erosion than category 3, covering all of bone surface	• Heavy erosion covering all of bone surface	• Extensive penetration and complete destruction of the bone surface

Appendix 2: Guidance on How to Use the Created Preservation Scale.

Research Potential Scale

The following are guidelines designed to help use and implement the research potential scale. The scale itself takes into account the surface preservation of the bone as well as the overall completeness, weathering damage and profile of bone. Using these factors it is believed that an estimation of the research potential for the bone can be found, meaning a researcher can understand the state of a collection prior to visiting the repository.

It is hoped that the following guidelines will make the scale quick and easy to use, even for those who are unfamiliar with human bone.

For use on long bones only (Humerus, Ulna, Radius, Metacarpals, Femur, Tibia, Fibula and Metatarsals)

PLEASE READ CAREFULLY BEFORE STARTING

All data collected will be anonymous

For the purpose of this test only a small area needs to be evaluated, so please only evaluate the shaft of the bone that is facing upwards.

Guidelines:

1. If bone is fragmentary and cannot be reassembled accurately, select the largest fragment.
2. Evaluate the approximate completeness (¾ , ½ , ¼) of the bone.
    - For those who are unfamiliar with human remains, **fig 1** shows the average lengths and shape profile of the complete bone.

Table 1

Completeness	Category Range
>75%	0-4
75%-25%	2-4
<25%	2-5+

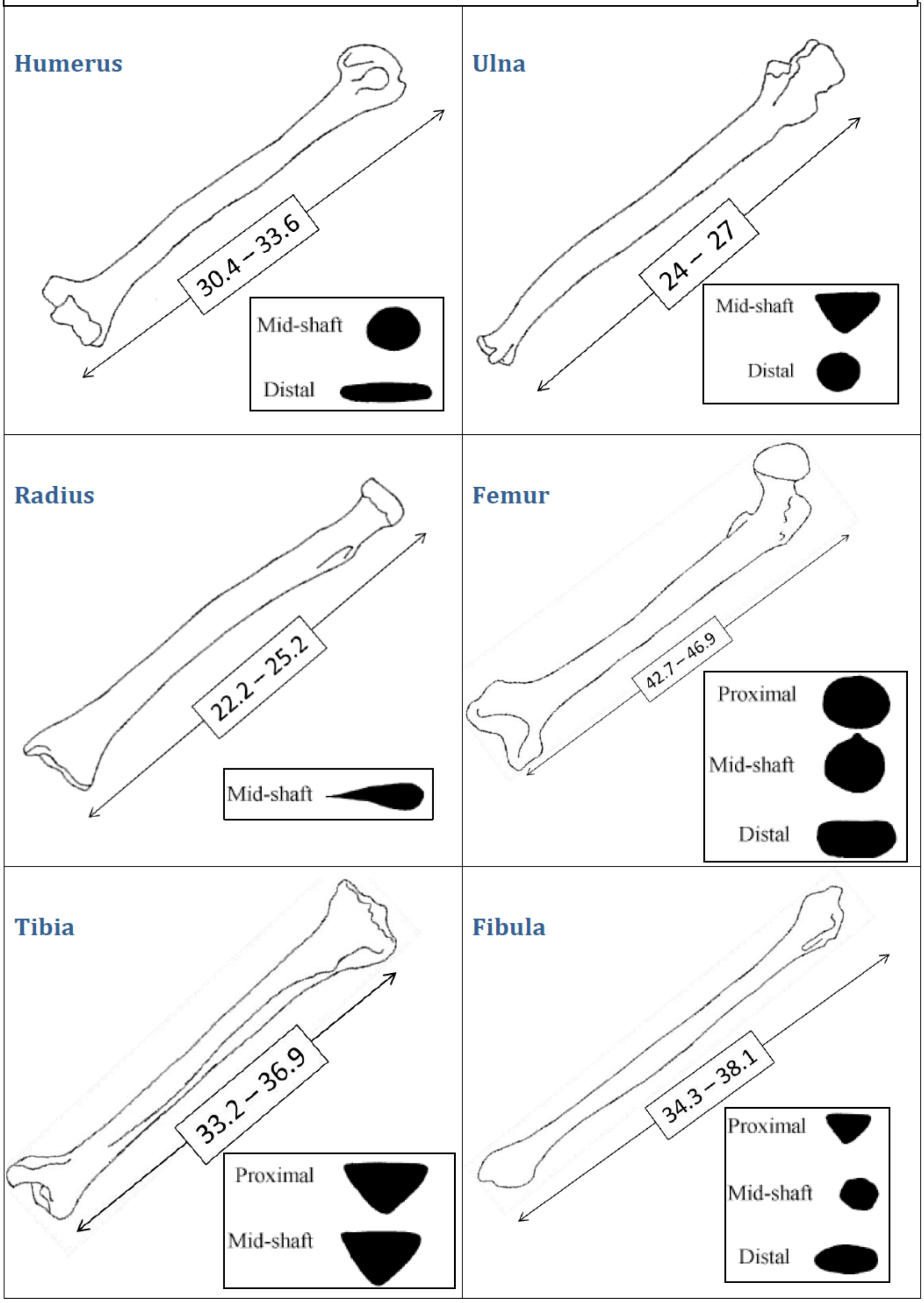
3. Evaluate the surface preservation AND profile of the bone (the normal shape of the bone), using the photographic examples.
4. Select the category that best fits the characteristics of the bone. If bone is between categories select highest category (worst).

Exceptions:

It is assumed that bones that are more than 75% complete are unlikely to have preservation worse than four (eg. Categories 5 or 5+). However, as category 5 and 5+ on the scale indicate extremely damaged bone, the author suggests that this preservation take precedent over completeness, and that these fragile bones be assigned to the 5 or 5+ categories, no matter the completeness, for their protection.

Appendix 3: "Figure 1" from the Preservation Scale Guidance.

Fig 1: Profile and approximate length of complete long bone (in cm) and cross sectional profile.



Appendix 4: Images of the 10 Bones Used in the Observer Testing.

Appendix 5: List of Participants Who Tested the Preservation Scale, including their Background and Answers Given.

	Observer Information			Preservation Estimations									
Participant	Human remains experience	Arch Experience	Museum Experience	Bone 1	Bone 2	Bone 3	Bone 4	Bone 5	Bone 6	Bone 7	Bone 8	Bone 9	Bone 10
1	PhD	YES	YES	1	0	4	2	4	5	1	3	0	4
2	PhD	YES	YES	1	0	4	2	4	5	1	3	0	4
3	None	NO	NO	2	1	3	5	6	6	2	2	1	4
4	None	NO	NO	1	1	2	2	5	6	1	3	1	4
5	None	NO	NO	1	0	2	4	6	6	0	4	3	3
6	None	NO	NO	2	1	4	2	6	6	0	3	2	4
7	None	NO	NO	1	0	3	2	4	5	1	3	0	5
8	PhD	YES	YES	1	0	4	2	4	5	1	3	0	4
9	None	NO	NO	2	1	3	4	5	6	2	4	0	4
10	None	NO	NO	1	0	3	2	5	5	1	4	0	4
11	Undergraduate	NO	NO	2	1	2	4	6	6	1	3	1	5
12	Undergraduate	YES	NO	0	1	3	5	6	6	0	5	1	4
13	Undergraduate	YES	YES	0	1	3	4	4	5	1	4	0	5
14	Masters	YES	YES	0	0	3	1	4	6	0	2	0	5
15	Masters	YES	NO	1	0	3	3	4	2	1	3	0	5
16	Masters	YES	YES	1	0	4	3	5	4	0	5	0	5
17	Masters	YES	NO	1	0	3	3	3	4	1	3	0	5
18	Masters	YES	NO	1	0	3	2	3	4	1	3	0	5
19	Masters	YES	NO	1	0	3	2	2	4	0	2	0	5
20	Masters	YES	NO	1	0	5	4	4	6	1	3	0	5
21	Masters	YES	NO	1	0	4	3	3	5	1	3	0	4
22	Undergraduate	YES	NO	1	2	3	3	4	6	2	2	1	4
23	Undergraduate	YES	NO	1	0	2	3	3	6	0	4	0	5
24	Undergraduate	YES	YES	2	1	4	3	4	3	1	6	1	5
25	Undergraduate	YES	YES	2	1	4	2	3	5	2	1	0	4
26	None	NO	NO	1	2	2	3	5	6	2	4	2	4
27	Undergraduate	YES	NO	2	0	3	3	4	6	2	4	0	4
28	Undergraduate	YES	NO	1	1	3	3	4	5	1	2	0	5
29	Undergraduate	YES	NO	1	0	4	3	4	5	1	3	0	4
30	None	NO	NO	2	1	3	3	4	6	1	4	0	5
31	PhD	YES	YES	1	0	3	1	4	5	1	3	0	4
32	None	NO	NO	2	1	3	3	5	6	1	6	0	4
33	None	NO	NO	1	0	2	4	5	6	1	4	0	3
34	None	NO	YES	1	1	3	4	6	6	1	6	0	4
35	None	NO	NO	1	1	3	4	6	6	3	4	0	6
36	None	NO	NO	3	1	3	4	5	6	1	4	0	5
37	None	NO	NO	1	0	3	2	4	6	1	3	0	4
38	Undergraduate	NO	NO	2	1	4	3	5	6	2	5	0	6
39	None	NO	NO	3	1	4	3	6	5	2	4	1	5
40	PhD	YES	NO	1	0	4	3	4	5	0	3	0	5
41	None	NO	NO	2	1	3	4	4	5	1	4	0	4
42	Masters	YES	NO	0	0	3	3	3	6	0	3	0	5
43	None	NO	NO	1	1	2	3	5	6	1	5	0	5
44	PhD	YES	YES	1	1	4	3	5	6	1	3	0	6
45	Undergraduate	NO	NO	1	1	3	4	6	6	1	4	0	5
46	Masters	NO	NO	1	0	4	4	4	5	1	3	0	5
47	Masters	NO	NO	2	0	4	3	4	4	1	3	0	5
48	Masters	YES	YES	2	1	3	3	5	5	3	5	1	5
49	Masters	YES	YES	1	0	3	1	3	4	0	1	0	4
50	None	NO	NO	1	0	2	3	6	4	1	4	0	4
51	PhD	YES	YES	1	0	2	1	3	4	1	2	0	5

Appendix 6: Observer Recording Form.

Observer Testing Record Form

Date:_____________

Observer Information

What is you level of experience with human remains? (Include any courses you are currently on)

PhD Masters Undergraduate None

Do you have any experience in archaeology?

YES NO

Do you have any experience working in a museum? (If yes, to what level?)

YES NO Level:_______________

Preservation Estimation

Note: Each bone should be scored using the accompanying "research potential scale (0-5+). Please read the guidance sheet carefully before starting.

Bone Number	Category		Bone Number	Category
1			6	
2			7	
3			8	
4			9	
5			10	

Comments

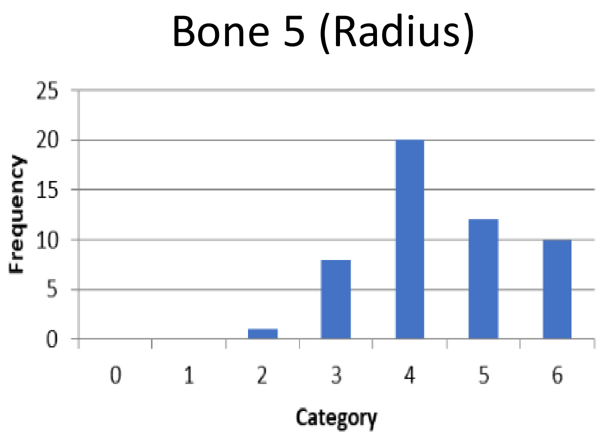
Which category was the most clear?

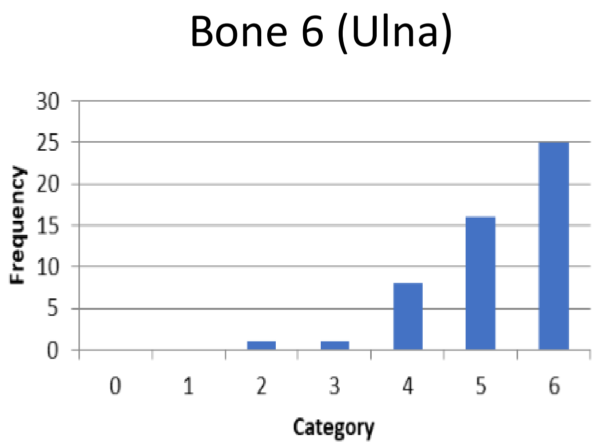
Which category was the least clear?

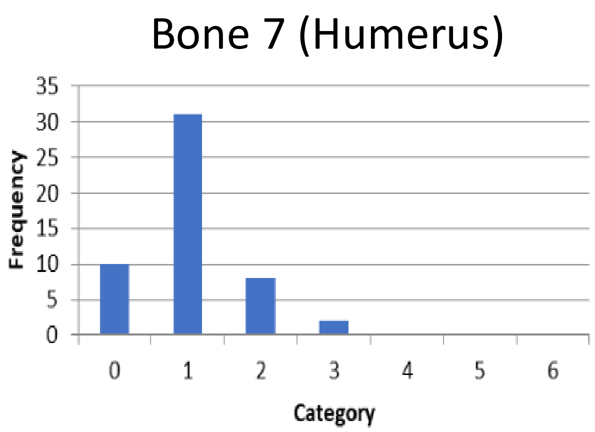
What difficulties (if any) did you have using this scale?

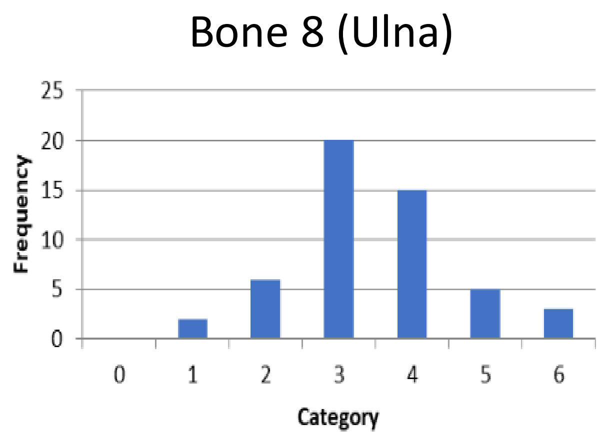
Any additional comments, thoughts or improvements?

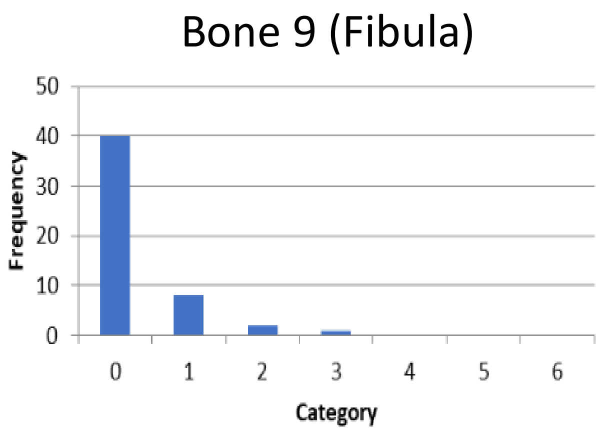
Appendix 7: Remainder of Graph Set 1 (Fig 3.3): Comparing All Individuals who Participated in the Observer Testing.

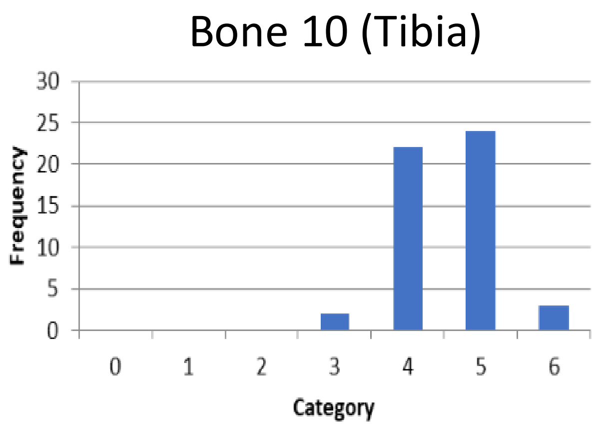




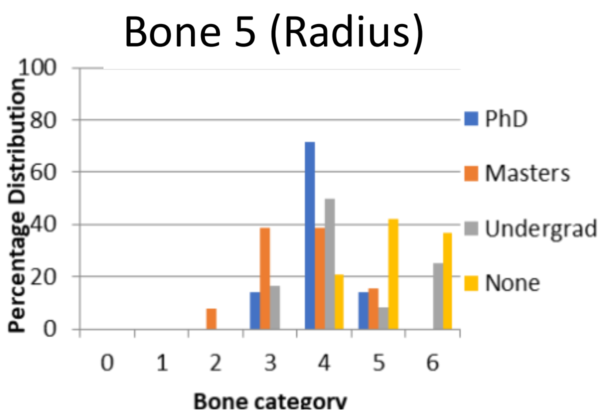


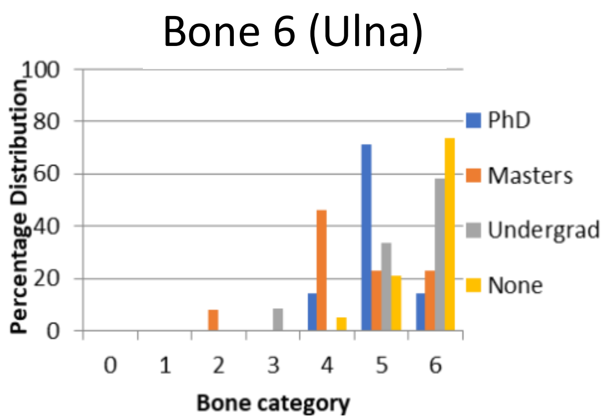


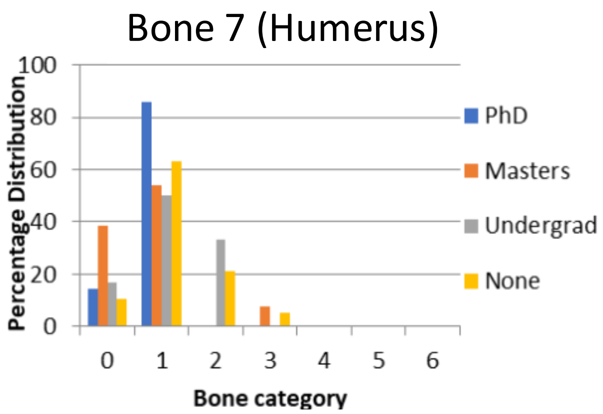


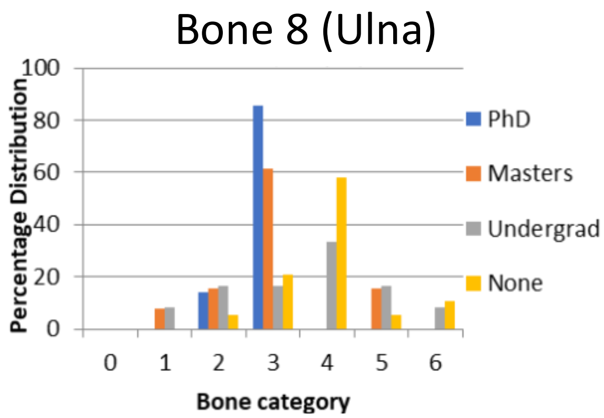


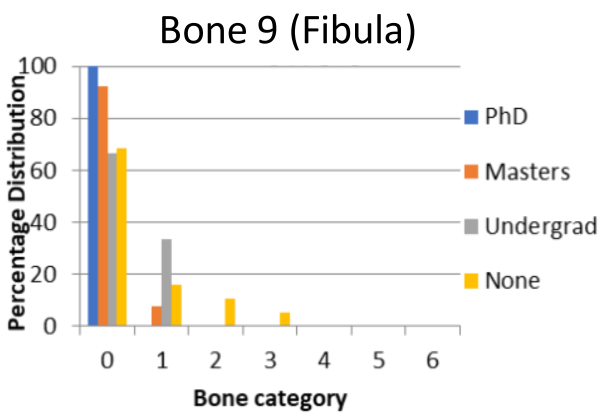
Appendix 8: Remainder of Graph Set 2 (Fig. 3.4): Participants' Separated by Experience with Human Remains.

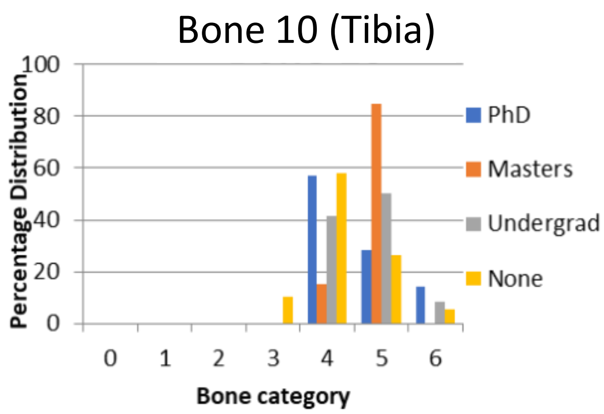




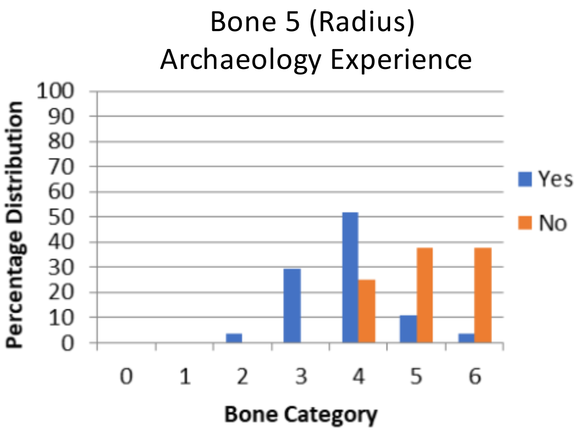


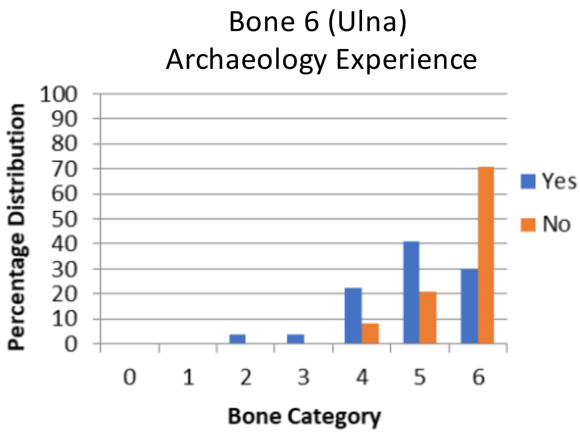


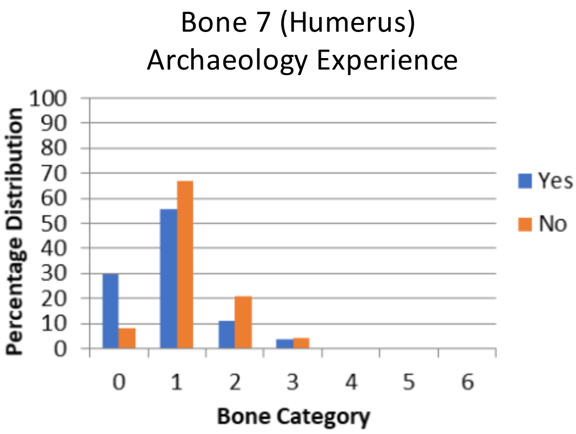


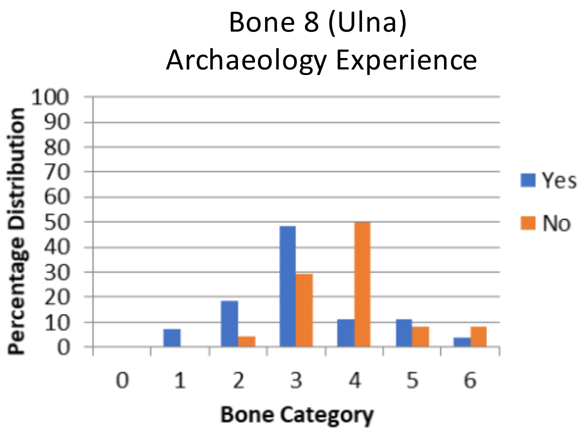


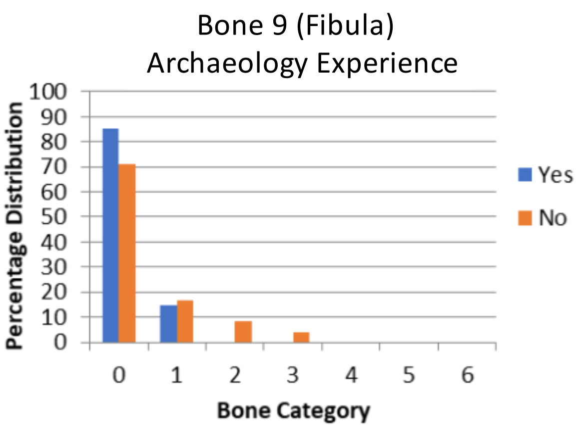
Appendix 9: Remainder of Graph Set 3 (Fig. 3.5): Participants Separated by Archaeological Experience.

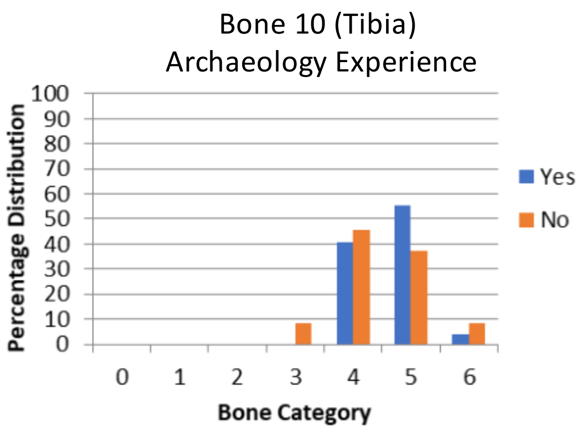




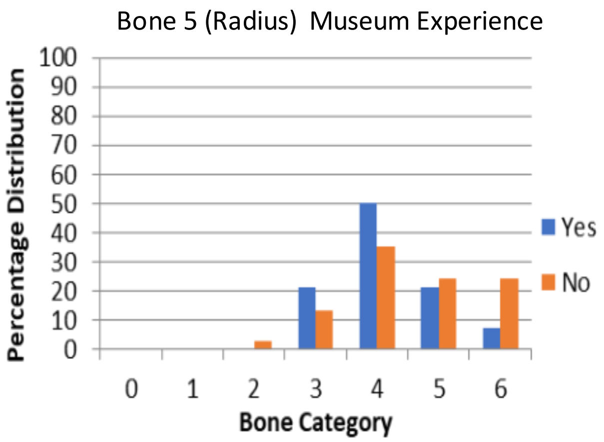


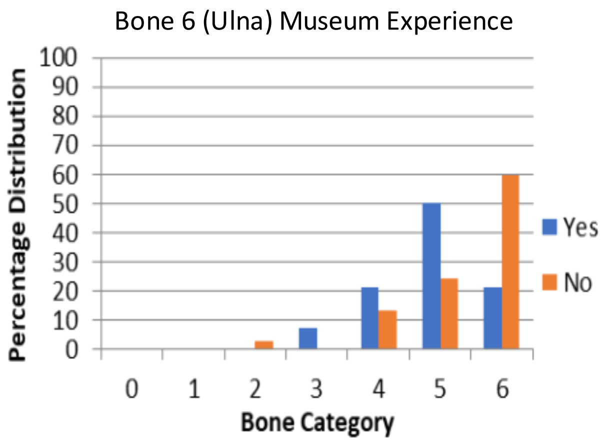


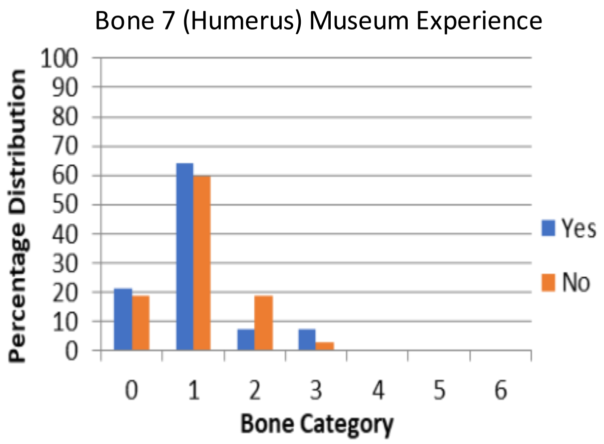


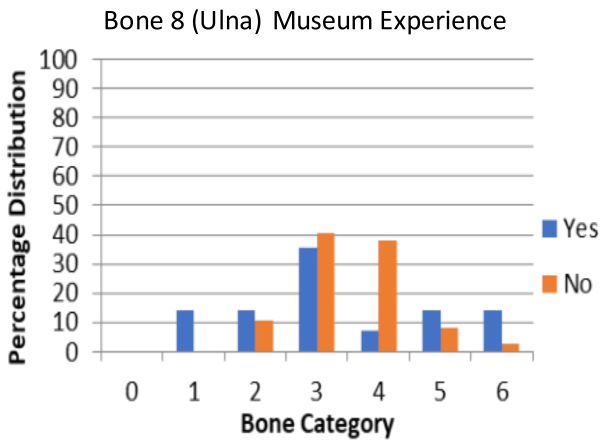


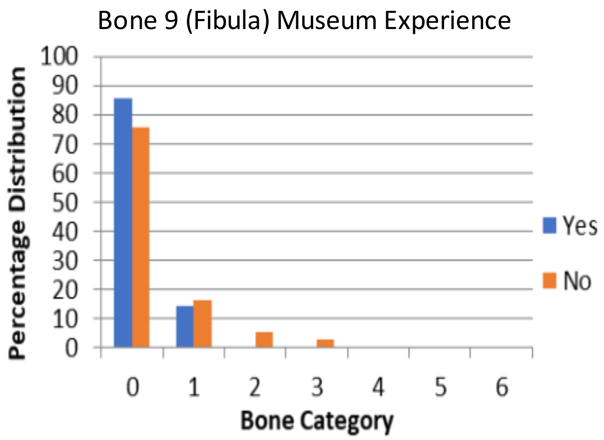
Appendix 10: Remainder of Graph Set 4 (Fig. 3.6): Participants Separated by Museum Experience.

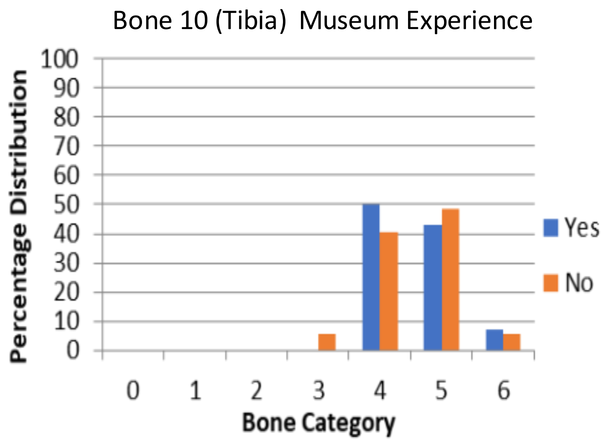












Appendix 11: Skeletal Recording Spreadsheet Used for Recording the Current and Past State of Preservation of Skeletal Remains.

No.	Museum	Collection	Age	Site Code	Skeletal Code	Source	Humerus (R/L)		Ulna (R/L)		Radius (R/L)		Femur (R/L)		Tibia (R/L)		Fibula (R/L)		Mean	Change
1	Verilanium	Folly Lane	26	A91/B	14	Report	4	4	4	5	x	4	4	4	5	4	x	x	4.222222	0.7777778
						Skeletal	5	4	6	5	x	4	6	6	5	4	x	x	5	
2	Verilanium	Folly Lane	26	A91/B	15	Report	3	3	x	3	3	2	3	x	x	x	x	x	2.833333	0.5
						Skeletal	3	4	x	4	3	2	4	x	x	x	x	x	3.333333	
3	Verilanium	Wheathampstead	19	WHW98	WHW98	Report	0	0	1	0	1	0	1	1	0	1	1	2	0.666667	1.0833333
						Skeletal	1	1	1	2	2	2	2	2	2	2	2	2	1.75	
4	Verilanium	St Stephens	31	B84-B89	B22	Report	1	1	x	x	x	x	2	2	2	1	1	1	1.375	0
						Skeletal	1	1	x	x	x	x	2	2	2	1	1	1	1.375	
5	Verilanium	St Stephens	31	B84-B89	ANQ	Report	4	4	4	4	3	4	2	2	2	2	2	2	2.916667	0.1666667
						Skeletal	4	4	4	5	3	5	2	2	2	2	2	2	3.083333	
6	Verilanium	St Stephens	31	B84-B89	AJC	Report	x	2	x	2	x	2	2	2	2	2	2	2	2	0.2222222
						Skeletal	x	2	x	2	x	2	3	2	3	2	2	2	2.222222	
7	Verilanium	St Stephens	31	B84-B89	AJL	Report	2	1	1	1	1	1	1	1	1	1	1	1	1.083333	0
						Skeletal	2	1	1	1	1	1	1	1	1	1	1	1	1.083333	
8	Verilanium	St Stephens	31	B84-B89	AJM	Report	3	3	x	4	x	4	3	3	2	3	3	3	3.1	1
						Skeletal	4	4	x	5	x	5	4	4	3	4	3	5	4.1	
9	Verilanium	St Stephens	31	B84-B89	AJS	Report	3	x	3	x	3	x	2	3	3	3	3	x	2.875	0.125
						Skeletal	3	x	3	x	3	x	2	3	3	3	4	x	3	
10	Verilanium	St Stephens	31	B84-B89	ALN	Report	x	x	x	x	x	x	5	5	x	x	x	x	5	1
						Skeletal	x	x	x	x	x	x	6	6	x	x	x	x	6	
11	Verilanium	St Stephens	31	B84-B89	ALD	Report	x	3	x	3	x	3	x	x	x	x	x	x	3	0
						Skeletal	x	3	x	3	x	3	x	x	x	x	x	x	3	
12	Verilanium	St Stephens	31	B84-B89	ADS	Report	x	x	x	x	x	x	2	2	3	3	2	2	2.333333	0.5
						Skeletal	x	x	x	x	x	x	3	3	3	3	2	3	2.833333	
13	Worcester	Technical College	10	WCM101369	122	Report	x	3	x	x	x	3	2	1	x	2	x	5	2.666667	0
						Skeletal	x	3	x	x	x	3	2	1	x	2	x	5	2.666667	
14	Worcester	Technical College	10	WCM101369	124	Report	2	x	2	x	2	x	1	1	1	1	2	3	1.666667	0.1111111
						Skeletal	2	x	3	x	2	x	1	1	1	1	2	3	1.777778	
15	Worcester	Technical College	10	WCM101369	130	Report	2	2	1	1	1	1	x	x	x	x	x	x	1.333333	0
						Skeletal	2	2	1	1	1	1	x	x	x	x	x	x	1.333333	
16	Worcester	Technical College	10	WCM101369	132	Report	x	x	x	x	x	x	?	x	2	x	2	x	2	1
						Skeletal	x	x	x	x	x	x	5	x	2	x	2	x	3	
17	Worcester	Technical College	10	WCM101369	136	Report	3	x	4	x	3	x	x	x	x	x	x	x	3.333333	0
						Skeletal	3	x	4	x	3	x	x	x	x	x	x	x	3.333333	
18	Worcester	Technical College	10	WCM101369	153	Report	2	x	3	2	3	x	4	2	3	2	2	3	2.6	0.0666667
						Skeletal	2	x	3	x	3	x	4	2	3	2	2	3	2.666667	
19	Worcester	Technical College	10	WCM101369	169	Report	3	2	2	1	2	2	3	2	x	2	x	1	2	0.2
						Skeletal	3	2	3	1	3	2	3	2	x	2	x	1	2.2	
20	Worcester	Technical College	10	WCM101369	177	Report	x	2	x	1	x	2	2	2	2	2	x	2	1.875	1.125
						Skeletal	x	2	x	1	x	2	3	4	4	4	x	4	3	
21	Worcester	Technical College	10	WCM101369	179	Report	x	x	x	x	x	x	2	x	2	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	x	2	x	x	x	2	
22	Worcester	Technical College	10	WCM101369	185	Report	2	2	1	1	2	1	2	1	2	3	2	2	1.75	0.1666667
						Skeletal	2	2	1	1	2	1	3	2	2	3	2	2	1.916667	
23	Worcester	Technical College	10	WCM101369	193	Report	1	1	1	1	1	1	x	x	x	x	x	x	1	0.1666667
						Skeletal	1	1	1	1	1	2	x	x	x	x	x	x	1.166667	
24	Worcester	Technical College	10	WCM101369	201	Report	x	x	x	x	x	x	x	x	x	3	x	3	3	0
						Skeletal	x	x	x	x	x	x	x	x	x	3	x	3	3	
25	Worcester	Technical College	10	WCM101369	216	Report	x	x	2	x	x	2	x	2	1	2	2	1	1.714286	0.4285714
						Skeletal	x	x	5	x	x	2	x	2	1	2	2	1	2.142857	
26	Worcester	Technical College	10	WCM101369	220	Report	1	1	1	2	2	2	4	3	4	1	4	2	2.25	0.0833333
						Skeletal	1	1	1	2	2	2	4	3	4	1	5	2	2.333333	
27	Worcester	Technical College	10	WCM101369	242	Report	x	x	x	2	x	2	2	3	1	1	3	3	2.125	0
						Skeletal	x	x	x	2	x	2	2	3	1	1	3	3	2.125	
28	Worcester	Technical College	10	WCM101369	245	Report	2	1	2	1	2	1	2	2	2	1	2	2	1.666667	0.0833333
						Skeletal	3	1	2	1	2	1	2	2	2	1	2	2	1.75	
29	Worcester	Technical College	10	WCM101369	266	Report	x	x	x	2	x	2	x	x	x	x	x	x	2	0
						Skeletal	x	x	x	2	x	2	x	x	x	x	x	x	2	
30	Worcester	Wormington Com.	14	WCS00-WSM29633	2428	Report	2	2	2	1	1	2	2	3	2	2	2	2	1.916667	0
						Skeletal	2	2	2	1	1	2	2	3	2	2	2	2	1.916667	
31	Worcester	Sainsbury St Johns	9	WCM 101591	1440	Report	4	x	3	x	3	x	2	3	2	2	2	1	2.444444	0.1111111
						Skeletal	5	x	3	x	3	x	2	3	2	2	2	1	2.555556	
32	Worcester	Sainsbury St Johns	9	WCM 101591	1442	Report	x	x	x	x	x	x	3	3	3	3	4	4	3.333333	0.3333333
						Skeletal	x	x	x	x	x	x	3	3	3	3	5	5	3.666667	
33	Worcester	Sainsbury St Johns	9	WCM 101591	1451	Report	3	4	4	4	x	x	2	2	x	3	4	x	3.25	0.5
						Skeletal	4	4	4	5	x	x	2	2	x	3	6	x	3.75	
34	Worcester	Old Yew Hill Wood	18	WSM27846	107	Report	1	1	x	1	x	1	2	2	1	1	2	2	1.4	0
						Skeletal	1	1	x	1	x	1	2	2	1	1	2	2	1.4	
35	Worcester	Deansway	28	HWCM3899	20375	Report	3	3	3	3	x	3	3	3	2	3	3	3	2.909091	0.0909091
						Skeletal	3	3	3	3	x	3	3	3	2	3	3	4	3	
36	Worcester	Deansway	28	HWCM3899	20360	Report	x	2	x	3	x	3	4	3	3	3	3	3	3	0.2222222
						Skeletal	x	2	x	3	x	3	5	3	3	3	3	4	3.222222	
37	Worcester	Deansway	28	HWCM3899	20436	Report	x	3	x	x	x	x	3	3	3	3	3	5	3.285714	0.8571429
						Skeletal	x	4	x	x	x	x	4	4	4	4	4	5	4.142857	
38	Worcester	Deansway	28	HWCM3899	20505	Report	4	4	x	4	4	4	3	4	3	3	3	3	3.545455	0.8181818
						Skeletal	6	6	x	5	4	5	3	4	4	3	4	4	4.363636	
39	Worcester	Deansway	28	HWCM3899	20512	Report	x	x	x	x	x	x	3	2	3	3	4	2	2.833333	0.3333333
						Skeletal	x	x	x	x	x	x	4	2	3	3	5	2	3.166667	
40	Worcester	Deansway	28	HWCM3899	20559	Report	4	3	x	4	x	x	4	3	x	x	x	x	3.6	0.4
						Skeletal	4	3	x	6	x	x	4	3	x	x	x	x	4	
41	Worcester	Deansway	28	HWCM3899	21072	Report	x	x	x	2	x	1	x	x	2	2	2	2	1.833333	0
						Skeletal	x	x	x	2	x	1	x	x	2	2	2	2	1.833333	
42	Worcester	Bredon Norton	?	WSM 67179	SK 5012	Report	x	x	x	2	x	1	x	x	2	2	2	2	1.833333	0
						Skeletal	1	1	2	2	2	2	2	2	1	2	1	1	1.583333	
43	Worcester	Bredon Norton		WSM 67179	SK 5202	Report	1	1	2	2	2	2	2	2	1	2	1	1	1.583333	0
						Skeletal	2	2	x	2	3	2	1	2	2	2	2	2	2	
44	Worcester	Bredon Norton		WSM 67179	SK 3300	Report	2	2	x	2	3	2	1	2	2	2	2	2	2	0
						Skeletal	3	x	2	x	3	x	3	2	2	2	3	3	2.555556	

45	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	15	Report	1	2	1	1	1	1	1	1	1	1	1	1	1.083333	0
						Skeletal	1	2	1	1	1	1	1	1	1	1	1	1	1.083333	
46	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	16	Report	1	x	2	2	2	2	2	1	1	1	x	x	1.555556	0.2222222
						Skeletal	1	x	3	2	3	2	2	1	1	1	x	x	1.777778	
47	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	26	Report	1	1	1	1	1	1	2	x	x	x	x	x	1.142857	0
						Skeletal	1	1	1	1	1	1	2	x	x	x	x	x	1.142857	
48	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	27	Report	2	2	2	2	x	2	2	2	x	2	x	x	2	0.5
						Skeletal	3	2	3	2	x	3	2	2	x	3	x	x	2.5	
49	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	30	Report	2	x	1	x	1	x	1	1	x	x	x	x	1.2	0
						Skeletal	2	x	1	x	1	x	1	1	x	x	x	x	1.2	
50	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	32	Report	x	x	x	1	x	1	1	1	1	x	x	x	1	0
						Skeletal	x	x	x	1	x	1	1	1	1	x	x	x	1	
51	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	36	Report	1	1	2	1	2	1	2	1	1	1	2	2	1.416667	0
						Skeletal	1	1	2	1	2	1	2	1	1	1	2	2	1.416667	
52	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	37	Report	2	2	2	x	2	x	2	2	2	1	x	2	1.888889	0
						Skeletal	2	2	2	x	2	x	2	2	2	1	x	2	1.888889	
53	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	41	Report	2	x	1	2	1	2	1	1	x	1	x	1	1.333333	0
						Skeletal	2	x	1	2	1	2	1	1	x	1	x	1	1.333333	
54	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	42	Report	1	1	2	1	1	2	1	1	1	x	2	2	1.363636	0.0909091
						Skeletal	1	1	2	2	1	2	1	1	1	x	2	2	1.454545	
55	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	43	Report	1	2	1	1	x	1	x	x	x	x	x	x	1.2	0
						Skeletal	1	2	1	1	x	1	x	x	x	x	x	x	1.2	
56	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	44	Report	1	2	1	1	1	1	1	1	x	x	x	x	1.125	0
						Skeletal	1	2	1	1	1	1	1	1	x	x	x	x	1.125	
57	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	45	Report	x	2	x	x	x	1	x	1	x	1	x	x	1.25	0
						Skeletal	x	2	x	x	x	1	x	1	x	1	x	x	1.25	
58	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	46	Report	1	1	x	x	x	x	2	1	1	1	x	1	1.142857	0
						Skeletal	1	1	x	x	x	x	2	1	1	1	x	1	1.142857	
59	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	48	Report	1	2	2	2	x	2	2	1	2	1	2	1	1.636364	0
						Skeletal	1	2	2	2	x	2	2	1	2	1	2	1	1.636364	
60	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	49	Report	1	2	x	x	x	x	2	1	2	1	1	2	1.5	0.125
						Skeletal	1	2	x	x	x	x	2	1	2	1	1	3	1.625	
61	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	50	Report	2	2	2	2	2	2	2	2	2	2	2	2	2	0
						Skeletal	2	2	2	2	2	2	2	2	2	2	2	2	2	
62	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	51	Report	1	2	1	2	2	1	1	1	1	1	1	1	1.25	0
						Skeletal	1	2	1	2	2	1	1	1	1	1	1	1	1.25	
63	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	54	Report	3	3	x	2	x	x	2	x	2	x	x	x	2.4	0.2
						Skeletal	3	4	x	2	x	x	2	x	2	x	x	x	2.6	
64	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	55	Report	2	x	2	2	1	2	2	1	1	1	1	1	1.454545	0
						Skeletal	2	x	2	2	1	2	2	1	1	1	1	1	1.454545	
65	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	57	Report	2	x	2	2	x	x	1	1	2	2	x	x	1.714286	0.1428571
						Skeletal	2	x	2	3	x	x	1	1	2	2	x	x	1.857143	
66	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	58	Report	2	2	1	1	1	1	1	1	2	1	0	1	1.166667	0
						Skeletal	2	2	1	1	1	1	1	1	2	1	0	1	1.166667	
67	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	64	Report	x	x	x	x	x	x	x	x	1	1	1	x	1	0
						Skeletal	x	x	x	x	x	x	x	x	1	1	1	x	1	
68	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	65	Report	2	1	1	2	1	2	2	2	x	x	x	x	1.625	0
						Skeletal	2	1	1	2	1	2	2	2	x	x	x	x	1.625	
69	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	66	Report	2	2	2	1	1	2	2	2	2	1	1	1	1.583333	0
						Skeletal	2	2	2	1	1	2	2	2	2	1	1	1	1.583333	
70	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	69	Report	3	x	3	3	3	3	2	2	2	2	3	3	2.636364	0.4545455
						Skeletal	3	x	4	4	4	3	2	2	2	2	4	4	3.090909	
71	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	71	Report	2	x	2	x	1	x	2	x	2	1	2	2	1.75	0
						Skeletal	2	x	2	x	1	x	2	x	2	1	2	2	1.75	
72	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	72	Report	1	x	2	1	1	1	1	1	x	1	1	1	1.1	0
						Skeletal	1	x	2	1	1	1	1	1	x	1	1	1	1.1	
73	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	73	Report	1	1	1	2	1	1	1	1	1	1	2	2	1.25	0
						Skeletal	1	1	1	2	1	1	1	1	1	1	2	2	1.25	
74	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	75	Report	1	1	1	2	1	2	2	2	2	2	2	1	1.583333	0.0833333
						Skeletal	1	1	1	2	1	2	2	3	2	2	2	1	1.666667	
75	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	76	Report	1	2	2	2	2	x	2	x	1	x	x	x	1.714286	0
						Skeletal	1	2	2	2	2	x	2	x	1	x	x	x	1.714286	
76	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	79	Report	2	2	1	2	2	2	2	2	2	2	1	2	1.833333	0
						Skeletal	2	2	1	2	3	2	2	2	2	2	1	1	1.833333	
77	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	81	Report	1	2	2	2	2	1	x	x	x	x	x	x	1.666667	0
						Skeletal	1	2	2	2	2	1	x	x	x	x	x	x	1.666667	
78	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	88	Report	1	1	2	2	1	1	1	1	1	1	2	2	1.333333	0
						Skeletal	1	1	2	2	1	1	1	1	1	1	2	2	1.333333	
79	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	95	Report	2	2	2	2	2	2	1	1	2	1	2	2	1.75	0.0833333
						Skeletal	2	2	2	2	2	2	1	1	2	1	3	2	1.833333	
80	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	95a	Report	1	1	2	2	2	1	x	x	x	x	x	x	1.5	0
						Skeletal	1	1	2	2	2	1	x	x	x	x	x	x	1.5	
81	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	96	Report	1	x	1	x	1	x	x	x	x	x	x	x	1	0
						Skeletal	1	x	1	x	1	x	x	x	x	x	x	x	1	
82	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	98	Report	1	1	1	0	1	1	x	x	x	x	x	x	0.833333	0.1666667
						Skeletal	1	1	1	1	1	1	x	x	x	x	x	x	1	
83	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	98a	Report	1	2	1	2	2	1	1	1	1	1	1	2	1.333333	0
						Skeletal	1	2	1	2	2	1	1	1	1	1	1	2	1.333333	
84	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	107	Report	1	2	1	x	x	x	2	x	1	1	1	2	1.375	0
						Skeletal	1	2	1	x	x	x	2	x	1	1	1	2	1.375	
85	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	108	Report	1	1	2	2	2	x	1	2	x	x	x	x	1.571429	0
						Skeletal	1	1	2	2	2	x	1	2	x	x	x	x	1.571429	
86	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	110	Report	x	1	x	x	x	x	x	x	x	x	x	x	1	0
						Skeletal	x	1	x	x	x	x	x	x	x	x	x	x	1	
87	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	111	Report	1	1	2	2	2	x	1	1	1	1	1	1	1.272727	0
						Skeletal	1	1	2	2	2	x	1	1	1	1	1	1	1.272727	
88	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	112	Report	2	2	2	1	x	2	2	2	1	1	1	1	1.545455	0.1818182
						Skeletal	2	2	2	1	x	2	2	2	1	1	2	2	1.727273	
89	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	115	Report	1	x	1	1	1	1	1	1	1	2	2	1	1.181818	0
						Skeletal	1	x	1	1	1	1	1	1	1	2	2	1	1.181818	
90	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	116	Report	2	1	2	2	2	2	2	1	1	2	2	2	1.75	0.0833333
						Skeletal	2	1	2	2	2	2	2	1	1	3	2	2	1.833333	
91	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	118	Report	x	2	2	2	x	x	1	1	1	1	2	2	1.555556	0
						Skeletal	x	2	2	2	x	x	1	1	1	1	2	2	1.555556	
92	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	119	Report	1	1	1	x	1	1	1	1	1	1	1	1	1	0
						Skeletal	1	1	1	x	1	1	1	1	1	1	1	1	1	
93	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	120	Report	1	2	1	1	1	2	2	2	2	1	2	x	1.545455	0
						Skeletal	1	2	1	1	1	2	2	2	2	1	2	x	1.545455	
94	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	121	Report	3	3	2	1	2	1	2	3	2	2	x	x	2.1	0.4
						Skeletal	3	5	2	1	2	1	2	5	2	2	x	x	2.5	
95	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	123	Report	1	2	2	1	2	2	1	2	2	2	2	2	1.75	0
						Skeletal	1	2	2	1	2	2	1	2	2	2	2	2	1.75	
96	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	124	Report	1	1	1	1	1	1	1	1	2	1	1	2	1.166667	0
						Skeletal	1	1	1	1	1	1	1	1	2	1	1	2	1.166667	
97	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	125	Report	1	1	1	1	1	1	1	1	1	1	1	1	1	0
						Skeletal	1	1	1	1	1	1	1	1	1	1	1	1	1	
98	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	126	Report	1	1	1	1	1	1	1	1	2	2	2	2	1.333333	0
						Skeletal	1	1	1	1	1	1	1	1	2	2	2	2	1.333333	
99	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	127	Report	1	1	2	1	2	2	1	1	2	1	2	1	1.416667	0
						Skeletal	1	1	2	1	2	2	1	1	2	1	2	1	1.416667	
100	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	128	Report	2	2	2	2	2	2	2	2	2	2	x	x	2	0
						Skeletal	2	2	2	2	2	2	2	2	2	2	x	x	2	
101	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	129	Report	1	1	1	2	2	1	2	1	1	x	x	1	1.3	0.1
						Skeletal	1	1	1	2	2	1	2	2	1	x	x	1	1.4	
102	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	131	Report	1	1	1	1	1	2	1	1	1	1	1	1	1.083333	0
						Skeletal	1	1	1	1	1	2	1	1	1	1	1	1	1.083333	
103	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	132	Report	1	1	1	1	1	1	1	1	1	x	x	x	1	0.2222222
						Skeletal	1	2	1	1	1	1	2	1	1	x	x	x	1.222222	
104	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	135	Report	2	2	2	2	2	2	2	2	2	2	2	2	2	0.5
						Skeletal	2	3	2	3	2	3	3	3	2	2	3	2	2.5	

105	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	136	Report	x	x	x	x	x	x	x	x	2	2	x	x	2	0
						Skeletal	x	x	x	x	x	x	x	x	2	2	x	x	2	
106	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	137	Report	1	1	1	1	2	2	1	2	1	1	x	2	1.363636	0
						Skeletal	1	1	1	1	2	2	1	2	1	1	x	2	1.363636	
107	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	138	Report	2	2	1	2	x	2	x	x	x	x	x	x	1.8	0
						Skeletal	2	2	1	2	x	2	x	x	x	x	x	x	1.8	
108	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	139	Report	x	x	x	x	2	x	1	1	1	1	1	1	1.142857	0
						Skeletal	x	x	x	x	2	x	1	1	1	1	1	1	1.142857	
109	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	140	Report	1	1	2	2	2	2	x	x	x	x	x	x	1.666667	0
						Skeletal	1	1	2	2	2	2	x	x	x	x	x	x	1.666667	
110	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	141	Report	x	x	x	x	x	x	2	x	1	2	2	2	1.8	0
						Skeletal	x	x	x	x	x	x	2	x	1	2	2	2	1.8	
111	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	142	Report	x	x	x	x	x	x	2	1	5	1	x	x	2.25	0.25
						Skeletal	x	x	x	x	x	x	3	1	5	1	x	x	2.5	
112	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	144	Report	1	1	x	1	1	1	1	1	1	1	1	1	1	0
						Skeletal	1	1	x	1	1	1	1	1	1	1	1	1	1	
113	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	145	Report	1	1	1	1	1	1	1	1	1	1	2	2	1.166667	0.0833333
						Skeletal	1	1	1	1	1	1	1	1	1	1	3	2	1.25	
114	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	150	Report	1	1	1	1	1	2	1	1	2	2	1	1	1.25	0
						Skeletal	1	1	1	1	1	2	1	1	2	2	1	1	1.25	
115	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	152	Report	2	2	2	2	1	2	2	2	2	2	2	2	1.916667	0.1666667
						Skeletal	2	3	2	2	1	2	3	2	2	2	2	2	2.083333	
116	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	153	Report	2	1	x	x	1	1	1	1	1	1	1	1	1.1	0
						Skeletal	2	1	x	x	1	1	1	1	1	1	1	1	1.1	
117	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	156	Report	1	1	1	2	1	1	1	1	1	1	2	2	1.25	0.0833333
						Skeletal	1	1	1	2	1	1	1	1	1	1	3	2	1.333333	
118	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	157	Report	2	x	2	x	1	x	1	1	2	1	2	2	1.555556	0.2222222
						Skeletal	2	x	2	x	1	x	1	1	2	1	2	4	1.777778	
119	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	161	Report	2	1	2	2	2	2	2	2	x	x	x	x	1.875	0.125
						Skeletal	2	1	3	2	2	2	2	2	x	x	x	x	2	
120	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	162	Report	x	x	1	2	1	1	1	1	1	1	2	x	1.222222	0.1111111
						Skeletal	x	x	1	2	1	2	1	1	1	1	2	x	1.333333	
121	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	163	Report	1	1	2	2	1	1	1	1	2	x	2	x	1.4	0
						Skeletal	1	1	2	2	1	1	1	1	2	x	2	x	1.4	
122	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	165	Report	2	2	1	2	1	2	2	x	2	x	2	x	1.777778	0
						Skeletal	2	2	1	2	1	2	2	x	2	x	2	x	1.777778	
123	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	166	Report	1	2	x	x	x	x	x	x	2	x	2	2	1.8	0.2
						Skeletal	1	2	x	x	x	x	x	x	2	x	3	2	2	
124	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	179	Report	1	1	2	2	x	1	x	2	x	1	x	x	1.428571	0
						Skeletal	1	1	2	2	x	1	x	2	x	1	x	x	1.428571	
125	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	180	Report	x	x	x	x	x	x	2	x	1	1	1	1	1.2	0
						Skeletal	x	x	x	x	x	x	2	x	1	1	1	1	1.2	
126	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	192	Report	1	2	x	x	x	2	1	2	2	2	2	2	1.777778	0
						Skeletal	1	2	x	x	x	2	1	2	2	2	2	2	1.777778	
127	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	193	Report	x	2	1	1	x	2	x	x	1	1	x	x	1.333333	0
						Skeletal	x	2	1	1	x	2	x	x	1	1	x	x	1.333333	
128	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	200	Report	x	x	x	x	x	x	x	x	1	1	2	2	1.5	0
						Skeletal	x	x	x	x	x	x	x	x	1	1	2	2	1.5	
129	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	201	Report	2	1	1	2	x	1	x	x	1	1	x	2	1.375	0.125
						Skeletal	2	1	1	3	x	1	x	x	1	1	x	2	1.5	
130	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	202	Report	1	x	2	2	2	x	1	2	x	2	x	x	1.714286	0.1428571
						Skeletal	1	x	3	2	2	x	1	2	x	2	x	x	1.857143	
131	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	205	Report	2	x	2	x	x	x	x	1	2	2	x	x	1.8	0
						Skeletal	2	x	2	x	x	x	x	1	2	2	x	x	1.8	
132	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	208	Report	1	1	x	2	1	2	2	x	2	x	x	x	1.571429	0
						Skeletal	1	1	x	2	1	2	2	x	2	x	x	x	1.571429	
133	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	210	Report	x	x	1	1	x	2	x	1	1	1	1	2	1.25	0.125
						Skeletal	x	x	1	1	x	2	x	1	2	1	1	2	1.375	
134	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	216	Report	x	x	x	x	x	x	2	1	2	1	2	x	1.6	0
						Skeletal	x	x	x	x	x	x	2	1	2	1	2	x	1.6	
135	Saffron Walden	Wicken Bonhunt	20	1997.26.XXX	377	Report	1	2	x	x	x	x	2	2	2	2	x	x	1.833333	0.1666667
						Skeletal	1	2	x	x	x	x	2	2	3	2	x	x	2	
136	Great North Museum	Hexham Golf Course	97	**box 136**	1	Report	2	2	3	x	x	2	3	3	x	x	2	x	2.428571	0.2857143
						Skeletal	2	2	3	x	x	2	4	4	x	x	2	x	2.714286	
137	Great North Museum	The Sneep	129	---	1	Report	x	x	x	2	x	1	x	x	2	2	2	x	1.8	1
						Skeletal	x	x	x	3	x	2	x	x	3	3	3	x	2.8	
138	Great North Museum	West Wharmley	89	box 313	1	Report	1	2	1	x	x	x	2	3	1	2	x	2	1.75	0.25
						Skeletal	1	2	1	x	x	x	2	3	2	3	x	2	2	
139	Great North Museum	West Wharmley	89	box 313	1a	Report	3	x	x	x	x	x	2	4	x	x	x	x	3	0
						Skeletal	3	x	x	x	x	x	2	4	x	x	x	x	3	
140	Great North Museum	Bewes Hill Cist	79	---	4	Report	2	x	2	x	1	x	1	x	x	x	x	x	1.5	0.25
						Skeletal	3	x	2	x	1	x	1	x	x	x	x	x	1.75	
141	Great North Museum	Bewes Hill Cist	79	---	2	Report	x	x	x	x	x	x	x	2	x	2	x	2	2	0
						Skeletal	x	x	x	x	x	x	x	2	x	2	x	2	2	
142	Great North Museum	Bewes Hill Cist	79	---	3	Report	x	2	x	3	x	2	x	2	x	x	x	x	2.25	0
						Skeletal	x	2	x	3	x	2	x	2	x	x	x	x	2.25	
143	Great North Museum	Bewes Hill Cist	79	---	1	Report	x	x	x	x	x	x	2	x	1	x	1	x	1.333333	0
						Skeletal	x	x	x	x	x	x	2	x	1	x	1	x	1.333333	
144	Great North Museum	Summer Hill	81	---	Cist 1	Report	2	x	2	x	x	x	x	x	x	x	x	x	2	0.5
						Skeletal	3	x	2	x	x	x	x	x	x	x	x	x	2.5	
145	Great North Museum	Summer Hill	81	---	Cist 2	Report	x	x	5	5	5	x	5	x	x	x	x	x	5	0
						Skeletal	x	x	5	5	5	x	5	x	x	x	x	x	5	
146	Great North Museum	Summer Hill	81	---	Cist 3	Report	x	x	x	x	x	x	4	5	x	x	x	x	4.5	0.5
						Skeletal	x	x	x	x	x	x	5	5	x	x	x	x	5	
147	Great North Museum	Summer Hill	81	---	Cist 4	Report	x	3	x	x	x	x	3	2	2	3	x	x	2.6	0
						Skeletal	x	3	x	x	x	x	3	2	2	3	x	x	2.6	
148	Newark Civil War	Ad Pontem	63	11.90.	131	Report	x	x	x	x	x	x	3	x	x	x	x	x	3	1
						Skeletal	x	x	x	x	x	x	4	x	x	x	x	x	4	
149	Newark Civil War	Ad Pontem	63	11.90.	200	Report	x	x	x	x	x	x	3	x	x	x	x	x	3	1
						Skeletal	x	x	x	x	x	x	4	x	x	x	x	x	4	
150	Newark Civil War	Ad Pontem	63	11.90.	71..1/7	Report	x	x	x	4	x	x	x	x	x	x	x	x	4	0
						Skeletal	x	x	x	4	x	x	x	x	x	x	x	x	4	
151	Newark Civil War	East Stoke	36		1	Report	3	1	x	x	3	x	x	2	x	x	x	x	2.25	0.5
						Skeletal	4	1	x	x	4	x	x	2	x	x	x	x	2.75	
152	Newark Civil War	East Stoke	36		2	Report	2	2	x	x	x	2	x	x	x	3	x	x	2.25	0
						Skeletal	2	2	x	x	x	2	x	x	x	3	x	x	2.25	
153	Newark Civil War	East Stoke	36		3	Report	x	x	1	x	2	x	x	x	x	x	x	x	1.5	0
						Skeletal	x	x	1	x	2	x	x	x	x	x	x	x	1.5	
154	Newark Civil War	East Stoke	36		5	Report	x	x	x	x	x	x	2	x	x	2	2	2	2	0
						Skeletal	x	x	x	x	x	x	2	x	x	2	2	2	2	
155	Newark Civil War	East Stoke	36		T10928	Report	x	x	3	3	3	x	x	x	x	x	x	x	3	0.3333333
						Skeletal	x	x	3	3	4	x	x	x	x	x	x	x	3.333333	
156	Newark Civil War	East Stoke	36		27.82	Report	2	2	2	2	2	2	x	x	x	x	x	x	2	0
						Skeletal	2	2	2	2	2	2	x	x	x	x	x	x	2	
157	Newark Civil War	East Stoke	36		27.82a	Report	3	3	x	x	x	x	x	x	x	x	x	x	3	0
						Skeletal	3	3	x	x	x	x	x	x	x	x	x	x	3	
158	Newark Civil War	East Stoke	36		27.82b	Report	2	x	x	x	x	x	x	x	x	x	x	x	2	0
						Skeletal	2	x	x	x	x	x	x	x	x	x	x	x	2	
159	Newark Civil War	East Stoke	36		6	Report	2	2	x	x	x	x	x	2	x	3	x	x	2.25	0
						Skeletal	2	2	x	x	x	x	x	2	x	3	x	x	2.25	
160	Newark Civil War	East Stoke	36		7	Report	x	2	x	2	x	3	x	2	x	x	x	x	2.25	0
						Skeletal	x	2	x	2	x	3	x	2	x	x	x	x	2.25	
161	Newark Civil War	East Stoke	36		8	Report	3	x	x	x	x	x	x	x	x	x	x	x	3	0
						Skeletal	3	x	x	x	x	x	x	x	x	x	x	x	3	
162	Newark Civil War	East Stoke	36		9	Report	x	x	3	x	3	x	x	x	x	x	x	x	3	0
						Skeletal	x	x	3	x	3	x	x	x	x	x	x	x	3	
163	Newark Civil War	East Stoke	36		10	Report	x	2	x	x	x	x	2	2	x	2	x	x	2	0
						Skeletal	x	2	x	x	x	x	2	2	x	2	x	x	2	

164	Newark Civil War	The Friary	40		10.84	Report	1	2	2	x	x	x	2	2	x	x	x	x	1.8	0
						Skeletal	1	2	2	x	x	x	2	2	x	x	x	x	1.8	
165	Newark Civil War	The Friary	40		29/21.78.1	Report	1	1	1	1	1	1	1	1	1	1	1	1	1	0
						Skeletal	1	1	1	1	1	1	1	1	1	1	1	1	1	
166	Newark Civil War	The Friary	40		T22330	Report	x	x	1	x	1	x	2	x	2	x	x	x	1.5	0
						Skeletal	x	x	1	x	1	x	2	x	2	x	x	x	1.5	
167	Newark Civil War	The Friary	40		22/12.78	Report	x	x	x	x	x	x	2	2	2	2	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	2	2	2	x	x	2	
168	Newark Civil War	The Friary	40		500	Report	x	x	x	x	x	x	2	x	2	3	3	1	2.2	0
						Skeletal	x	x	x	x	x	x	2	x	2	3	3	1	2.2	
169	Newark Civil War	The Friary	40		29/2.76.1	Report	x	x	x	x	x	2	x	x	2	2	1	x	1.75	0
						Skeletal	x	x	x	x	x	2	x	x	2	2	1	x	1.75	
170	Newark Civil War	The Friary	40		29/2.76.2	Report	x	x	x	x	x	x	x	1	1	2	x	x	1.333333	0
						Skeletal	x	x	x	x	x	x	x	1	1	2	x	x	1.333333	
171	Newark Civil War	The Friary	40		29/1.76.2a	Report	x	x	x	x	x	x	1	1	x	x	x	x	1	0
						Skeletal	x	x	x	x	x	x	1	1	x	x	x	x	1	
172	Newark Civil War	The Friary	40		29/1.76.2b	Report	x	x	x	x	x	x	2	x	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	x	x	x	x	x	2	
173	Newark Civil War	The Friary	40		29/1.76.2c	Report	x	x	x	x	x	x	2	2	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	2	x	x	x	x	2	
174	Newark Civil War	The Friary	40		29/1.76.2d	Report	x	x	x	x	x	x	2	x	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	x	x	x	x	x	2	
175	Newark Civil War	The Friary	40		29/1.76.2e	Report	x	x	x	x	x	x	2	x	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	x	x	x	x	x	2	
176	Newark Civil War	Lincoln Road	41		T22264	Report	x	x	2	2	x	x	2	1	x	x	x	x	1.75	0
						Skeletal	x	x	2	2	x	x	2	1	x	x	x	x	1.75	
177	Newark Civil War	Lincoln Road	41		T2213x	Report	x	2	x	2	x	2	2	2	x	x	x	x	2	0
						Skeletal	x	2	x	2	x	2	2	2	x	x	x	x	2	
178	Newark Civil War	Lincoln Road	41		T22277	Report	1	x	x	x	x	x	2	x	x	x	x	x	1.5	0
						Skeletal	1	x	x	x	x	x	2	x	x	x	x	x	1.5	
179	Newark Civil War	Lincoln Road	41		T2211x	Report	x	x	x	x	x	x	1	1	x	x	x	x	1	0
						Skeletal	x	x	x	x	x	x	1	1	x	x	x	x	1	
180	Newark Civil War	Lincoln Road	41		T22115	Report	x	x	x	x	x	x	x	2	2	2	x	2	2	0.25
						Skeletal	x	x	x	x	x	x	x	2	3	2	x	2	2.25	
181	Newark Civil War	Lincoln Road	41		T22112	Report	x	2	x	2	x	x	x	x	x	x	x	x	2	0
						Skeletal	x	2	x	2	x	x	x	x	x	x	x	x	2	
182	Newark Civil War	Lincoln Road	41		T22114	Report	x	x	x	x	x	x	x	x	2	2	x	3	2.333333	0
						Skeletal	x	x	x	x	x	x	x	x	2	2	x	3	2.333333	
183	Newark Civil War	Lincoln Road	41		T22113	Report	x	x	x	x	x	x	x	x	x	x	2	2	2	0
						Skeletal	x	x	x	x	x	x	x	x	x	x	2	2	2	
184	Newark Civil War	Lincoln Road	41		T22109	Report	x	x	x	x	x	x	x	2	x	2	x	x	2	0.5
						Skeletal	x	x	x	x	x	x	x	3	x	2	x	x	2.5	
185	Newark Civil War	Lincoln Road	41		S50	Report	x	1	1	2	2	2	x	1	1	2	x	1	1.444444	0
						Skeletal	x	1	1	2	2	2	x	1	1	2	x	1	1.444444	
186	Newark Civil War	Lincoln Road	41		T22111a	Report	x	x	x	x	x	x	x	x	2	3	x	x	2.5	0
						Skeletal	x	x	x	x	x	x	x	x	2	3	x	x	2.5	
187	Newark Civil War	Lincoln Road	41		T22111b	Report	x	x	x	x	x	x	x	x	2	3	x	x	2.5	0
						Skeletal	x	x	x	x	x	x	x	x	2	3	x	x	2.5	
188	Newark Civil War	Lincoln Road	41		T22111c	Report	x	x	x	x	x	x	x	x	2	2	x	x	2	0
						Skeletal	x	x	x	x	x	x	x	x	2	2	x	x	2	
189	Newark Civil War	Lincoln Road	41		T22111d	Report	x	x	x	x	x	x	x	x	3	2	x	x	2.5	0
						Skeletal	x	x	x	x	x	x	x	x	3	2	x	x	2.5	
190	Newark Civil War	Lincoln Road	41		T22111e	Report	x	x	x	x	x	x	x	x	3	3	x	x	3	0
						Skeletal	x	x	x	x	x	x	x	x	3	3	x	x	3	
191	Newark Civil War	Lincoln Road	41		T22117a	Report	x	x	x	x	x	x	2	2	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	2	x	x	x	x	2	
192	Newark Civil War	Lincoln Road	41		T22117b	Report	x	x	x	x	x	x	2	2	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	2	x	x	x	x	2	
193	Newark Civil War	Lincoln Road	41		T22117c	Report	x	x	x	x	x	x	2	2	x	x	x	x	2	1
						Skeletal	x	x	x	x	x	x	3	3	x	x	x	x	3	
194	Newark Civil War	Lincoln Road	41		T22110a	Report	x	x	x	x	x	x	2	3	x	x	x	x	2.5	0
						Skeletal	x	x	x	x	x	x	2	3	x	x	x	x	2.5	
195	Newark Civil War	Lincoln Road	41		T22110b	Report	x	x	x	x	x	x	2	3	x	x	x	x	2.5	0
						Skeletal	x	x	x	x	x	x	2	3	x	x	x	x	2.5	
196	Newark Civil War	Lincoln Road	41		T22110c	Report	x	x	x	x	x	x	2	x	x	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	x	x	x	x	x	2	
197	Newark Civil War	Newark Castle	24	1994.21.xx	756	Report	1	1	x	1	x	1	1	1	1	1	x	x	1	0
						Skeletal	1	1	x	1	x	1	1	1	1	1	x	x	1	
198	Newark Civil War	Newark Castle	24	1994.21.xx	756a	Report	x	x	x	x	x	x	x	2	x	1	x	x	1.5	0
						Skeletal	x	x	x	x	x	x	x	2	x	1	x	x	1.5	
199	Newark Civil War	Newark Castle	24	1994.21.xx	856	Report	3	3	x	3	x	3	x	x	x	x	x	x	3	0
						Skeletal	3	3	x	3	x	3	x	x	x	x	x	x	3	
200	Newark Civil War	Newark Castle	24	1994.21.xx	630	Report	x	x	x	x	x	x	x	4	x	x	x	x	4	0
						Skeletal	x	x	x	x	x	x	x	4	x	x	x	x	4	
201	Newark Civil War	Newark Castle	24	1994.21.xx	615	Report	x	2	2	2	x	x	x	x	x	x	x	x	2	0
						Skeletal	x	2	2	2	x	x	x	x	x	x	x	x	2	
202	Newark Civil War	Newark Castle	24	1994.21.xx	671	Report	x	x	x	2	x	x	x	2	x	x	x	x	2	0
						Skeletal	x	x	x	2	x	x	x	2	x	x	x	x	2	
203	Newark Civil War	Newark Castle	24	1994.21.xx	845a	Report	1	x	1	x	x	2	2	1	x	x	x	x	1.4	0
						Skeletal	1	x	1	x	x	2	2	1	x	x	x	x	1.4	
204	Newark Civil War	Newark Castle	24	1994.21.xx	622	Report	x	x	x	3	x	3	x	x	x	x	x	x	3	1
						Skeletal	x	x	x	4	x	4	x	x	x	x	x	x	4	
205	Newark Civil War	Newark Castle	24	1994.21.xx	626	Report	x	x	x	x	x	x	x	x	2	2	2	2	2	0
						Skeletal	x	x	x	x	x	x	x	x	2	2	2	2	2	
206	Newark Civil War	Newark Castle	24	1994.21.xx	803	Report	1	2	x	x	2	x	2	x	x	x	x	x	1.75	0.25
						Skeletal	2	2	x	x	2	x	2	x	x	x	x	x	2	
207	Newark Civil War	Newark Castle	24	1994.21.xx	708	Report	x	x	x	x	x	2	x	x	x	3	x	3	2.666667	0.3333333
						Skeletal	x	x	x	x	x	2	x	x	x	3	x	4	3	
208	Newark Civil War	Newark Castle	24	1994.21.xx	705	Report	x	x	x	x	x	x	2	2	2	x	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	2	2	x	x	x	2	
209	Newark Civil War	Newark Castle	24	1994.21.xx	847	Report	x	2	x	x	x	x	x	2	x	x	x	x	2	0.5
						Skeletal	x	2	x	x	x	x	x	3	x	x	x	x	2.5	
210	Newark Civil War	Newark Castle	24	1994.21.xx	843	Report	2	2	2	x	x	x	x	x	3	3	x	x	2.4	0.35
						Skeletal	x	2	2	x	x	x	x	x	3	4	x	x	2.75	
211	Newark Civil War	Newark Castle	24	1994.21.xx	756	Report	x	1	2	x	1	1	1	x	x	1	1	1	1.125	0
						Skeletal	x	1	2	x	1	1	1	x	x	1	1	1	1.125	
212	Newark Civil War	Newark Castle	24	1994.21.xx	845	Report	x	x	x	x	x	x	2	x	2	2	x	x	2	0
						Skeletal	x	x	x	x	x	x	2	x	2	2	x	x	2	
213	Newark Civil War	Newark Castle	24	1994.21.xx	801	Report	2	x	x	2	x	2	2	2	1	1	2	3	1.888889	0
						Skeletal	2	x	x	2	x	2	2	2	1	1	2	3	1.888889	
214	Newark Civil War	Newark Castle	24	1994.21.xx	865	Report	x	x	x	x	x	x	1	1	2	3	2	1	1.666667	0
						Skeletal	x	x	x	x	x	x	1	1	2	3	2	1	1.666667	
215	Newark Civil War	Newark Castle	24	1994.21.xx	603	Report	1	2	1	1	1	2	1	1	2	1	1	x	1.272727	0.0909091
						Skeletal	1	2	1	1	1	2	1	1	2	2	1	x	1.363636	
216	Newark Civil War	Newark Castle	24	1994.21.xx	858	Report	1	1	1	1	x	1	1	1	1	1	1	2	1.090909	0
						Skeletal	1	1	1	1	x	1	1	1	1	1	1	2	1.090909	
217	Newark Civil War	Newark Castle	24	1994.21.xx	869	Report	x	x	2	1	2	2	1	x	1	1	1	2	1.444444	0
						Skeletal	x	x	2	1	2	2	1	x	1	1	1	2	1.444444	
218	Newark Civil War	Newark Castle	24	1994.21.xx	T22880	Report	x	x	x	x	x	x	1	x	x	x	x	x	1	0
						Skeletal	x	x	x	x	x	x	1	x	x	x	x	x	1	
219	Newark Civil War	Staythorpe	21		Find spot 5	Report	x	x	x	x	x	x	x	1	x	x	x	x	1	0
						Skeletal	x	x	x	x	x	x	x	1	x	x	x	x	1	

Appendix 12: Museum Information Recording Sheet.

Museum Information Recording Sheet

Museum Name: ____

Ownership: Independent Council/government University Other________________

Entrance Fee: Yes No

Size: Small Medium Large

Details:____
____
____

Dedicated storage: Yes No

Considered display of remains: Yes No

Guidelines implemented for staff Yes No

Destructive analyses allowed Yes No

Access limitations Anyone Students Phd researchers

Notes:____
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Appendix 13: Collated Museum Box and Packing Information.

Museum	Collection	Period	Boxes (Cardboard unless stated otherwise)			Boxes Stacked		Packing Material								Order	
								Bags				Labels	Additional Packing Material		Suitable		
			Appropriate Size	State of Repair	Suitable			Type	Suitable Size	Sealed	State of Repair		Used Appropriately	Type			
Verulamium	Folly Lane	Roman	Yes	Good	1	Yes	0	Heavy Paper	Yes	No	Good	On Bags	No	N/A	0	Rarely	0
Verulamium	Wheathampstead	Iron Age	Yes	Good	1	Yes	0	Heavy Paper	Yes	No	Good	On Bags	No	N/A	0	Rarely	0
Verulamium	St. Stephen	Roman	Yes	Good	1	Yes	0	Heavy Paper	Yes	No	Good	On Bags	No	N/A	0	Rarely	0
Worcester City Museum	Worcester Tech College	post-medieval	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Mostly	1
Worcester City Museum	Wormington Compression	Roman	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Mostly	1
Worcester City Museum	Sainsbury St. John	Roman	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Mostly	1
Worcester City Museum	Old Yew Hill Wood	Iron Age	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Mostly	1
Worcester City Museum	Deansway	medieval	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	Boxes Only	Yes	Acid-free Tissue	1	Mostly	1
Worcester City Museum	Bredon Norton	Roman	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Mostly	1
Saffron Walden Museum	Wicken Bonhunt	Anglo-Saxon	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Acid-free Tissue	1	Always	1
Great North (Hancock) Museum Newcastle	Summer Hill	Bronze Age	Yes - plastic tubs	Good	1	No	1	Plastic[2]	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Always	1
Great North (Hancock) Museum Newcastle	Beacon Hill	Bronze Age	Yes - plastic tubs	Good	1	No	1	Plastic[2]	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Always	1
Great North (Hancock) Museum Newcastle	West Wharmley Farm	Bronze Age	Yes - plastic tubs	Good	1	No	1	Plastic[2]	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Always	1
Great North (Hancock) Museum Newcastle	The Sneep	Bronze Age	Yes - plastic tubs	Good	1	No	1	Plastic[2]	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Always	1
Great North (Hancock) Museum Newcastle	Hexham Golf Course	Bronze Age	Yes - plastic tubs	Good	1	No	1	Plastic[2]	Yes	Yes	Good	Tags	Yes	Acid-free Tissue	1	Always	1
Newark National Civil War Centre	Ad Pontem	Roman	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Acid-free Tissue	1	Mostly	1
Newark National Civil War Centre	St. Leonards	medieval	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Acid-free Tissue	1	Mostly	1
Newark National Civil War Centre	The Friary	medieval	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Acid-free Tissue	1	Mostly	1
Newark National Civil War Centre	East Stoke	medieval	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Acid-free Tissue	1	Mostly	1
Newark National Civil War Centre	Newark Castle	Anglo-Saxon	Yes[1]	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Acid-free Tissue	1	Mostly	1
Newark National Civil War Centre	Staythorpe	Mesolithic	Yes	Good	1	Yes	0	Plastic	Yes	Yes	Good	On Bags	Yes	Bubble Wrap	1	Mostly	1

Notes: The shaded columns are used in Table 4.5 as part of the storage quality values.

Definitions:

- Boxes appropriate size: sufficient for remains to be packed without stretching the fabric of the box, allow the lids to close without risk of crushing the remains
- Boxes good state of repair: defined as no evidence of structural instability
- Bags appropriate size: remains do not prevent the sealing of bags, for larger elements two bags used to completely cover the bones
- Bags good state of repair: no evidence of tears. Holes made to avoid damp or mould growth were not included.
- The gauge of bags were not measured.
- Packing material used appropriately: bottom of the box lined, delicate or fragmentary elements wrapped, pathological material wrapped
- Order of packing consistent with guidelines, heavy elements on the bottom (Roberts 2009 p.88)
- Whilst Tyvek® labels are preferred, any type of labels were included.

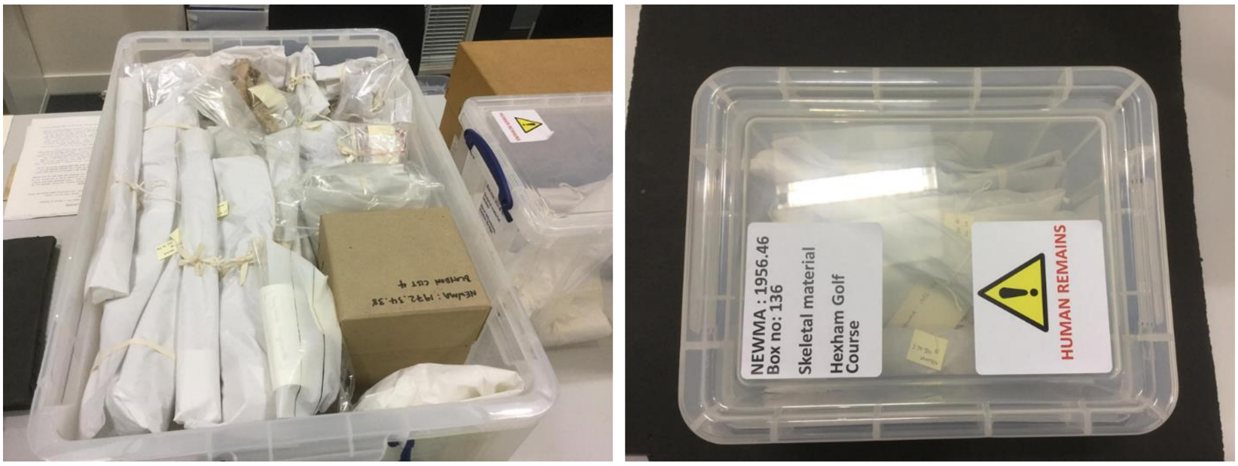
Caveats:

- 1) For the Newark Castle collection, the same size of box was used for each individual. In cases where individuals were represented by fewer skeletal elements, these boxes were over-sized. However, as these boxes were packed well to prevent damaging the remains, this strategy was considered suitable.
- 2) Some remains at Newcastle upon Tyne were not bagged but were entirely wrapped in other packing materials. Those remains that were bagged were held in sealed plastic bags.

Appendix 14: Museum Storage Photographs.

St Albans Museum (Verulamium). Showing roller racks and sturdy metal shelving. (Photographs taken by author)

Worcester Museum Storage Facility. Human Remains stored in a "Pod" separated from main facility. (Photographs taken by author)



Great North Museum (Hancock) – Newcastle upon Tyne. Plastic Containers used rather than cardboard. Individual bones wrapped and labelled. All boxes clearly marked as human remains. (Photographs taken by author)

National Civil War Centre – Newark. Strong cardboard boxes, elements grouped together and bagged appropriately, although larger elements were not bagged. Bags clearly labelled, although Tyvek® labels were not used, and the information was not written in permanent marker. (Photographs taken by author)

**No Photographs from Saffron Walden Museum were available.*

Appendix 15: Contacts.

Name	Affiliation	Information Provided
Dr Kamal Badreshany	Durham University	Contacted with regards to 3D scanning and printing of human skeletal remains.
Jelena Bekvalac	Museum of London and University College London	Contacted with regards to the deaccessioning of disarticulated remains from the Museum of London, and the distribution of human remains specialists across the country.
Katie Braithwaite	Durham University	Contacted with regards to the Bodies of Evidence exhibition and the feedback from visitors.
Dr Anwen Caffell	Durham University	Examiner provided feedback.
Deborah Fox	Museums Worcestershire	Museum Contact.
Prof. Rebecca Gowland	Durham University	Contacted regarding the challenges of VR and 3D digital images used in teaching.
Lauren Kancle	Durham University	Contacted regarding her Master's thesis and the use of the third molar in isotopic analysis.
Prof. Mary Lewis	University of Reading	Contacted regarding the Reading osteology teaching collection and how it was acquired.
Jacqueline McKinley	Wessex Archaeology	Contacted regarding background information on her 2004 preservation scale.
Dr Andrew Millard	Durham University	Contacted regarding statistical testing and analysis.
Rose Nicholson	North Lincolnshire Museum	Contacted with regards to museum storage.
Andrew Parkin	Great North Museum: Hancock	Museum Contact.
Dr Rebecca Redfern	Museum of London and Newcastle University	Examiner provided feedback.
Prof. Charlotte Roberts	Durham University	Supervisor provided feedback.
Prof. Robin Skeates	Durham University	Supervisor provided feedback.
Simon West	St Albans Museum and Gallery	Museum Contact.
Carolyn Wingfield	Saffron Walden Museum	Museum Contact.
Kevin Winter	National Civil War Centre	Museum Contact.