RECONSTRUCTING CHRISTIAN LIFEWAYS:

A bioarchaeological study of medieval
inhabitants from Portmahomack, Scotland
and Norton Priory, England.

Shirley Curtis-Summers

Thesis submitted in accordance with the requirements of the
University of Liverpool for the degree of Doctor in Philosophy

April 2015

"The pattern of disease or injury that affects any group of people is never a matter of chance. It is invariable the expression of stresses and strains to which they were exposed, a response to everything in their environment and behaviour. It reflects their genetic inheritance, the climate in which they lived, the soil that gave them sustenance and the animals or plants that shared their homeland. It is influenced by their daily occupations, their habits of diet, their choice of dwelling and clothes, their social structure, even their folklore and mythology."

(Calvin Wells 1964: 17).

This thesis is dedicated to my husband Colin.

Thank you for all your love and support.

Reconstructing Christian Lifeways: A bioarchaeological study of medieval inhabitants from Portmahomack, Scotland and Norton Priory, England.

Shirley Curtis-Summers

Abstract

This thesis investigates lifeways of medieval Christian communities from Portmahomack, Northeast Scotland and Norton Priory, Northwest England, to ascertain the extent to which skeletal indicators of diet, disease or trauma reflect religious or social influences. Osteology and palaeopathology methods on human adult and sub-adult skeletons from Portmahomack (6^{th} to 17^{th} century) and Norton Priory (12^{th} to 16^{th} century) was undertaken to provide evidence relating to the four key themes proposed in this study: 'biological or familial affinity', 'the living environment', 'trauma and conflict', and 'diet and nutrition-related stresses'. Stable carbon and nitrogen isotope analysis of bone collagen from adult humans from Portmahomack (including and a sub-sample of sub-adults) and Norton Priory were measured for dietary reconstructions. Faunal bone collagen was also analysed from Portmahomack and Norton Priory (plus a selection of fish bones from Chester Cathedral) to provide isotopic baselines to reconstruct human diets.

The results suggest past lifeways of Christian communities from Portmahomack and Norton Priory can indeed be successfully reconstructed through bioarchaeology. The evidence from this study has found that skeletal traits, alongside burial evidence, can elucidate familial affinities, especially from Norton Priory, and that differences in cultural and religious practices are reflected within the living environment of ecclesiastic and lay groups. Evidence of violence, reflecting interpersonal conflict and vulnerability was found from both Portmahomack and Norton Priory, which was inconsistent with the role of ecclesiastic and lay communities that were expected to follow strict Christian doctrines. Stable isotope data revealed a diachronic change in diet at Portmahomack; no fish were consumed during the monastic period, whereas significant amounts were consumed by layfolk in the later periods, suggesting Christian dietary practices changed over time. The isotope data from Norton Priory reflected a more homogeneous diet that did not change greatly over time, suggesting conformity to the same fasting practices.

Overall, this study has demonstrated that adopting a multidisciplinary bioarchaeological approach, integrating skeletal, chemical, archaeological, and historical evidence, results in a powerful research tool that enables reconstructions of medieval Christian lifeways and interpretations of religious and social influences therein.

Acknowledgements

I would like thank the Arts & Humanities Research Council (AHRC) for funding this research; the Natural Environment Research Council (NERC) for funding the isotope analysis, and Historic Scotland for contributing toward the Portmahomack isotope analysis.

I would like to give a special thank you to my primary supervisor, Jess Pearson, for her endless motivation, guidance and invaluable comments on this thesis, and for her support and empathy during difficult times. This thesis would have been a shadow of its former self without her. I would also like to give special thanks to my supervisor, Harold Mytum, for his support, advice and many helpful comments.

Many thanks to Martin Carver and Cecily Spall, for granting me access to the Portmahomack skeletal material and for all their help and advice. Many thanks also to Justin Garner-Lahire and the FAS Heritage team, and to Michele Cadger, Tony Watson and the people of Portmahomack for entrusting me with such precious material. Huge thanks also to Lynn Smith, Frank Hargrave and the Board of Trustees from Norton Priory for granting me access to their skeletal collection and to Lynn, for all her invaluable help along the way. Thanks also to Oxford Archaeology North and to OR3D for supplying Norton Priory digital images and to Andrew Abram and Robert Connolly for their expert advice.

Grateful thanks to the following people for their help throughout this research: Krish Seetah, Sue Stallibrass, Matilda Holmes, Hannah Russ and David Orton for faunal species identification; Angela Lamb at NERC for isotope mass spectrometry training, Matt Grove for his advice on statistical analysis, and Simon Mays, Clark Spencer Larsen, Jo Buckberry, Anthea Boylston, Alan Ogden and Charlotte Roberts for their expert opinions and advice. Thanks also to Liz MacDonald at the Royal Liverpool University Hospital Radiology Department, for x-raying some of the skeletal material. Huge thanks also to my friends and colleagues for their help, support and encouragement. There are too many to mention but you know who you are.

This journey has come with the usual challenges one expects during a PhD, but some unexpected difficult times have also occurred and one source of inspiration has been my sister Trish. Her bravery, resilience and strength have motivated me to succeed. Throughout all of this however, the one person who has given me unconditional love and constant support is my husband Colin. He has been with me every step of the way, through tears, tantrums and joy, and his constant positivity has given me the strength I never knew I had. I can never thank you enough darling, so I'll simply say 'I love you' and 'please pour me a dram!'

Shirley Curtis-Summers,
University of Liverpool, April 2015.

Table of Contents

List of Figures

NB: Unless otherwise stated, photographs were taken by the author.

List of Tables

Chapter 1

INTRODUCTION

1.1 Introduction

The purpose of this study is to reconstruct the lifeways of early to late medieval Christian communities from northeast Scotland and northwest England. Bioarchaeological evidence of health, disease, trauma and diet, is used to investigate how society and religion influenced medieval Christian lifeways across all social strata, including both ecclesiastics and the laity. Human skeletal remains can be used to investigate aspects of religion, for example, through diet or burial practices (Zakrzewski 2011), hence identifying religious practices as socially entwined with the formation of identities. Archaeological and historical studies on religion in medieval Britain however have been largely focused on monastic layout or economy. Moreover, multidisciplinary approaches, using osteological, historical and stable isotope methods, are rarely employed to reconstruct Christian lifeways from medieval Britain. This research will therefore provide important new data to reconstruct many facets of past lifeways, from the environment in which one lived and worked, to influences on the types of food consumed, which was inextricably linked to Christian practices.

Herren and Brown (2002) stated that it is difficult to understand the relationship between ecclesiastics and the laity in medieval Britain and Ireland. This statement was largely based on evidence from historical sources, which are often bias towards elite or ecclesiastical groups (see section 1.2), hence bioarchaeological methods can significantly contribute to this area of research. Rather than concentrate on one perspective of medieval life, such as monastic groups, bioarchaeological research on medieval Christian communities that include both ecclesiastics and the laity, may elucidate how past lifeways were influenced by cultural norms and religious practices.

Two medieval religious sites were chosen for this research. The first is Portmahomack in northeast Scotland (6^{th} to 17^{th} century), which has the most extensively examined early medieval monastery excavated in western Europe in 40 years, and which is similar to other religious sites of Insular origin, such as Iona, in western Scotland (Carver 2004). The second site is Norton Priory in northwest England (12^{th} to 16^{th} century), which is unique in Britain because of the size of the skeletal population, combined with an understanding of the cultural context and sequence of the priory itself (Greene 1989).

The early medieval phases at Portmahomack represent a lay community and later a monastic community, both of which were largely self-sufficient. The laity from the mid-late medieval period at Portmahomack represented a small-scale parish church community; also largely self-sufficient, whereas those from the same period at Norton Priory, represented wealthy benefactors, ecclesiastics and those closely associated with the Priory, reflecting a more diverse society. Augustinian canons from mid-late medieval Norton Priory differed temporally, geographically and in their religious practices to the early medieval monks from Portmahomack. However, some similarity of religious practices occurred at Norton Priory and the later medieval phase at Portmahomack, both of which followed the Rule of St Augustine (see chapters 2 and 3). Overall, the inhabitants from Portmahomack and Norton Priory represent medieval Christian communities that may have shared a widespread adherence to Christian practices, such as fasting, although the types of food consumed may have depended on social status and their interpretation of such rules. Skeletal investigations from these sites allow interpretations of religious influences on food consumption and also health consequences, not just on monastic brethren, but from the wider Christian community.

1.2 Research Context

Whilst much effort has been expended on changes in monastic economy or structural layout, there has been little modern archaeological focus on religious lifeways and everyday experience from the medieval period (Coppack 1998, 2006). Early medieval documents are mostly Irish or Northumbrian and they concentrate on political events as listed in their annals, or in legal tracts and saints' lives. Later medieval documents indicate sometimes in considerable detail the products and income from estates, but not what was consumed in religious houses or by whom. The potential of concentrating on religious communities generally has been highlighted by Gilchrist (1995, 2005) and from skeletal evidence by Zakrzewski (2011). Although previous isotope studies have provided important data on diets from medieval religious communities (e.g. Müldner *et al.* 2009), most research in England has centred around Yorkshire (e.g. Mays 1997; Müldner and Richards 2007a, 2007b), and in Scotland, around the Orkneys (e.g. Barratt and Richards 2004; Richards *et al.* 2006). Moreover, only a small number have combined skeletal and stable isotope evidence (e.g. Spencer 2008, 2009), giving us few details about the impact of religious practices on human health overall, let alone whether these are region-, period- or status-specific.

It is now timely to apply techniques that more closely link archaeological contextual information and human osteological and palaeopathological evidence with isotopic data, creating in combination a powerful research tool, enabling the reconstruction of health, diet and disease in medieval Britain. This research will therefore enable interpretations of medieval lifeways and the social and religious influences therein.

1.3 Research Questions and Hypotheses

This project focuses on one overall question: To what extent can Christian lifeways be reconstructed through bioarchaeology using the case study sites of Portmahomack and Norton Priory? Therein, a number of research questions and associated hypotheses are proposed to provide a comprehensive study, including:

1) To what extent can bioarchaeology be used to infer bio-cultural or familial affinity?
   Hypothesis: Lay communities tend to bury their dead in family groups, with males and females identifiable from their skeletal remains. However, ecclesiastical communities should represent all male individuals with no familial relationships.

2) To what extent did the way of life of Christian communities have an impact on their skeletal remains?
   Hypothesis: The living environment of individuals differed depending on their lifestyles and roles within their Christian communities, which had an impact on their skeleton. It is expected that conditions such as infectious disease were more prevalent in more densely populated Christian communities compared to those from rural areas. Occupation-related skeletal differences may also occur between monastic and lay communities.

3) What evidence is there for trauma and conflict in Christian communities?
   Hypothesis: It might be expected that there is little evidence of interpersonal

violence from ecclesiastical and lay communities that closely followed Christian doctrines.

4) To what extent did diet differ between communities that followed different Christian practices, and were these practices followed similarly by men/women, young/old, ecclesiastical/lay status? Additionally, are there any dietary stresses that can be specifically tied to Christian practices?
   Hypothesis: If Christian practices were carefully followed, we might expect to see uniformity in diet and nutrition within a population. Therefore, no differences would be expected between men/women, young/old, ecclesiastical/lay status.

1.4 Thesis Structure

This thesis will first provide an historical background (chapter 2), focusing on Christianity in medieval Britain, which aims to offer an understanding of the spread of Christianity, the diversity of religious orders, and the relationship between the laity and ecclesiastics in medieval Britain. In chapter 3, the archaeological backgrounds of Portmahomack and Norton Priory are presented, including information on the human burials and faunal evidence, to provide context for later considerations in this thesis. Chapter 4 discusses lifeways in medieval Britain, in terms of indicators of health, disease and diet, which can be reconstructed from the skeletal body to interpret aspects of the society in which past people lived. Chapter 5 presents a background on stable carbon and nitrogen isotopes in the biosphere and their application in archaeological research. Osteological, palaeopathological and stable isotope methods and materials used in this study will be presented in chapter 6, and the results from these analyses will be reported in chapter 7. Chapter 8 will provide a discussion of the research conducted in this thesis, with a focus on the skeletal health indicators of inhabitants from medieval Portmahomack and Norton

Priory and the contribution to our understanding of past lifeways from Christian communities in medieval Britain. The final chapter will conclude this thesis by presenting a summary of the evidence from a multi-focal approach that combines osteological and stable isotope methods, thereby providing a crucial insight into our understanding of past medieval religious lifeways. Recommendations for future work that has been identified during this research, but beyond the scope of this study, will also be presented, enabling even greater insights into medieval religious lifeways.

Chapter 2

CHRISTIANITY IN MEDIEVAL BRITAIN

2.1 Introduction

Tracing the origins of Christianity in Britain is a complex and multi-faceted task, one which draws upon evidence from a range of different sources, such as art, literature, toponymy, architecture and archaeology. Christian conversion in Britain was not an overnight phenomenon but a process that took many centuries to reach its peak, resulting in rulers, ecclesiastics and the laity following a shared religion. However, this was not a uniform conversion or adherence to one specific religious doctrine, but an ever-evolving religious structure which influenced political, social and economic systems, which, in early Christian Ireland for example, led to 'major irreversible structural changes to the system' (Mytum 1992: 15). The majority of evidence for Christian ideology in medieval Britain often stems from literature written by those of high status, such as hagiographies and penitentials written by monks, or law codes commissioned by kings. Moreover, despite what was expected of the laity, very little of how they responded or adhered to Christian doctrines were documented; their lives were simply not important enough. Bioarchaeological methods can therefore provide primary evidence on how people from all levels of social strata were influenced by their culture, environment and even religion, through reconstructing aspects of diet, health and disease.

2.2 Clarification of Chronology and Terminology

The lack of uniformity when reporting chronological terms in Britain and Ireland, from pre-history to the late medieval period, is a result of differences in political, cultural, religious and economic events. Thus, chronological terminology reported is dependent on the country and time period in question. For example, when describing the 5th – 8th centuries in Britain and Ireland, scholars use the terms 'Early Historic'

(Fraser 2009), 'early medieval' (Yorke 2006), 'Anglo-Saxon' (Burton 1994) or 'early Christian' (Mytum 1992). The periods of the 9th – mid-11th centuries are described as 'Viking' (Woolfe 2007); 'Hiberno-Norse' in some Irish contexts (Duffy 2005) and 'Anglo-Scandinavian' in northeast England (Carver 1999b). The 11th – 12th century periods are described as 'Norman' (England and Wales), 'Norse' (Scotland) and in Ireland during the 12th – mid-14th century, 'Anglo-Norman' (Hines 2003). Collectively, these periods are referred to as 'early medieval' (5th – 11th centuries), 'high (or mid) medieval' (mid-11th – mid-14th centuries) and 'late medieval' (mid-14th – mid-16th centuries) (Hines 2003). This collective terminology will be used for the purpose of this study to cover both Britain and Ireland from the early to late medieval periods and to conform to current standards. Moreover, unless otherwise stated, all dates will refer to 'AD', rather than 'BC'.

A number of different languages were spoken in Britain and Ireland throughout the medieval period, such as Gaelic (Scottish and Irish), Welsh, Pictish, Old English, Old Norse and more widely, with the advent of Christianity, Latin (Woolf 2007). As a result, many literary sources differ in their spelling of a particular word or name. Fraser (2009: 71) notes that due to the nature of such small handwriting in many manuscripts, names and places were misread, often mistaking the letter '*u*' for the letter '*n*' resulting in, for example, '*Iona*', instead of '*Ioua*' or St *'Uinniau'* into St '*Finnian'.* Over time, texts were translated into the regional vernacular, as were the misrepresentations of original spellings and in the absence of historical texts, as with the Pictish language, they were derived from other sources, such as place-names or stone sculptures (Yorke 2006: 6).

Terms associated with the history of Christianity in Britain and Ireland, such as 'monastic' and the 'Celtic Church' are laden with difficulties and inaccuracies, yet are still used in modern scholarship, albeit to a lesser extent. The Greek words *monos* ('monk') and *monazein* ('monastery') translate respectively as 'one' and 'to live alone' (Lawrence 1989: 1; Online Etymology Dictionary: monastery). Yet the term 'monasticism' is used to describe a range of different religious communities (Burton 1994: ix), from the strictly ascetic Cistercian order to secular clergy, such as the Canons Regular, many of whom did not live an isolated life. Yorke (2006: 161) states that the term 'religious communities' would be more appropriate, unless there is clear evidence of a monastic rule being followed, as at Iona (and its daughter house at Portmahomack) or Jarrow, where the terms 'monastery', 'monastic', and 'monk' could be used. It also appears prudent to include the laity when describing certain aspects of Christianity as many were ingrained within ecclesiastic life, such as the *conversi* (lay brothers) of the Cistercian order or lay benefactors who founded monasteries and were thereafter, closely associated with them. As well as the clergy, the majority of the laity were required to adhere to the overarching doctrines of papal supremacy, such as observing fasting rules on holy days, as well as laws on baptism, marriage and burial (Yorke 2006; Hamilton 2011). Overall, the laity were part of the 'community of the faithful' (Brown 2003: 1), a Christian society, which was dominant throughout medieval Britain.

The terms 'Celtic Church' or 'Celtic Christianity' are used to describe a shared belief system between the early medieval churches in Britain and Ireland (Corning 2006: 4; Edwards 2009: 1). Similarly, the 'Roman Tradition' often refers to those who followed the shared religious practices of Rome, including churches from 7th century

Frankish and Anglo-Saxon kingdoms (Corning 2006: 4). For Scotland in particular, late 19th and early 20th century scholars routinely used the term 'the Celtic Church' throughout their literature as an overarching representation of early religious houses in Scotland (McLaughlan 1865; Watson 1904). This term has also been associated with the rise of nationalism in Scotland during the Celtic revival in the late 19th century (Bradley 1999). In the past thirty years, the term 'Celtic' has been questioned more widely. Scholars such as Kathleen Hughes (1981) and Wendy Davies (1992) have argued against such terms being used, on the basis that there were just as many differences within these early churches in Britain and Ireland and moreover, implications of a uniformed Celtic Church, in opposition to the Roman Church, are significantly inaccurate (Wormald 2006). In fact, it has been noted that both the Celtic and Roman churches held a shared acceptance of the papacy and although they differed in traditions, such as the dating of Easter, the use of penitentials and the form of tonsure, their papal allegiances were similar (Corning 2006). The multi-layered and complex aspects of Christianity in early medieval Britain and Ireland render terms such as the 'Celtic Church' and the 'Roman Church' far too simplistic to use. Some scholars have therefore sought to find alternatives to these terms, such as the 'Insular Church' (Charles-Edwards 2002; Fraser 2009; Herren and Brown 2002) to demonstrate that some religious communities in Britain and Ireland had practices and traditions that differed from the wider Christian world, differences that came to a head at the Synod of Whitby in 664. Again, terms such as the 'Insular Church', albeit less problematic, is still inaccurate and suggests inward-looking religious groups situated on the peripheries of Britain and Ireland with no external contact. Influential early medieval religious houses and their ecclesiastics were far from inward-looking; Lindisfarne had close links with Iona and vice versa, saints such as Adomnán and Columba of Iona had contacts with the continent, and Maelrubai of Bangor made lasting links by founding a monastery in western Scotland in 673 (Fletcher 1998: 169). Despite these misgivings and in the absence of a standardised term, 'Insular' will be used in this study when referring to Christianity in medieval Britain of Irish, Welsh or Scottish origin.

When it comes to describing the process of conversion in Europe, some scholars (e.g. Fletcher 1998; Urbanczyk 1998; Yorke 2006) used the term 'Christianisation' to denote the adoption from non-Christian to Christian religious practices. Pickles (2009: 160) has clearly defined this term as an "enthusiastic investment in Christian culture and institutions" rather than a process of conversion. However, it has been suggested that this term is misleading when used in place of 'conversion', because although 'Christianisation' and 'conversion' are parallel, they are clearly distinct and represent different strands in the study of religion (Kilbride 2000: 2*ff*.). It is judicious to note that the word 'conversion' was not used in the medieval period, even though modern scholars use this term to describe the transition from paganism to Christianity. The Latin word *Conversio* was used, for example, in the *Conversio Bagoariorum et Carantanorum Libellus*, composed in 870, yet this appears to have been used to describe the transition to a more intense Christian way of life, the way in which a lay benefactor would become a monk for example. The adoption to Christianity by a community however, was referred to as 'submitting to' or 'accepting' (Fletcher 1998: 515). Examples such as these reaffirm the need to avoid anachronistic views about the period of study. Moreover, in the absence or dearth of historical literature; archaeological evidence provides a vital source of understanding.

Finally, it is worth noting that the countries of England, Wales, Scotland and Northern Ireland, collectively known today as Britain, would not have been referred to as such during the early medieval period. Pictland, for example, was formed from earlier Iron Age tribes and by the 5th century, the Picts controlled Scotland in the north and east. In western Scotland, around Argyll, was the kingdom of Dál Riata whose inhabitants originated from Ireland and were to become known as Scots, from '*Scotti*' meaning Irish (Armit 2006: 150). By 843, the Pictish kingdom came to an end with the Scottish king Kenneth MacAlpin uniting Pictland and Dál Riata as one nation (Ritchie and Ritchie 1991; Woolf 2009). In Anglo-Saxon England, by 700, there were seven main kingdoms: East Anglia, Mercia, Kent, the East Saxons, the West Saxons, the South Saxons and Northumbria, the latter of which was a merger of two earlier kingdoms, Bernicia and Deira (Arnold 2005). To use generic modern-day place-names such as 'Britain' or 'England' can therefore be misleading, which Fraser (2009: 338) cautions to and notes certain monasteries that were based in the kingdom of Bernicia (modern Northumberland), such as Lindisfarne and Wearmouth-Jarrow would have been influential and intertwined with religious houses in what is now known as Scotland. It is prudent to be clear on the temporal context of a place, region or country, although where appropriate, modern place-names, including 'Britain' or 'Ireland', will be used in this study for continuity and clarity of understanding.

2.3 Setting the Scene: Religious Orders in Medieval Britain

The adoption of Christianity in Britain and Ireland saw a wave of new religious orders established. The most successful of these orders were those that followed the Rule of St Benedict and the Rule of St Augustine, which were predominant throughout the mid to late medieval periods in Britain and Ireland. Prior to the widespread adoption of these Rules, early medieval religious houses followed the Rules of their founders, mother houses or even from their neighbouring religious communities (Herren and Brown 2002; Pickles 2009). Early Rules of Insular origin included the Rule of St Columba (Iona), the Rule of Tallaght by Mael Ruain (Tallaght, Ireland) or the Rule of St Columbanus (Gaul), the latter of which, was combined with the Rule of St Benedict in some 7th century Frankish monasteries resulting in a mixed rule, known as the *regula mixta* (Charles-Edwards 2002; Fouracre 2009; Herren and Brown 2002; Lawrence 1989). The distinction between the two most successful rules is that those who followed the Rule of St Benedict were monastic and those of St Augustine were more secular in nature, although the latter were influenced by the Benedictine Rule (Brooke 2003; Lawrence 1989).

According to papal legislation, an ecclesiastic could transfer to another order but only if the new order was more austere, hence passing into a stricter life, an '*arctior vita'.* For example, regular canons could become Benedictines but Cistercians could not become regular canons (Milis 1992). Unfortunately, many early medieval religious houses left little, if no evidence of what Rule they followed, hence our understanding of their daily routine, practices and religious influences are lost. Portmahomack is one such religious house, where the religious Rule followed is unknown, although their association with Iona suggests they were influenced by the teachings of St Columba. Archaeological investigations however, provide a greater understanding of the lifeways and activities of the early inhabitants at Portmahomack (M.O.H. Carver, *pers.comm.*; Curtis-Summers *et al*. 2014). To understand the origin, practices and growth of Christianity in medieval Britain, we first need to look at those who spread the word of the Christian faith and the impact it had on society.

2.3.1 The Rule of St Columba

St Columba (also known as Columcille or Crimthann) was most famous for founding the monastery on Iona in the kingdom of Dál Riata (*c.*565). Originating from the noble Irish dynasty of the Uí Néill, Columba also founded monasteries at Derry and Durrow in Ireland before settling on the Island of Iona (Fletcher 1998; Lawrence 1989). No specific Rule was written by Columba, although his teachings inspired a later Rule to be followed in his name and his life to be documented (Fletcher 1998), most notably by Adomnán, ninth abbot of Iona, in his *Vita Columbae*, around 697 (*Life of St Columba*, translated by Sharpe 1995). The influence of Columban monasticism influenced religious houses across Britain and Ireland, although the subject of Columban conversion is more complex to unravel. This influence endured after Columba's death (*c.*597) and his successors prevailed in their teachings of Columban monasticism, certainly in northern Britain and Ireland, although the influence of the Roman Church was steadily gaining dominance as the ruling church in Britain.

2.3.2 The Rule of St Columbanus

St Columbanus (also known as Columbán) was a missionary from Leinster in Ireland, who received his monastic education at Bangor Abbey in County Down. During the late-6th to early-7th centuries, Columbanus founded a number of monasteries on the European continent, most notably Bobbio Abbey in Italy and Luxeuil Abbey in France (Herren and Brown 2002). The Rule of St Columbanus was compiled from his monastic penitential (*Regula coenobialis*) and his works on monastic virtues (*Regula monachorum*), which gained followers across Britain, Ireland and Europe. However, no specific religious order was born out of his Rule, possibly due to the ascetic regime being so strict. For example, in his *Regula monachorum* (*RM*), Columbanus wrote that a monk should '...come to his bed weary, and sleep walking and let him be forced to rise while his sleep is not yet finished' (*RM*, § 10, cited by Fraser 2009: 79), and on the subject of the monks' diet: 'Let the monks' food be poor and taken in the evening...' (*RM*, § 3, cited by Fraser 2009: 79).

2.3.3 The Rule of St Benedict

The Rule of St Benedict of Nursia was written around 526, which consists of a prologue and seventy-three chapters. It was aimed to teach monks, who were presided over by an abbot, about the organisation of monastic life and their obligations and duties, such as the reading of psalms, fasting practices and their daily round of prayer (Lawrence 1989: 22). The Rule offered a new way of life within a monastic community, which was in contrast to a hermitic, isolated existence. Those who sought to enter a monastic life had to abide by the vow, or more precisely, the promise of obedience, *conversatio morum* (loyalty to the monastic life), and stability (*Rule of St Benedict*, 58, translated by Kardong 1996). A number of different orders followed the Benedictine Rule, namely the Benedictines, Cistercians, Grandmontines, Carthusians and the Knights Templar. An overview of the two orders that had the greatest impact in medieval Britain, the Benedictines and the Cistercians, will be discussed here.

2.3.3.1 The Benedictine Order

St Benedict's Rule was written, not to create a "Benedictine Order", but for the abbeys Benedict established, such as Monte Cassino in Italy (Derwich 2000: 138). However, the Benedictines became one of the most successful orders in western

Christendom and one of the oldest and largest religious orders in England. The Benedictines, also known as the 'Black Monks' due to the colour of their robes, came to England with the arrival of St Augustine in 597; around the same time that monasticism of Irish origin was spreading across Scotland and into Northumbria. In the following centuries, these two monastic traditions became the dominant forms of Christian life in England (Hylson-Smith 2000: 61). The Benedictine Rule was gaining momentum by the mid-7th century, largely due to the efforts of St Wilfrid, abbot of Ripon and subsequently, bishop of Northumbria. Wilfrid introduced the Benedictine Rule at Ripon (*c*.660) and at Lindisfarne during 687-8 (Charles-Edwards 2002; Lawrence 1989). This influenced Bede to describe Wilfrid, in his *Historia Ecclesiastica Gentis Anglorum* (*The Ecclesiastical History of the English People;* hereafter *HE*, translated by Sherley-Price 1990), as the first English bishop who was to 'teach the churches of the English the catholic way of life' (*HE*, IV, 2, Sherley-Price 1990: 205).

The Benedictines maintained some continuity throughout the early medieval period, although it was severely threatened due to Viking raids in the 9th century (Derwich 2000). A monastic revival began in the 10th century, which resulted in the resurrection and founding of monasteries around southern England, which was led by Dunstan, Archbishop of Canterbury and Oswald, Bishop of Winchester. This revival was encapsulated in the *Regularis Concordia*, a set of laws based on the Benedictine Rule, which was produced by Æthelwold, Bishop of Winchester around 970 (Burton 1994; Hylson-Smith 2000). In the north, Wales and Scotland, little was still known of Benedictine monasticism until later in the 12th century with the establishment of Benedictine communities, such as Dunfermline, which was founded by Queen

Margaret and raised to abbey status by her son, King David I in 1128 (Burton 1994). The Benedictines continued to gain favour throughout the 11^{th} – 13^{th} centuries, with the establishment of cathedral abbeys and priories, such as Westminster Abbey and Durham Cathedral. With the arrival of new orders, such as the Grandmontines and Cistercians, and the rise of Augustinian orders, the dominance of the Benedictine order began to fade (Milis 1992; Derwich 2000).

2.3.3.2 The Cistercian Order

The Cistercians, who originated from France under the influence of St Bernard of Clairvaux in the late 11^{th} century, were the result of a group of monks who rejected the profit-making developments of the Cluniac Order and sought to follow a stricter form of the Benedictine Rule. They rejected any form of wealth that was made through income from rents, manors, labour, mills, churches and tithes (Burton 1994). They strove to create a more secluded and austere existence, centred on gaining spiritual value through agriculture and manual labour; a reform which the Benedictines did not emulate (Lawrence 1989). This secluded lifestyle however may have been conceptual in some ways rather than literal, as they were not completely cut off from the world and were often situated close to, or with transport routes to urban centres (Burton and Kerr 2011). The Cistercians, also known as the 'White Monks' began in Britain in 1128 and flourished throughout the mid-late medieval period. Waverly Abbey in Surrey was founded in the same year, with the aid of the Bishop of Winchester. Thereafter, a flurry of abbeys emerged, including Rievaulx Abbey (1131) and Fountains Abbey (1132) in Yorkshire and the first of many Cistercian foundations in Scotland, such as Melrose Abbey, founded by King David I in 1136 (Burton 1994: 69*ff*.).

Archbishop Malachy of Armagh introduced Cistercian monasticism to Ireland, which contributed to the demise of the traditional Insular church (Joyce 1998). It was in Wales and Yorkshire where the Cistercians made the most impact, choosing mountainous and upland areas where they would excel in arable and sheep farming and in the wool trade (Burton 1994). Thirteen Cistercian houses were founded in Wales between 1131 and 1226, such as Tintern Abbey, Conwy and Valle Crucis (Williams 2001). The Cistercians were the first to reject the admission of oblates (children accepted into a monastery), instead preferring to accept men over the age of fifteen, who freely sought admission into the monastic community. This created a new form of brethren, the *conversi* (lay brother), who were not servants, but members of the Cistercian community derived from both peasants and men of higher status, who worshipped God through a simplified round of prayer and their labours (Burton 1994; Watkins 2011). The *conversi* performed work on Cistercian lands and had a wealth of experience and knowledge; some being farmers, shepherds, labourers, cloth-makers and masons (Brooke 2003).

2.3.4 The Rule of St Augustine

St Augustine, Bishop of Hippo, North Africa (*c*.396–430), developed a practice, which he required his monks to follow, of relinquishing all personal possessions and to live in common prayer. This practice of religious life was from his written work, *Letter 211*, which was amalgamated with another document that listed daily services and regulated the order (*ordo*) of discipline and manual labour. Although Augustine did not write a specific Rule, these two documents were later adapted to form the *Regula Tertia* and the *Regula Secunda*, forming the Rule of St Augustine (Burton 1994; Lawrence 1989). This Rule was widely adopted in the 12^{th} century and gained particular favour in cathedrals, hospitals and those serving collegiate churches, due to the regular canons living a common life and adapting a timetable more in line with their pastoral and social concerns. Caring for the sick, for example, was one of the roles the Augustinian canons undertook as part of their religious duty (Burton 1994). However, the Rule of St Augustine was not as strict as the Benedictine Rule and gave little practical guidance on the organisation of religious life. Therefore, most canons regular compiled their own customaries, which drew from the Benedictine Rule and legislations from the Synod of Aachen (816–819). The latter sought to distinguish between monastic communities and canonical orders, although incorporating aspects of the Benedictine Rule into an Augustinian house would leave distinctive divisions between the two difficult to identify (Lawrence 1989). Augustinian canons regular are therefore classes as 'a hybrid order of clerical monks', emulating both the monastic ideal whilst following the Christian faith in the form of secular clergy (Lawrence 1989: 163*f*.). During the mid-late medieval period at Portmahomack and Norton Priory, the Rule of St Augustine was followed, although to what extent or whether it changed over time is unclear. However, evidence of adhering to certain religious rules, such as fasting practices, may be elucidated through dietary reconstructions of these inhabitants, through stable isotope analysis (see chapter 8).

The majority of Augustinian houses were under the title of 'priory', the head of which being the prior. Only a small number of Augustinian houses had 'abbey' status, where the abbot was *primus inter pares*, first among equals (Burton 1994: 168), one being Norton Priory, which was granted abbey status by Pope Boniface IX in 1391 (Bliss and Twemlow 1902: 405). According to the *Regularis Concordia*, an abbot could only be elected with the king's consent and in accordance with the Benedictine Rule (Burton 1994: 168), giving these houses elevated status. Augustinian houses varied in character, such as those centred around towns (St Botolph's, Colchester) or in the countryside (Bolton Abbey, Wharfedale), or those on a more grand scale as at Merton Priory, which was founded in 1114 and had a number of daughter houses in Cornwall, Scotland and Normandy (Hylson-Smith 2000). Between the 11^{th} and 13^{th} centuries a number of different religious orders emerged through the Rule of St Augustine, including the Augustinians, Premonstratensians, Dominicans, Franciscans, Gilbertines, Carmelites and Knights Hospitaller (Burton 1994: 43). The Premonstratensians and Augustinians, being the most successful of the Augustinian orders in Britain and the most pertinent to this study, will be discussed further.

2.3.4.1 The Augustinian Order

The Augustinian order, also known as 'Austin Canons' or 'Black Canons' (due to their black habit), differed from monastic communities in the sense that they went out into the lay community to preach and to give alms and hospitality, making them a highly popular order within their society. The Augustinians were unique as they did not emerge from the Benedictine order but developed alongside them (Hylson-Smith 2000). One of the first Augustinian houses in England was St Botolph's Priory, Colchester, which was founded around 1103. Between 1100 and 1135, around forty Augustinian houses were established in England, including Norton Priory, with another hundred in the 14^{th} century, resulting in over two hundred by 1350 (Hylson-Smith 2004).

The Augustinians were also the first major religious order in Scotland, with the first Augustinian house established at Scone (*c.*1120) and three major houses subsequently founded by King David I at Holyrood (1128), Jedburgh (1138) and Cambuskenneth (1147). At the more inconspicuous end of the spectrum, some Augustinian houses were in the form of enclosed communities, situated in isolated areas, such as at Llanthony, Monmouthshire (Lawrence 1989). The Augustinians were the first major religious order to have an impact across Britain following the Norman Conquest (Burton 1994). Secular canons were often married, although pressures from The Lateran Council of 1059, which did not enforce a monastic way of life on the canons, yet extolled the virtues of living a celibate existence, ultimately resulted in the majority of clergy being celibate by the late 12th century (Hylson-Smith 2000).

2.3.4.2 The Premonstratensian Order

The Premonstratensian Canons, also known as the 'White Canons' (due to their white habit), were founded by St Norbert at Prémontré in northeast France around 1120. They followed the Augustinian Rule but also incorporated Cistercian rules into their religious life, making them more strict and austere than the Augustinian Order (Burton 1994; Hylson-Smith 2000). The first Premonstratensian house was founded at Newhouse, Lincolnshire in 1143 and a foundation in Scotland quickly followed at Dryburgh Abbey, which was founded by Hugh de Morville in 1150. Their progress was swift and there were thirty-seven abbeys, three nunneries and six cells established by 1267 (Burton 1994: 57), including a Premonstratensian lay community at Portmahomack during the mid-late medieval period.

2.4 Christianity in Medieval Britain: an Overview

From the 3rd century, monasticism began to take hold in Egypt with early desert fathers, such as St Antony, taking on the life of an ascetic hermit and inspiring followers to build monastic communities dedicated to following a pious life according to a religious rule (Fletcher 1998). During the 4th century, these new religious communities spread to Italy and Gaul, with the support of elite rulers, such as Licinius Augustus and Constantine the Great, who in 313 legally established Christianity as the chosen religion in Rome, under an agreement known as the Edict of Milan (Herren and Brown 2002; Hutton 1993; Yorke 2006). Constantine, was the first Christian Roman emperor of Britain (306–337) and although it would be another two hundred years before the widespread adoption to Christianity in Britain, his support of this new religion would have been influential, although to how many and to what extent is unknown. Moreover, although Constantine supported the Christian church throughout his reign, he only converted to Christianity just before his death in 337, suggesting he maintained his pagan beliefs (Fletcher 1998).

By the 5th century, Christianity was beginning to take root in Britain (via Gaul) and became more widespread in Ireland (via the Britons), making it the dominant religion (Fouracre 2009; Herren and Brown 2002). However, this was far from a swift or uniform process; Britain was comprised of a number of different tribes and kingdoms (Figure 2.1) that had deep-rooted beliefs in pagan religion. It would take centuries for Christianity to become the favoured religion in Britain, and even then, it would need to mould itself to the varying complexities and needs of its societies (Pryce 2009).

Tracing the origins of Christianity in Britain is extremely difficult considering the ambiguous and incomplete nature of the evidence available (Herren and Brown 2002; Pryce 2009). For example, certain historical evidence, such as Bede's *Historia ecclesiastica* or Adomnán's *Vita Columbae*, are neither contemporaneous nor accurate accounts of the events or individuals they write about (Fletcher 1998: 10). In light of this, archaeological evidence can provide vital evidence as part of a multidisciplinary tool, especially in the study of historic periods (Mytum 1992; Pryce 2009).

Figure 2.1: British and Irish Kingdoms and Christian activity *c*.400-600. Location of Portmahomack and Norton Priory are included (after Bartlett 2001: 55).

Some scholars maintain a post-processual view that the study of early medieval Christianity should take into account the role that human agency plays in the diverse nature of ecclesiastical organisation and that processual approaches do not account for a greater understanding of Christian ideology (Carver 1989, 2003). Conversely, proponents of processual archaeology advocate a more systemic approach, understanding early Christianity as a "sociocultural system comprising of a series of subsystems (ideology, society, subsistence economy, craft production and trade)" that can be understood through material culture (Mytum 1992: 12, 20). To consider and discuss all forms of evidence for Christianity in medieval Britain is beyond the scope of this study. However, key events, individuals and places, will be discussed to provide a clear overview of Christianity in Britain throughout the medieval period and how it affected the lives of both ecclesiastics and the laity.

2.4.1 Christian Conversions in Early Medieval Britain

In 597, Pope Gregory I sent Augustine, a monk from Rome, to convert the English. Arriving in Kent, Augustine and his missionaries sought to gain an allegiance with King Æthelbehrt who granted him lands to establish a monastery at Thanet and thereafter, becoming the first archbishop at his established episcopal church at Canterbury (Burton 1994; Herren and Brown 2002). This account is often described as one of the most successful events relating to the introduction of Christianity into Britain. None more so than by Bede, who wrote in his 8th century *Historia ecclesiastica*, seemingly didactic accounts of the conversion of the English peoples, the accuracy of which has cause for concern in modern scholarship (Fletcher 1998; Wood 1994). Christianity was not unknown to the people of Britain and Ireland prior to the Gregorian mission. In fact, some two-hundred and eighty-three years earlier, five clergy members (three bishops, a deacon and a priest) were sent to the Council of Arles in 314 to represent Britannia, suggesting the Christian church was established in Britain, albeit on a small scale, before Constantine declared Christianity the chosen religion of Rome (Yorke 2006). Moreover, Augustine was not the first bishop to arrive in Kent. King Æthelbehrt's wife Bertha, a Christian Merovingian princess brought a Frankish bishop, Liudhard, with her upon her marriage to the king in *c*.580, seventeen years before Augustine's arrival (*HE* i, 25, Sherley-Price 1990: 75). The Gregorian mission was merely the latest in a number of conversion processes that had taken root in Britain from the 3rd to 4th century onwards (Pryce 2009).

Another ecclesiastic that predated a more successfully documented one was Palladius, who in 431 was sent by Pope Celestine of Rome to Ireland, not to convert the pagan people of Ireland, but to minister the extant Christians (Charles-Edwards 2002; Hill 2001; Pryce 2009). Apart from his activities being documented by Columbanus nearly two-hundred years later, there is scant evidence to support Palladius as the first apostle of Ireland. This title was given to Patrick, who was a Briton of noble birth; his father (Calpornius) was a deacon and his grandfather (Potitus) was a priest. At the age of sixteen, Patrick was taken to Ireland as a slave, during which time his faith in Christianity increased. After six years Patrick escaped to Gaul, then revisited his family in Britain and returned to Ireland as bishop (*c*.432) to begin his process of converting the Irish pagans to Christianity (Fletcher 1998). In his *Confessio,* Patrick stated that he was the first to take Christianity 'even to remote parts, where no one lived any further' (*Confessio*, c.51; cited by Charles-Edwards 2002: 215).

Contemporary Christian efforts to that of Patrick in Ireland were also gaining favour in southwest Scotland, where bishop Ninian, also a Briton, had established a stone church dedicated to St Martin of Tours at Whithorn around the early-5th century (Fletcher 1998). According to Bede, Ninian was responsible for converting the southern Picts (*HE*, iii, 4, Sherley-Price 1990: 148), although this account is ambiguous, anachronistic and has recently been opposed fervently (Clancy 2001; Fletcher 1998). The presence of a Christian community at Whithorn from the 5th century is supported through material remains, in the form of an inscribed funerary monument called the Latinus Stone, which dates to around the mid-5th century. The stone commemorates a thirty-five year old man named Latinus and his four-year old daughter. The stone is clearly Christian with the opening words reading *Te Dominum laudamus*, which translates as ‘We praise thee O Lord’ (Thomas 1981: 283). A similar funerary stone is the Cat Stane, situated within what is now Edinburgh airport. This stone dates to around the late-5th century and although some letters are missing, it has been suggested to translate to 'In this tomb lies Vetta, daughter of Victricius' (Rutherford and Ritchie 1974: 185; Thomas 1991-2: 4). Such funerary monuments have been found throughout Scotland and suggest Christian communities were using these stones as a way of commemorating their dead. Moreover, Christian burials were becoming more characteristic with the spread of conversion in 5th and 6th century Britain; they were largely single inhumations that were usually, but not exclusively, devoid of any grave goods and had a uniform grave orientation with the head placed towards the east. Burial type was not uniform however; graves could range from shroud burials placed in the ground or in coffins to stone-lined cist graves (Yorke 2006), and could represent both Christian and pagan beliefs, as seen in the burial of King Rædwald of the East Angles at Sutton Hoo (Hutton 1993). Unfurnished non-Christian and furnished Christian graves have been found, with a range of orientations, contributing to the complexity of assigning a specific religious practice to certain burials (Carver 1998).

Following Ninian's success in building a Christian community in southwest Scotland, Insular Christianity began to expand, with the arrival of St Columba at Iona (Lawrence 1989). In his *Vita Columbae (VC),* Adomnán writes of Columba visiting King Bridei's Pictish court, probably based at a hillfort in Craig Phádraig, near modern day Inverness (*Vita Columbae* ii, 35; Smyth 1984: 103). However, there is no account by Adomnán of Columba's conversion of King Bridei or his subjects and any mention of actual conversions only relate to a small number of individuals (Alcock 2003; Smyth 1984). Conversely, Bede attributes the conversion of the northern Picts to Columba, as he did the conversion of the southern Picts to Ninian. He writes that Columba 'converted that people to the faith of Christ by his preaching and example…' (*HE* iii, 4, Sherley-Price 1990: 148). Adomnán's accounts of Columba, like Bede's interpretations, appear ambiguous, didactic and anachronistic; especially considering the *Vita Columbae* was written one-hundred years after Columba's death and centred mostly on miracle stories rather than actual events (Smyth 1984; Yorke 2006). However, some scholars suggest it has a "vivid immediacy which may lead us to respect some of the circumstantial details" (Alcock 2003: 61). At best, hagiographical sources such as these give us a secondary view of the lives of saints and of associated people and events, especially considering the dearth of contemporary historical sources relating to Christian conversions in early medieval Britain.

In 597, the year of Columba's death, the aforementioned Gregorian mission, led by Augustine to convert the Anglo-Saxons had begun. By this time, the monastery on Iona was flourishing and was the major centre for Columban monasticism, which would influence the people of Dál Riata, Ireland, Northumbria and further afield for centuries to come. Such influence is attested in Adomnán's Law of Innocents (*Cáin Adomnáin*), written in 697 to protect non-combatants, such as women, children, clergy and the elderly from the effects of war. Ninety-one guarantors gave their backing to Adomnán's Law and representatives such as King Bridei of the Picts, Bishop Curetán of Rosemarkie, King Eochaid of the Scots and Bishop Wictbert of Clonmelsh in Ireland all attended the Synod of Birr, County Offaly, in the same year to proclaim his law (Smyth 1984; Yorke 2006). It appears that Adomnán was not only promulgating Columban monasticism but with the support of powerful noblemen and clergy, he was becoming protector of his fellow Christians and subsequently securing their allegiance to the Columban church. Earlier written work by Adomnán includes his *De Locis Sanctis* (The Holy Places), which was written around 686 and documented the accounts of a Gaulish bishop, Arculf who became marooned on Iona between 679 and 686 after his travels from the Holy Land. Adomnán's biblical education at Durrow and his knowledge of Byzantine and Coptic lands are attested in this written work (Smyth 1984; Yorke 2006). Pictish Class II cross slabs depicting hunting scenes, suggestive of Byzantine and Coptic influence, are found on the 8th century Nigg and Hilton of Cadboll stones that are situated where, according to Adomnán, Columba had sought out King Bridei of the Picts (Smyth 1984: 127).

Bishop Paulinus, who was part of the original Gregorian mission in Kent in 597, arrived at the court of King Edwin of Northumbria in 625 as chaplain to the king's wife Æthelburh. The king was eventually baptised on Easter day, 12th April 627, initiating the conversion of Northumbria to Christianity (Alcock 2003; Fletcher 1998; Pryce 2009). However, in 633, the conversion process was halted when King

Penda of Mercia and King Cadwallon of Gwynedd formed an alliance and killed Edwin, effectively ending the mission of Paulinus. After Edwin's death, Penda retired and Cadwallon's rule was short-lived when he was killed in 634 by Oswald, son of King Ethelfrith who himself was killed by Edwin (Alcock 2003; Fletcher 1998). Oswald, along with his brother Oswy, was in exile on Iona since their father's death and had converted to Christianity. In 634, they returned to Northumbria where Oswald, now king of Northumbria (634–642), founded a daughter house of Iona on Lindisfarne, thereby reinstating Christianity as the chosen religion. Oswald requested a bishop from Iona to convert his subjects to Christianity. Bishop Aidan was sent to Lindisfarne in 635 where he remained, firmly promulgating the Christian faith to the people until his death in 651 (Alcock 2003; Fletcher 1998). Oswald's brother, Oswy, became king (642–670) and under his rule Ionan monks restored Christianity, which spread to the East Saxons, the Middle Angles and to Mercia, after the death of King Penda in 655 (Pryce 2009).

Bede writes of his admiration for Bishop Aidan's qualities, such as his humility, diligence in study and prayer and attending to the sick and poor. However, Bede's tone changes when speaking of the observance of Easter, where he states 'I greatly admire and love all these things about Aidan, because I have no doubt that they are pleasing to God; but I cannot approve or commend his failure to observe Easter at the proper time…' (*HE* iii, 17, Sherley-Price 1990: 170). The difference between the Insular and Roman churches on when to observe Easter came to a head at the Synod of Whitby in 664. Discussions at the synod (or more specifically, the council (Witan), as it was not called by papal authority) were focused on the correct form of tonsure and the dating of Easter. The Ionan church observed Easter on a different

Sunday to that of the Roman church and wore a difference style tonsure, hence not in line with the Christian practices of Rome and the rest of western Christendom (Charles-Edwards 2002; Joyce 1998; Yorke 2006). Bishop Colman of Lindisfarne attended in defence of the Ionan church, as did Cuthbert and Abbess Hilda. Wilfred, who was appointed bishop of York in the same year, was the spokesman for the Roman church. Although King Oswy 'thought nothing could be better than the Irish teaching, having been instructed and baptized by the Irish…' (*HE* iii, 25, Sherley-Price 1990: 187), upon hearing of the teachings of St Peter during Wilfrid's defence, he ruled in favour of the Roman cause. In defeat, Colman left for Ireland with many English and Irish monks who would not conform to the new Roman practices (Hunter-Blair 1990). Iona itself resisted Roman practices until 716, as did churches in Wales until around 768. Although southern Ireland had accepted Roman Christian practices in the early 7th century, before the Synod of Whitby (Alcock 2003), Northern Ireland and settlements in Dál Riata and Pictland remained true to the Ionan traditions in the 8th century.

In 710, King Nechtan of the Picts decided to expel Columban clerics from southern Pictland and sought the help of abbot Ceolfrith of Jarrow, to request architects to build him a stone church in the Roman fashion ('*in more Romanorum*') (Ritchie and Ritchie 1991: 172; Carver 1999a: 9, 40*ff*., 2008: 23*ff*.; Ralston and Armit 1997: 233). The church is suggested to have been built at the southern Pictish centre Restenneth (Forfar), which had connections with the teachings of Bishop Curetán of Rosemarkie in northern Pictland (Yorke 2006). Nechtan's intention was that he and his subjects may better preserve the customs of the Roman church, therefore seeking to bring an end to Columban monasticism in Pictland. It therefore appears that by the early 8th century, the majority of Pictland had embraced the ways of the Roman church. The monastery at Portmahomack, a Columban foundation, housing both Pictish and Gaelic monks (Fraser 2009), may have resisted Roman practices until its demise in the late 8th to early 9th century when a Viking raid brought an end to the monastic phase (Carver 2008). However, with Curetán as a Columban missionary in the area and a close collaborator with Adomnán, who converted Iona to the Roman tradition (Veitch 1997), Portmahomack may have fell in line and followed the Roman church.

In the late 8th to 9th century, Norwegian and Danish Viking raiders were targeting coastline monasteries in Britain and Ireland that were seemingly defenceless and more importantly, held riches to fund further raids (Fletcher 1998). Monasteries that were victim to such invasions included Lindisfarne (793), Monkwearmouth-Jarrow (794), Portmahomack (*c.*780–830) and Iona; the wealth and status of the latter seemingly being the reason for repeated attacks in 795, 802, 806, 807 and 825 (Bartlett 2001: 62-63; Carver 2008: 199). It was Ireland however, that bore the greatest devastation with the majority of major monasteries and ports raided, although many attacks were not just by Vikings but by native Irish raiders (Lucas 1967). Viking settlements such as Dublin, which was founded in 841, became established towns by the 10th century (Bartlett 2001). The earliest and largest Viking settlement however, was located in Orkney, which by the late 9th century had become one of the most powerful Norse earldoms in Britain, from where Norwegian raids, especially in Pictland, Dál Riata and Ireland occurred (Bartlett 2001).

By the 10th and 11th centuries, Viking settlers in Britain and Ireland had integrated with native inhabitants and adopted the life of fishermen and farmers, many of whom took over towns such as York and established towns around the coast of Ireland (Smyth 1984). Scandinavian place-names elements such as *–staðir* and *–by*, probably denoting some form of village or farm, attest to prime lands being taken for the Viking settlers themselves (Bartlett 2001: 65). Although the Vikings reinstated pagan religion initially, they adopted Christianity within a few decades of their settlement (Hutton 1993), hence this was by no means a rapid conversion and indeed has been described as “a rather complex road to religious change” (Downham 2012: 28). The church responded to pagan practices by laying down strict laws, by Wulfstan, Archbishop of York, for example, who between 1000 and 1002, wrote extensive rules forbidding pagan activities such as necromancy, magic, pagan songs and worshipping non-Christian deities. By the early 1020’s, King Canute, the Viking ruler of England and Denmark, adopted these rules throughout his kingdom (Hutton 1993). Monasticism in England, Scotland and Wales was transformed with the Norman Conquest of 1066, resulting in a new system of land tenure and with the emergence of new religious orders; the face of Christianity in Britain was changing (Burton 1994; Hylson-Smith 2000).

2.4.2 Christianity in Mid to Late Medieval Britain

English churches underwent a number of changes after the Norman invasion of 1066. Those religious houses that held land were embroiled in the feudal system of land tenure and within two decades, thirty continental houses acquired English estates, such as Fécamp in Normandy (Burton 1994). Cubitt (2009: 389) notes that by 1087, most major monastic houses in Britain were ruled by Norman or continental abbots; sixty of which were appointed between 1066 and 1135. Many religious houses in England that came under Norman rule were either new monasteries or existing monasteries that were rebuilt to their style. Norman monasteries followed the Benedictine Rule and many were endowed with an increased number of monks. For example, a Norman monk, Serlo, was appointed abbot of St Peter at Gloucester in 1072, which at the time, had only eight small boys and two monks. However, on Serlo's deathbed in 1104 over one hundred inmates were housed in the monastery, attesting to a considerable expansion during his appointment (Hylson-Smith 2000).

The religious traditions of the Welsh *clas* and the Scottish culdee churches continued into the 13th century, although in areas where Norman conquests prevailed, such practices were suppressed (Brown 1994). Welsh churches were subjected to asset-stripping by the Normans. St David's, for example, was only regained from lay control after appeals to the papacy and archbishop (Cubitt 2009). By the mid-12th century, the Welsh *clas* tradition had disappeared and was replaced by the establishment of territorial parishes. Welsh churches were no longer under the direct authority of Rome but of Canterbury, which introduced monastic order from the continent (Kock and Minard 2012).

In 10th and 11th century Ireland, religious communities continued to flourish, such as Armagh, Kells and Clonmacnoise, which have been described as proto-towns that held great political and economic power (Mytum 2003). Archaeological investigations have revealed that sites, such as Navan Fort, Armagh, were considerable settlements within large enclosures that housed ceremonial centres, lay housing and economic activities (Waterman and Lynn 1997; Lynn *et al*. 2003; Lynn 2003; Cubitt 2009). The fragmentation of minster 'parochiae' into smaller 'proto-parishes' that emerged in 10th century England, led to an increase in parish churches by the 11th century; seemingly an 'English phenomenon' (Brown 2003: 20). By the mid-12th century, King David I of Scotland established new religious orders from the continent thereby replacing the monastic system with a diocesan one (Joyce 1998).

The practice of mass pilgrimage began to appear in the 11th century and the veneration of saints and their relics continued to thrive through to the late medieval period. Major pilgrimage sites profited from such visitations, such as St Asaph (Wales), Canterbury (England) and Tain in Scotland (McNeill and MacQueen 1996; Fletcher 1998; Bartlett 2001). Norton Priory also gained from pilgrimage income in the 13th century, due to housing a relic, supposedly a piece of the holy cross of Christ. The income from such visits may have funded the construction of the east chapel, where the relic was probably displayed (Greene 1989).

The century and a half after the Norman invasion has been described as the "golden age of English monasticism" (Hylson-Smith 2000: 71), with an increase of around 1100 monastic brethren in 1066 to about 17,500 by the time the Black Death arrived in 1348. This increase has been attributed to the arrival of successful new religious orders in England, such as the Cistercians and the Augustinians (Hylson-Smith 2000). By the 14th century however, Christianity had reached a point of stagnation despite the arrival of new religious orders (Brown 2003). The number of monastic foundations was decreasing and existing monasteries were struggling financially or through natural disasters, such as the Black Death (Hylson-Smith 2000; Stöber 2006). By this point, the monastic ideal was lost and the influence of once powerful clerics was waning. The once devout lay Christian became dissatisfied with the Church, imposed taxes and tensions mounting from the socio-economic strains of the

Black Death. This resulted in anti-papalism, anti-establishmentism and anti-clericalism, which culminated in the Peasants Revolt of 1381 (Hylson-Smith 2000).

By the mid-16th century, England's link with the Roman Catholic Church was broken. The instigator of such change was King Henry VIII, who in 1527 sought the approval of Pope Clement VII for a divorce from Catherine of Aragon to marry Anne Boleyn and to ensure a male heir. This request was denied and resulted in Henry VIII breaking away from Rome and becoming supreme head of the Church in England in 1534 (Smith 2012). This subsequently led to overall authority of the English, Welsh and Irish churches and to Protestantism as the principal religion. A resurgence of the Catholic Church emerged under the rule of Queen Mary between 1553 and 1558 but the Protestant faith was soon reclaimed under the rule of Queen Elizabeth I (Bartlett 2001). By the late-16th century, Protestantism was widespread in Scotland and in 1560 the Reformed Church of Scotland was founded by John Knox, rector of St Giles' Cathedral in Edinburgh. This new Presbyterian Church rejected the Christian tradition of celebrating mass and of papal authority (Joyce 1998). Many Scottish monasteries, such as the abbeys of Kelso, Jedburgh and Melrose, had suffered financially under the rule of King James V (1513–42) and by English raids. The emerging shared Protestantism between England and Scotland under the rule of King James I healed the rift somewhat. By the late 16th century, prayer books and Bibles were widely available throughout Britain in the vernacular rather than in Latin, the latter of which many layfolk could not understand. (Bartlett 2001). This gave layfolk more of an understanding of Christian teachings and control over their own faith, where before they had little.

2.4.3 Christianity and the Laity in Medieval Britain

The relationship between the laity and ecclesiastics in medieval Britain is often referred to in a dichotomised manner, both in modern (e.g. Milis 1992) and contemporary (e.g. *HE*, III, 30, Sherley-Price 1990) literature. Although such works may document lay involvement in everyday activities or religious events, nonetheless, they are regarded as secondary to the clerical proponents of the Christian faith. From an archaeological perspective, it has been noted that secular society can be indistinguishable to ecclesiastical society. The Anglo-Saxon site of Flixborough in Lincolnshire, for example, yielded evidence for craft production, writing, high status artefacts, aligned buildings and human burials. However, Crawford (2009: 440) states that “None of these features, singly or in combination, may be used to prove the presence of either a secular or ecclesiastical site, as aligned buildings, burials and craft production have been found on both.” In contrast, clear evidence of a monastic community has been found at Portmahomack, where the aforementioned are present, as are stone sculpture depicting ecclesiastical scenes and Latin text, burials that were predominantly adult male and evidence of a vallum surrounding the site (Carver 2008). What is less clear is the relationship between the laity and monks during the monastic phase at PMK. The presence of one sub-adult and two adult female burials from the monastic phase suggests a link with the laity, either familial or reciprocal. The sub-adult burial may represent an oblate, who unlike the other monastic brethren, did not survive into adulthood. However, although the practice of accepting oblates was common at many medieval monasteries (Mays 2006b), it cannot be conclusively proven that this practice was followed at such an early religious site as Portmahomack.

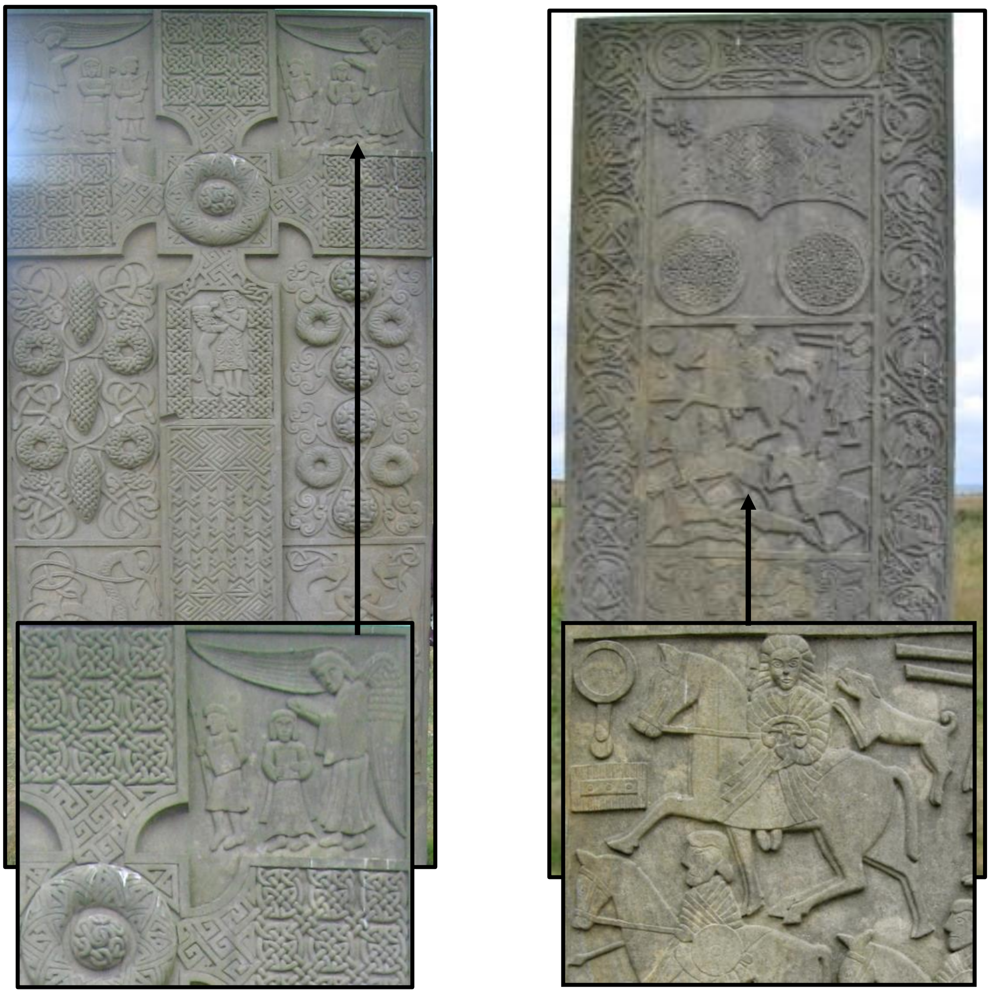


Figure 2.2: The Hilton of Cadboll Pictish cross slab replica. Biblical scenes and Christian cross (left) and hunting scene (right). Photographs: author's own.

Divisions between the laity and ecclesiastics are also seen on stone sculptures. The Hilton of Cadboll stone (Figure 2.2) in Ross and Cromarty, for example, depicts biblical scenes and a Christian cross on one side and a hunting scene on the other, where a female who is the central figure, is riding a horse and wearing a large brooch, with a mirror and comb symbol beside her. The items appear to be exaggerated as if to draw attention to their importance, suggesting a mark of status (O'Floinn 1989). It has also been suggested that female depictions are very rare on Pictish stones (Foster 2004) and may indicate that this female was of some importance, perhaps of noble or royal birth. Such stones may have served as grave or boundary markers or were connected to ecclesiastical centres as at Meigle and St Vigeans in Angus (Armit 2006), and more recently at Portmahomack (Carver 2008).

The laity, mostly in the form of nobility or kings and queens, served as founders and benefactors for the establishment of many religious houses and therefore played an integral part in the spread of Christianity in medieval Britain (Burton 1994). In exchange for gifts of lands, property and revenue, lay founders expected ecclesiastics to pray 'for the salvation of the soul of' (*pro salute anime*) themselves and their kin (Burton 1994: 210); a reciprocal agreement that sealed the connection between the secular and the sacred. Lay founders were not simply silent beneficiaries however, they had the power to hire and fire priests under their authority, as is evidenced in Anglo-Saxon guild statutes (Watkins 2011). Lay patrons, who inherited similar religious privileges to their ancestral founders, did not however have the same powers. By the 11th century, according to canon law, lay patrons could not be proprietors of religious houses and could not own monasteries. They could however, claim corrodies such as food, drink, lodgings and an allowance for themselves, their family and their servants (Lawrence 1989; Burton 1994). Such a strain on the resources of a religious house would be burdensome, although income from benefactors in return for prayers for their soul was a welcome relief (Greene 2005).

Many layfolk also lived and worked within monastic estates. In early medieval Ireland, monastic tenants (*manaig*) would live and work within the monastic estate, along with their wives and children (Etchingham 1999). They would have to follow the same religious observances as the monastic brethren, including periods of fasting and abstinence from sex three times per year, known as the 'three Lents' (Herren and

Brown 2002: 33). Such groups continued into the 12th and 13th centuries, most notably with the Cistercians who hired peasants as *conversi* to work their land, thereby developing a highly successful farming system within Cistercian estates (Burton 1994; Watkins 2011).

Prior to the late medieval period in Britain, most layfolk could not read Latin prayer books or indeed were illiterate and could not read prayer books produced in the vernacular (Bartlett 2001). Many layfolk therefore had to rely on clerics to disseminate the Christian faith as well as various rules and penitentials. However, other forms of Christian teachings were available to layfolk, in the form of paintings, theatre, song and poetry. For example, painted biblical scenes on church walls have been discovered, as at Chaldon church, Surrey, where a 12th century mural depicts images of heaven, hell and damnation (Watkins 2011). Plays were performed in monastic or church grounds, which were centred on biblical tales or saints' lives (Brown 2003), no doubt with the intention to reinforce a collective adherence to the Christian faith within the lay community.

No sooner had Christianity firmly established itself as the chosen religion in medieval Britain than ecclesiastics were concerned with how to instruct the laity on religious matters. Aside from saints' Rules, a number of law codes, council policies and penitentials emerged to ensure Christian obedience by the laity. Early medieval penitentials include that of Gildas (6th century), which is thought to be one of the earliest, possibly pre-dating that of Uinniau (Carswell 2006); Theodore of Canterbury's penitential, and law codes, such as the 8th century Irish *Collectio Canonum Hibernensis*. These relate to the concerns of clerics on lay behaviour, their sins and how to atone for them by following the rules of the church, such as devout prayer and fasting. These were implemented by major religious houses, such as Iona and its daughter house at Lindisfarne as well as in Pictland (Yorke 2006), suggesting that Portmahomack may have conformed to these rules also.

By the high medieval period, Church control over the laity became more centred on family matters in the form of strict adherence to the rules of births, marriages and deaths. The 10th century *Scriftboc*, a vernacular penitential partly derived from that of Theodore, ordered that if a child died by three years of age without being baptised, the parents were to undergo three winters' fast (*Scriftboc*, IV, 15, Oxford, Bodleian Library). Archaeological evidence suggests child burials in pagan burial grounds are lacking, whereas there is clear evidence of those in cemeteries associated with churches, such as at the late Anglo-Saxon cemetery at Norwich, where forty-five percent of child burials are present (Hamilton 2011). The Fourth Lateran Council, called by Pope Innocent III in 1215 in Rome, emphasised the importance that the laity were required to be baptised, married and buried within their own parish churches (Watkins 2011). The local priest, as a 'doctor of souls' was to instruct the laity on such matters and ensure Christian observances were met, such as taking confession and communion at Easter (Rider 2010: 328), perform penances such as fasting, church attendance and holy festivals (Brown 2003). Once baptised, the laity became part of the Christian community and although instructed by their priest on how to observe Christian practices, they were responsible for their own salvation. On occasion, this would lead to lax or ignorant behaviour, which in minor cases, the priest would overlook to retain the numbers of his parishioners (Tanner and Watson 2006).

Where burial is concerned, they laity appeared to have put a lot of effort into adhering to Christian rules upon their deathbed to ensure the salvation of their souls. In early medieval Britain the majority of the laity was buried in unenclosed rural cemeteries, although by the 9th century, burials emerged in enclosed cemeteries that were associated with the parish church, as at Raunds Furnells, Northamptonshire (Hamilton 2011). Archaeological evidence of Christian burials often shows spatial hierarchies relating to the status of an individual. Whether an ecclesiastic or a lay noble, peasant, man, woman or child, would determine their place of burial (Gilchrist and Sloane 2005). Burials in a church were common for the laity, especially within the nave, although areas closer to the high altar were reserved for those who either earned or paid for the right to be buried in such a revered place. The chapterhouse was an important area for clerics to pray and commemorate the dead, which is why burials in this area were set aside mostly for high status clerics and with exception, the laity (Gilchrist and Sloane 2005), as found at Norton Priory (see chapter 3).

Burial types varied greatly across the medieval period in Britain, from stone cist and pillow graves, a high percentage of which have been found relating to early Christian graves in Scotland (Maldonado 2011), to stone or wooden coffins, many of which have been found at Portmahomack and Norton Priory (see chapter 3). Many of the lower classes who could not afford a coffin were simply wrapped in a 'cere-cloth' and buried in the ground (Hylson-Smith 2000: 243). However, absence of a coffin does not necessarily indicate one was not used in the funerary procession. The deceased may have been transported from the home to the burial ground in a coffin, which would then be re-used for another family member, as was common practice in the medieval period (Gilchrist and Sloane 2005). At the opposite end of the scale, wealthy families built or adapted existing chapels as mausoleums to house their dead, as at Norton Priory, where wealthy benefactors adapted the Lady chapel as their mausoleum (Greene 1989).

One of the difficulties when trying to determine status from Christian burials, either religious, wealthy or poor, is that apart from the aforementioned spatial hierarchy of graves, there are rarely any indicators of status within the burial. Ecclesiastical superiors such as abbots or archbishops may be buried with a crozier or ring of office, as found at Whithorn Priory (Hill 1997), or more recently at Furness Abbey (Oxford Archaeology North). Some wealthy lay benefactors or nobles converted to a monastic life, either to devote themselves to God or to ensure the salvation of their soul upon their deathbed, an entry known as *ad succurrendum* (Burton 1994: 217). Such cases of separation, whereby nobles would renounce their secular life and enter a monastery, include Anglo-Saxon queens such as Eanflæd who was married to King Oswiu during the mid-6th century and became abbess of Whitby upon her husbands' death (Herren and Brown 2002). Many kings also renounced their secular life to become monks, including King Centwine of the West Saxons in 685, King Saebbi of the East Saxons in 694, and King Æthelred of Mercia in 704 (Pryce 2009), thereby receiving an ecclesiastical burial. From an archaeological perspective, a lay individual in life may therefore appear as an ecclesiastic in death, although without historical evidence, this is difficulty to reconstruct, yet such cases are apparent (see section 8.4.4).

2.5 Chapter Conclusion

This chapter has aimed to provide an overview of the key events and individuals relating to the introduction of, and adoption to Christianity in Britain and Ireland. It is beyond the scope of this study however, to investigate comprehensive origins of Christianity and the multi-faceted interactions between Britain and the rest of western Christendom. Early medieval Britain converted to Christianity through the work of missionaries with the support and permission of nobles and kings. The relationship between ecclesiastics and noble founders and benefactors became one of reciprocity; religious support in return for land, protection and revenue. The lower classes were also ingrained into religious life, either in the form of lay brethren who lived and worked within a monastic estate, or in every-day life, where devout prayer and observance was expected. Where laxity and sin occurred, strict penance was the motivational tool to repent and obey Christian rules. Although Christianity in Britain was constantly evolving and moulding itself to the needs of its communities, the greatest change occurred in the mid-late medieval periods with the introduction of new religious orders, strengthening papal legislations, financial strains and devastation by disease. Lay parishioners were given new responsibilities as churchwardens, whereas others, who lived in the country and were poor and illiterate, were more concerned with their labours than church organisation. By the late medieval period the clergy were no longer seen as the omnipotent proponents of the Christian faith, but just another official, like solicitors or judges (Hylson-Smith 2000). Increased knowledge and control by the laity, in not only religious matters, but in socio-political issues too resulted in a new social structure. The reciprocal relationship between ecclesiastics and the laity may have waned, apart from at the highest social structure, but the community of the faithful endured.

Chapter 3

ARCHAEOLOGICAL BACKGROUND

3.1 Introduction

This chapter presents the archaeological backgrounds of Portmahomack and Norton Priory, including evidence of human burials, faunal remains and economic activity that are relevant to this thesis. A historical overview will also be presented for Norton, although this could not be provided in any useful detail for Portmahomack, due to the lack of direct historical evidence. Firstly, a general background on the socio-economic environment in Europe will be presented, to provide an understanding of certain climatic and biological effects on subsistence and economy in Britain, during the medieval period.

3.2 Socio-economic background

In temperate Europe, several cooling periods and the Little Ice Age would have had profound implications for farmers and the provision of food. A general cooling occurred between 400 and 900, with dry summers and cold winters, which would have shortened growing seasons (Pearson 1997). The 'dust-veil event' of 536 was caused by activity from a volcano (or volcanoes) of unknown origin. This event resulted in episodes of crop failure and famine in China, the Mediterranean and Europe. This event was thought to have had a causal relationship with the Justinian plague that emerged in Egypt in 542 and spread across Europe and into Britain after 544 (Baille 1991, 1994). The Justinian plague is said to have been as devastating as the Black Death that occurred in the 14th century, despite it being less documented (Burgess 1985). Such events may have related to documentary sources reporting '*mortalitas in Brittanium et Hibernium*' in 537 in Britain (Williams 1860) and the 'failure of bread' in Ireland in 536 and 539 (Warner 1990).

The onset of the Little Ice Age, associated with an advance of polar and alpine glaciers, occurred from around 970 to 1200, followed by a warm phase that persisted in Europe until around 1300. This would have affected the growing season by around three weeks or more, with growth of crops decreasing and harvest failures increasing (McNeill and MacQueen 1996). From 1303 to 1328, winter temperatures in Central Europe lowered, then became highly variable from 1354 to 1375 (Pfister *et al.* 1996). Although some intermissions occurred, including a warm spell in the early 16th century, the cold winters quickly returned and continued up until the Victorian period (McNeill and MacQueen 1996). Evidence of harsh climatic events has been found, suggesting extreme coastal sand-blown episodes destroyed whole settlements. For example, at Forvie (Moray) in October 1413, severe climatic episodes resulted in sand that advanced over the site by 250 metres (Yeoman 1995). Although evidence of such episodes has not been found at Portmahomack, its shared coastline with Forvie, along the Moray Firth, suggest that it was also affected by such harsh climates around this time.

During the 14th century, two catastrophic events occurred in Europe that would change the economic and demographic landscape dramatically, namely, the Great European Famine of 1315-1321 and the Black Death of 1346-1353. Following severe climatic changes, the Great European Famine resulted in the highest record of mortality related to a subsistence crisis. Subsequently, farm workers' pay decreased and the price of grain increased, with wheat yield being the worst affected, followed by barley and oats (Campbell 2010). This would have had a catastrophic effect on people's subsistence, considering the chief staple of many medieval diets included grain for producing foodstuffs, such as bread, ale and pottage. A contributory event that affected subsistence in 14th-century Britain occurred with the arrival of a cattle plague, which reached England by 1319 and Ireland by 1321. This resulted in the reduction of cattle numbers by half within two years, which would have had a dramatic effect on productivity outputs of dairy, meat, manure and on the numbers of cattle needed for traction (Campbell 2010).

Despite the severe effect the Great European Famine had on people during the early-14th century, it was dramatically overshadowed by the spread of the Black Death, which occurred in Europe between 1346 and 1353 and in Britain between 1348 and 1350 (Benedictow 2004). The Black Death resulted in mortality up to five times greater than from the Great European Famine and subsequently shifted the status quo of supply and demand. Despite continued harvest failures, this shift in economic resources resulted in increased wages for workers, which by the late-15th century had increased to levels that would not be seen for another five centuries (Campbell 2010). People from Portmahomack and Norton may have been affected by catastrophic events, such as harvest failures. Such events may have affected those from Portmahomack more so, due to relying on a self-sufficient existence, whereas at Norton, a reciprocal relationship with nobility (see section 3.4.4) may have proved beneficial during times of hardship.

3.3 Archaeological Background: Portmahomack

Portmahomack is situated on the Tarbat Peninsula in northeast Scotland (Figure 3.1), with the area of archaeological interest centred around St Colman’s church (NH 915 840) (Carver 2006). The archaeological importance of this area was known from the 20th century, when antiquarians observed carved stones from Portmahomack, including one stone with a Latin inscription (Allen and Anderson 1903). This carved stone would later be likened to inscriptions found in early Christian manuscripts, such as the Lindisfarne Gospels and the Book of Kells, thereby suggesting evidence of an early literate monastic community at Portmahomack (Higgitt 1982). More recent archaeological investigations (1994-2007), under the direction of Professor Martin Carver (University of York), recovered another 200 fragments of carved stones, one of which formed part of a large cross-slab along with the Latin stone. This stone, which dates to around the late-8th century, depicts four clerical figures, and is thought to have originally represented the twelve apostles and Christ (Carver 1996, 2008), therefore presenting further evidence of monastic activity at Portmahomack during this time.

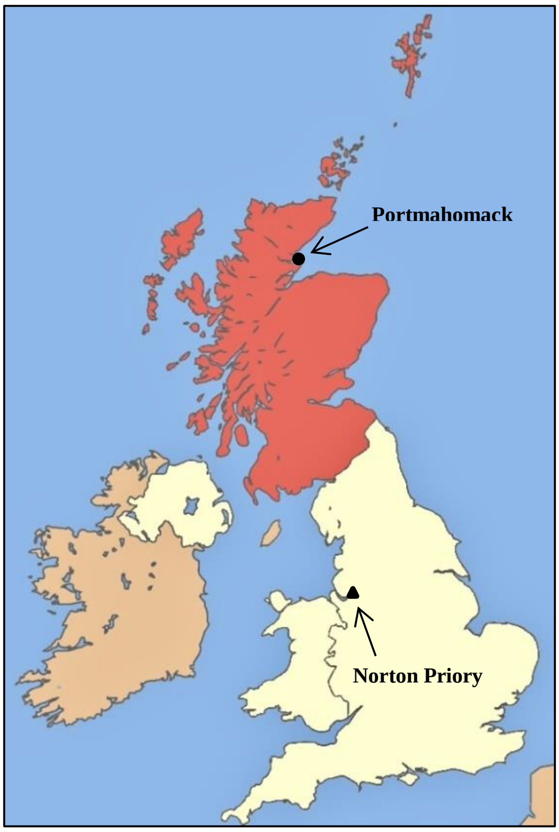


Figure 3.1: Location map of Portmahomack and Norton Priory. Adapted from UK map Scotland (2008): http://commons.wikimedia.org/wiki/File:Uk_map_scotland.png

The church at Portmahomack underwent different phases of rebuilding and expansion a number of times, from an 8th-century simple monastery to a 17th-century extended and restructured church, reflecting the needs of the growing parish church community (Carver 2008). Important information on the social, economic and cultural practices throughout the medieval period at Portmahomack is identified below, through evidence from burials (3.3.1), animal exploitation (3.3.2) and manufacture (3.3.3).

3.3.1 Burials at Portmahomack

The burials at Portmahomack were well stratified and contained 178 articulated human skeletons, which were assessed for this study. Radiocarbon dates on a selection of material, including human remains, indicate dates between the mid-6th to the late-17th-century (Carver *et al.* forthcoming). These burials, the majority of which were discovered within the church, comprise four distinct chronological groups (Carver 2012): period 1 (*c.*550 – *c.*700), period 2 (*c.*700 – *c.*800), period 3 (*c.*900 – *c.*1100), period 4 (*c.*1100 – *c.*1600), and period 5 (*c.*1600 – *c.*1700). Periods 1, 2 and 3 contained mainly adult burials, with period 4 and 5 containing adult and sub-adult burials (see section 7.2.1 for demographic information).

3.3.1.1 Period 1 Burials (c.550 – c.700)

Period 1 burials consisted of long-cist graves and simple inhumations that contained adult men and women. Three cist burials from this period were discovered outside the church, in the northern area of Sector 2 (see section 3.3.3). These burials are thought to represent a lay community at Portmahomack, being supposedly high status, suggested by the graves in Sector 2 having originally been marked by burial mounds. Orientation of the graves varied from WSW-ENE to west-east (Figure 3.2) and body positions included extended, supine, as well as one prone and one slightly flexed (Carver 2012). It is unknown what religion was followed during period 1, although a proto-monastic community is suggested (Carver 2008), and some early Christian focus may have been emerging considering Christian conversions were underway in Scotland during this time.

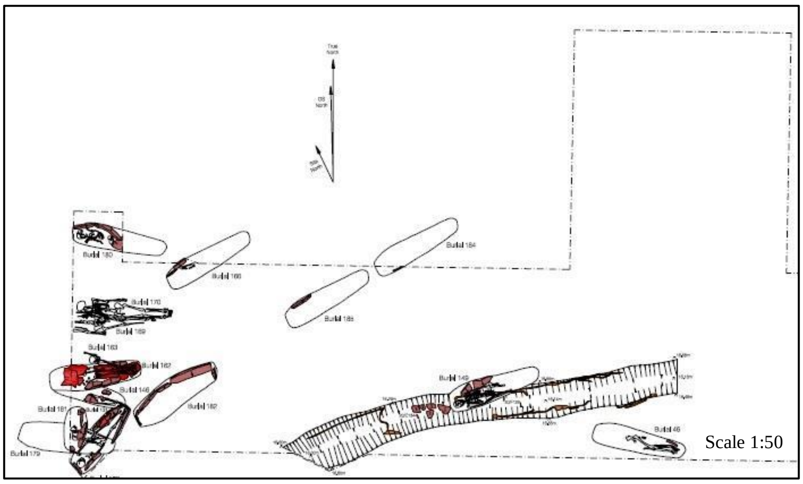


Figure 3.2: Burial plan from period 1 at Portmahomack (Carver 2004, 2012).

3.3.1.2 Period 2 Burials (c.700 – c.800)

The majority of graves from period 2 contained adult males, with only two adult female burials and one sub-adult burial recovered. These burials represent the monastic phase at Portmahomack, which probably represented a religious order of Irish origin. A number of burials from period 2 featured stone slabs set beside the head, with a third slab covering the face in some cases. This 'head box rite' was possibly the original burial furnishing practice in the cemetery during the monastic phase (Carver 2012: 21). However, some variation occurred, including one burial with a stone slab placed on the torso, one burial with organic remains of wood or wicker, and some burials that were simply shrouded. Overall, burials were oriented to true west-east (Figure 3.3) and body positions were mostly supine, extended inhumations, in simple, unfurnished graves, as is the expected Christian burial rite (Carver 2012).

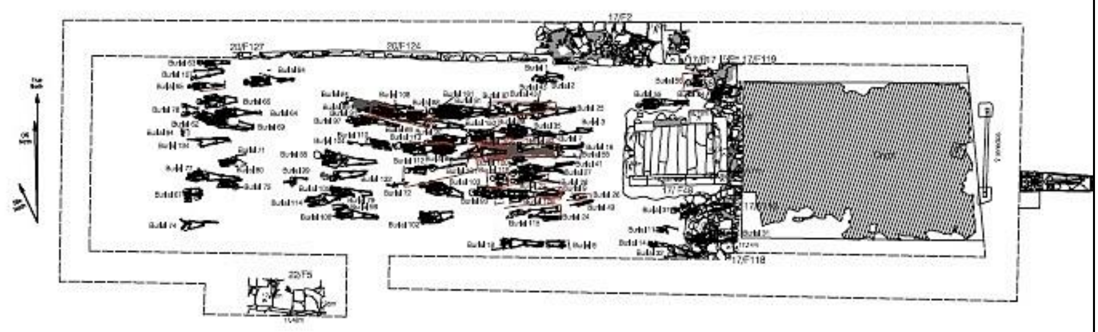
Figure 3.3: Burial plan from period 2 at Portmahomack (Carver 2012).

3.3.1.3 Period 3 Burials (c.900 – c.1100)

From period 3, only three adult male burials were recovered, which were also orientated west-east. Two of these burials had stone slabs placed beside the head, as found in period 2. Archaeological investigations suggest that period 3 burials are closely associated with those from the monastic phase in period 2 (Carver 2012). Therefore, where relevant, burials from both these periods are considered together as period 2-3 in this study.

3.3.1.4 Period 4 Burials (c.1100 – c.1600)

Burials of men, women and children from period 4 represent the lay parish church community that was established during the 12th century at Portmahomack, although the majority of burials belong to the 15th and 16th centuries (Carver 2008). During this period, the religious focus seemed to shift from its origins of Irish or Roman Catholic monasticism, to predominantly Roman Catholic during the 11th to 12th centuries. During the 13th to 16th centuries, the church at Portmahomack had a Premonstratensian focus, thereby following the Augustinian Rule, as did the Augustinian canons at Norton. Burial types from period 4 were either shrouded or coffined, with the majority being supine, extended inhumations, oriented west-east (Figure 3.4).



Scale 1:100

Figure 3.4: Burial plan from period 4 at Portmahomack (Carver 2012).

One coffin burial group from period 4 is thought to represent two males (PMK30 and PMK36) of high status. PMK30 was firstly placed within an oak coffin and accompanied by four skulls, a practice notably divergent from the usual medieval burial rite (Carver 2012). This individual's skull was later moved to accommodate the burial of a second male (PMK36). The removal of the skull of PMK30 suggests that some time had passed, and that this grave was marked for identification at a later date. This burial was closely associated with a coffin burial containing a sub-adult; aged 0-1 years (PMK58) that was placed at the feet of the adult burial, all of which possibly reflects a high status family group (Carver 2012).

3.3.1.5 Period 5 Burials (c.1600 – c.1700)

The majority of burials from period 5 were sub-adults, with the exception of an adult male and female. The two adults were buried in the north aisle of the church beneath a plaque dated to around 1642. This plaque was dedicated to William Mackenzie, who was minister to the Tarbat parish between 1638 and 1642 (Carver 2008). These burials are therefore suggested to be that of William Mackenzie and his wife, the former of which represents the only known ecclesiastic outside the earlier monastic phase at Portmahomack. By the 17th century at Portmahomack, the church had shifted its religious focus again to follow the Presbyterian faith, although the Christian burial rite of west-east oriented unfurnished graves was still practiced (Carver 2008). The period 5 burials mark the end of interments within the church at Portmahomack, with major rebuilding occurring in the mid-18th century and burials placed within the surrounding cemetery thereafter (Carver 2012).

3.3.2 Faunal Remains at Portmahomack

The faunal remains provide an important source of information relating to the socio-economic activities that occurred from the early to late medieval periods at Portmahomack. Overall, the majority of faunal bones recovered belonged to cattle, representing 73% of the identifiable assemblage. The greatest non-domesticate species found overall were red deer and roe deer (Seetah 2011). No faunal remains were recovered from period 5, although period-specific assemblages from periods 1-4 provide information on animal exploitation for the majority of the medieval period at Portmahomack.

From lay period 1, faunal remains were few, although a high percentage of cattle bones (67%) were recovered, followed by pig (20%) and sheep/goat (5%). Faunal remains from other species included red deer and roe deer, chicken and seal (Seetah 2011). Surviving deposits of barley and wheat were also recovered from this period (Carver 2012). Few fish bones were recovered, representing 2 char, 1 horse mackerel and 1 gadidae, allocated to period 1-2, therefore it is possible some of these remains may belong to the monastic phase (Holmes 2012a). A small amount of shellfish was recovered, including winkle, cockle, limpet and oyster (Holmes 2012b). However, these are also allocated to period 1 or 2; hence it is unclear what exact period they represent. Although no butchery marks were identified on the faunal remains from period 1, the predominance of cattle bones and the presence of other domesticates suggest these species contributed as food resources, along with native cereals of wheat and barley.

In contrast to period 1, period 2 was rich in faunal remains. Again, the highest prevalence was cattle (76%), followed by pig (13%) and sheep/goat (3%). This represents an increase in cattle, yet a decrease in pig and sheep/goat remains compared to period 1, which may suggest a shift in the types of animal meat consumed. Butchery marks were identified on some cattle bones, including evidence of pole-axing on one cattle skull, suggesting slaughter activities were undertaken on-site (Seetah 2011). A greater diversity of species was found in period 2, including red deer, dog, hare, cat, horse, wolf, gull, porpoise, whale and otter (Seetah 2011).

Period 3 (monastic) species were also dominated by cattle (79%), followed by pig (10%) and sheep/goat (5%), with a range of species similar to those found from period 2. Butchery marks were also found on cattle from period 3, representing the continuation of animal processing from the previous period (Seetah 2011). Very few fish bones were recovered from the monastic phases, representing 1 char bone (period 2), 2 char and 1 cod (period 2 or 3) and 1 char and 3 cod allocated to period 3 (Holmes 2012a). A small amount of shellfish was recovered from period 2, mostly of the whelk and winkle variety, which could have been easily exploited from the lower shore (Holmes 2012b).

The arrival of the lay community in the 12th century was accompanied by a remarkable increase in fish and shellfish remains, with fish bones being exclusively from marine species. Marine fish species dominate the faunal assemblage from period 4 and included cod (n=823) and haddock (n=730), with smaller quantities of conger eel, pollack, plaice and herring (Holmes 2012a). The prevalence of terrestrial species included cattle (59%), dog (11%), horse (10%), sheep/goat (9%) and pig (6%), with other species including those found from previous periods (Seetah 2011). Shellfish middens were abundant in period 4, which were dominated by winkles, followed by mussels and limpets, with a small number of oyster shells and crab claws (Holmes 2012b). A notable increase in marine consumption in the mid-late medieval period in Scotland has been previously identified (e.g. Barrett *et al.* 1999) and is discussed further in chapter 8.

3.3.3 Economic Activity at Portmahomack

Archaeological investigations at Portmahomack (Carver 2008) were conducted in four sectors (Figure 3.5): Sector 1 (South Field), Sector 2 (Glebe Field), Sector 3 (area beyond Tarbatness Road) and Sector 4 (church and cemetery). The whole area was enclosed by a D-shaped ditch, which was suggested to be reminiscent of the vallum around the monastery on Iona (Carver 2008). No archaeological finds were recovered from Sector 3 and Sector 4 was where the majority of burials were located. There were traces of a contemporary settlement from period 1, with round houses and evidence for ard cultivation and metalworking in Sectors 1 and 2. However, the majority of activity from these sectors is confined to the monastic phase (period 2-3) when a massive development, including the building of the monastery in Sector 4 occurred (Carver 2008, 2012).

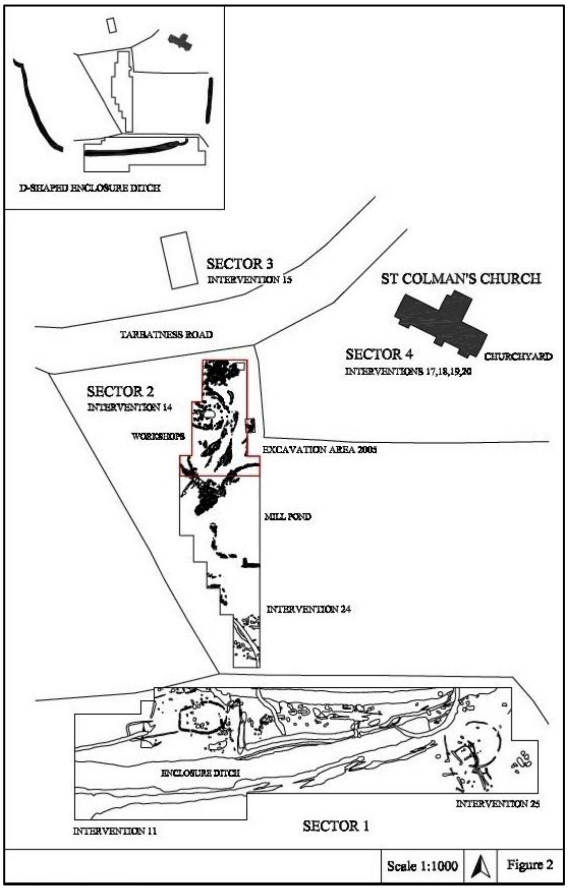


Figure 3.5: Areas of excavation at Portmahomack (after Carver 2006).

Finds from Sector 1 presented evidence of butchery and glass-, leather- and metal-working (Carver and Spall 2004; Carver 2008). Excavations in Sector 2 unearthed a bone stylus and revealed evidence of processing cattle hides, with a number of cattle metapodials arranged in an unusual v-shape. These finds were probably used for the manufacture of vellum to make books, with cattle metapodials used for stretching the cattle skins (Carver and Spall 2004). Finds such as metal moulds, crucibles and evidence of gold recycling suggests the monks at Portmahomack were also gilding mercury, most likely to decorate their holy books with gold leaf (Carver 2008). Evidence of book-making and scribing suggests the presence of an early Christian literate community during the monastic phase at Portmahomack (Carver 2008). As Christianity spread, laws were introduced that forbade the use of hand querns, necessitating a shift to water mill production, either through full or shared ownership (Mytum 1992). A number of hand querns were dumped in the dam pool in Sector 2, which suggests the monks at Portmahomack may have adhered to such laws and converted to water mill production, although no conclusive evidence of a mill was found on site (Carver 2008).

The monastery at Portmahomack was raided around the late-8th to early-9th century, with sculpture broken up, the workshops burnt down and a number of monks attacked (see chapter 8). The settlement re-emerged with an industrial focus towards the end of the monastic phase (period 3), making metal objects and weights, although no vellum or sculpture making occurred. There is little evidence of the land and cemetery being used during the 11th century, suggesting the monastic phase at Portmahomack had come to an end by this time (Carver 2008). As aforementioned, the first parish church was formed in the 12th century and a small lay community had established itself thereafter. By the 15th century, manufacturing activity in the village was mainly from the production of iron, with adjacent land probably used for animal husbandry (Carver 2008).

Regarding subsistence activities, a mixed strategy would have been needed in remote communities, such as Portmahomack, where access to local markets was sporadic. It appears that domesticates such as cattle, sheep and pigs were kept for a range of uses, from meat consumption to wool and dairy processing. The Tarbat peninsula and land clusters around Dornoch, Cromarty and Beauly Firths, boasts some of the most fertile arable land in Scotland, making it suitable for growing native crops, such as barley (McNeill and MacQueen 1996). These areas form a fertile coastline hundreds of miles long, with farms and estates in view of each other and in reach by boat (Carver 2008). In the lay phase (period 4) at Portmahomack, fish consumption increased, providing another source of subsistence. The [Old] Statistical Account of Scotland provides clues to subsistence methods in Scotland, documenting that a largely self-sufficient community at Canisbay in Caithness exploited both terrestrial and marine resources (Sinclair 1791-9, in Jones 1995). Communities such as these were not restricted to one type of subsistence strategy but indeed exploited surrounding resources to their full potential suggesting that ‘every fisherman in the parish is a farmer and every farmer is a fisherman’ (Sinclair 1791-9, in Jones 1995: 179). Reliance on a number of different subsistence methods may have minimised the effects that certain events, such as harvest failures or harsh climatic episodes, had on people, although adopting mixed subsistence strategies would depend on a number of factors, including adequate land and quality soil for arable and pastoral farming, and proximity to coasts or rivers to exploit aquatic resources.

3.4 Archaeological background: Norton Priory

Norton Priory is situated (SJ 547 831) in Runcorn, Cheshire, near the River Mersey (Figure 3.1), around 2km from the baronial castle at Halton. Archaeological excavation at Norton began in 1971 by Patrick Greene, initially as a six month project. However, the excavation became the largest at the time to be carried out on any European monastic site using modern archaeological methods, and ran for another twelve years (Greene 1989). The developmental sequence of the medieval Priory was discovered during excavations (Figure 3.6), including the 12th to 16th century foundations and identifiable areas of the Priory complex, including the cloister, chapterhouse, kitchens, refectory and church, the latter of which being where the majority of burials were discovered (Greene 1989).

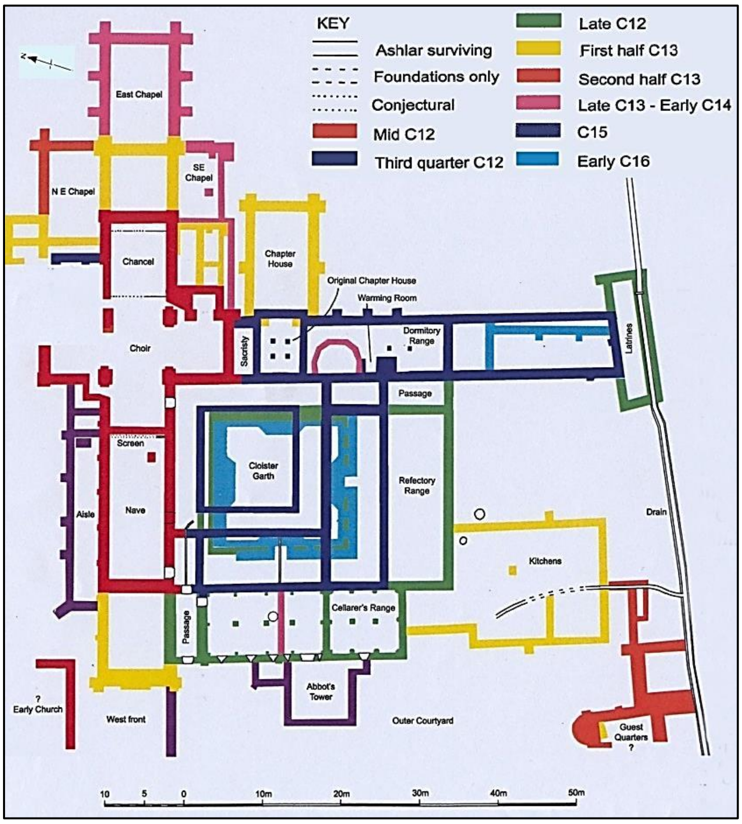


Figure 3.6: Sequence of the buildings at Norton Priory (after Greene 1989).

Brown and Howard-Davis (2008) stated that although Greene's publication in 1989 provided important information and interpretation following excavations at Norton, it did not present post-excavation analysis data in conventional form; for example, no osteology report was presented in the publication. Therefore, in 1999, Oxford Archaeology North was commissioned by English Heritage and the Norton Priory Museum Trust to upgrade the archaeological records, by digitising all stratigraphic data and providing a renumbering system to accommodate the large number of extra stratigraphic units (Brown and Howard-Davis 2008). This work, along with specialist assessments, including those from the human skeletal assemblage (Boylston 2008; Ogden 2008), formed the latest publication on archaeological investigations at Norton (Brown and Howard-Davis 2008). This thesis presents new evidence, in the form of a detailed bioarchaeological study, with a greater focus on religious and social influences on the lifeways of those buried at Norton.

3.4.1 Historical Overview of Norton Priory

In 1115, the 2nd Baron of Halton, William Fitz Nigel, established a religious house in Runcorn and by 1134; the canons were moved to Norton, by the request of the Bishop of Chester (Greene 1989). Norton Priory started out as a modest building but extensions and donations over the years transformed it and in 1391 the Priory was granted abbey status by Pope Boniface IX, which meant that the abbot could ordain his own canons (Greene 1989). The ecclesiastic community at Norton were canons who lived a religious life, but who engaged with the outside world. These canons followed the rule of St Augustine (see chapter 2), which was based on principles of charity, chastity and concord.

All the farm work at Norton was done by lay workers from the local village and servants attended to most of the manual work. The Priory was maintained by gifts from benefactors, such as the Barons of Halton and the Dutton family. At its height in the late-14th century, Norton Priory housed twenty-four canons and an abbot, although thereafter the number decreased to sixteen in 1401, nine in 1496 and seven by 1524 (Greene 1989). The reduction in the number of canons may have been in an effort to save money, considering that in 1429, the Priory was considered ruinous due to loss of revenue (Greene 1989). After the dissolution of Norton Priory in 1536 and the arrest and acquittal of its abbot in 1538, the estate was sold to the Brooke family in 1545 bringing an end to the ecclesiastical use of the Priory (Greene 1989).

3.4.2 Burials at Norton Priory

Human burials were excavated at Norton between 1971 and 1983, with 128 articulated skeletons available for examination in this study. No radiocarbon analysis has been done on the skeletal material, although contextual evidence, such as tile, pottery or grave type, suggests these burials belong to the 12th to 16th centuries (Greene 1989). The burials included adults from the 12th to 16th century and sub-adults from the 14th and 15th century (see section 7.2.1). Lay burials occurred more commonly within the nave and the transept chapels, whereas burials of ecclesiastics were towards the eastern end of the church, in the crossing, chancel and the south transept (Brown and Howard-Davis 2008). Lay burials that were placed further towards the east of the church held more divine importance, which is reflected in the position of the Dutton family chapel (Figure 3.7). However, one caveat to note is that in many cases, ecclesiastic or lay status was only interpreted from burial type or location, hence the exact status of individuals from Norton cannot be identified

(Greene 1989). Nevertheless, there is no doubt of their association with Norton as benefactors, ecclesiastics (abbots, priors, canons) or lay members of the surrounding Christian community. There are a number of burials that remain unrecovered from Norton, namely lay burials beyond the north aisle and a canons graveyard to the east of the Priory, suggesting that the Christian community at Norton was greater than what is represented in this study. Unlike Portmahomack, the religious focus at Norton did not change, hence the ecclesiastics and laity would have followed the Augustinian Rule from the Priory's foundation to its dissolution.

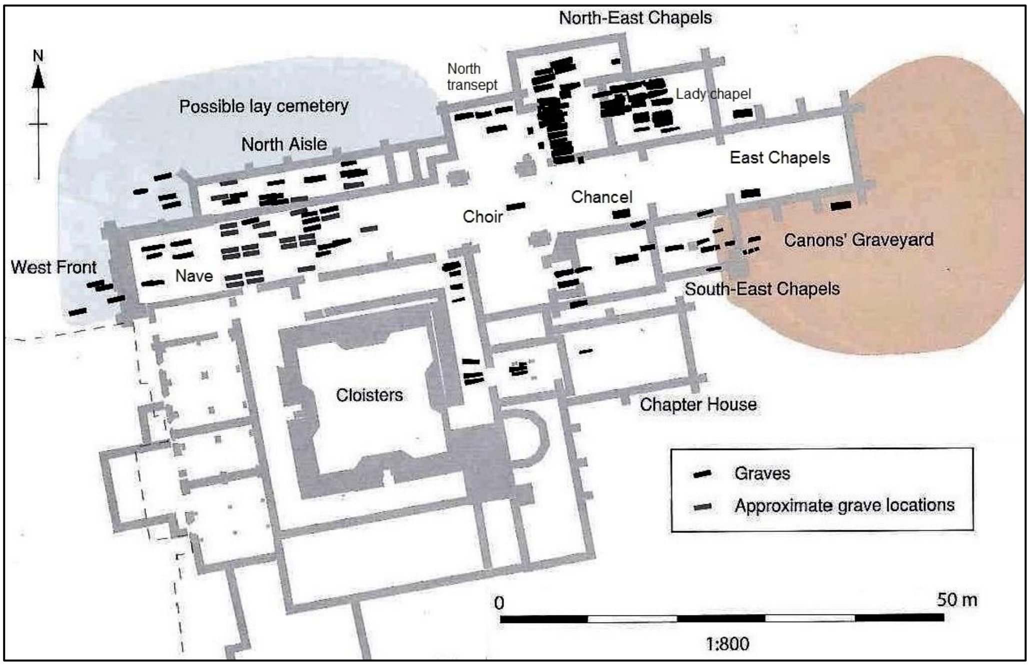


Figure 3.7: Burial plan from Norton Priory (after Greene 1989).

3.4.2.1 Burials in the Nave, North Aisle and West Front

The earliest burials from the nave date to the 13th century, which were two graves that were situated towards the eastern end, suggesting lay individuals of high rank (Brown and Howard-Davies 2008). One of these burials was that of an adult male, interred in a monolithic stone coffin, capped with a decorated lid of two carved shields, an indication of a knightly status (Greene 1989). This individual (NP22) is suggested to have been Sir Geoffrey de Dutton (d.1248), a wealthy knight, crusader and lay benefactor to Norton Priory in the 13th century, who suffered from Paget's disease and inflicted trauma (see chapters 7 and 8). The other 13th-century grave, directly behind the carved shield coffin, also had a decorated stone lid depicting a floriate cross and sword, again suggesting an individual of military rank (Brown and Howard-Davis 2008). The individual from this burial (NP59) is suggested to be Adam de Dutton (d.1210), who was steward to the constables of Chester, benefactor to Norton Priory and Geoffrey de Dutton's father (A. Abram, *pers.comm.*; Abram 2007). Burials from the 14th and 15th century were also found within the nave, with just one sub-adult buried in this area, aged 6.6-10.5 years (date unknown).

The majority of burials from the north aisle are from the 15th century and comprise of men, women and children, suggesting a group of lay burials. Moreover, considering by this period, Norton was established as an important Augustinian abbey, it is plausible to suggest these burials contained high-ranking individuals (Greene 1989; Brown and Howard-Davis 2008). Few burials from the north aisle were coffined, suggesting the practice of simple shroud burials began to dominate during this time.

As with the nave and north aisle burials, individuals buried at the west front are suggested to have been of lay status, dating from the 12th to 15th centuries. Again, these burials contained men, women and children, although few were coffined and their position outside the church suggests their status was not as high-ranking as those who could afford to be buried within the church (Brown and Howard-Davis 2008).

3.4.2.2 Burials in the North and South Transepts

The majority of burials in the north transept were in monolithic stone coffins, which has been suggested to represent high status burials of the local gentry or a local patron family, most likely the Duttons (Greene 1989; Howard and Brown-Davis 2008). The Dutton family became principal benefactors to the Priory from the 13th century and had their own burial chapel at the north transept, which included the northeast and Lady chapels. Burials from the northeast chapel date from the 13th to 14th century, the majority of which were stone coffins containing adult men and women. This chapel was still in use when the new Lady chapel became the main Dutton family mausoleum (Greene 1989; Brown and Howard-Davis 2008).

The Lady chapel was in use from the 13th to 16th century and included the burials of men, women and children. A large number of graves contained wooden coffins, although some stone coffins were also present (Greene 1989). These burials were arranged in three rows towards the west of the chapel, suggesting that some form of altar or shrine occupied the east end of the chapel (Brown and Howard-Davis 2008). The Lady chapel appears to reflect a growing concern throughout the 13th to 16th centuries of the need for the laity to be buried within important locations of Norton Priory, namely towards the east, where ecclesiastics were most likely buried.

Burials in the south transept chapel date to the 13th to 16th century, which included mostly stone coffins. This burial type is interesting, considering they are broadly contemporaneous to those from the Lady chapel, where wooden coffins predominated. This difference in burial type may suggest that either important ecclesiastics were buried in these stone coffins or that a different lay family were buried here (Brown and Howard-Davis 2008), thereby marking their difference to the Dutton family in their style of burial. However, with the exception of a sub-adult burial, all burials in the south transept are adult males, which may suggest this area was used as a resting place for ecclesiastics.

3.4.2.3 Burials in the East of the Church

Burials towards the east of the church included those in the crossing (choir), the chancel and the east chapel. In the crossing, only one burial was discovered, that of an adult male dated to the 15th century. This burial has been suggested to be of the first abbot at Norton, Richard Wyche (Brown and Howard-Davis 2008). Burials in the chancel and the chancel extension were of adult males and date to the 13th and 14th centuries. One adult male is thought to have been Canon William, a member of the Dutton family, who suffered from both Paget’s disease and DISH (see chapter 8). Two burials, dated to the 14th and 15th centuries, were associated with the east chapel, although one possibly predates the chapel construction and may have originated from the canons graveyard (Brown and Howard-Davis 2008). Both individuals were adult males, one of whom also suffered from DISH. It is possible that these males were ecclesiastics at Norton considering their burial location to the east end of the Priory. An area to the southeast of the east chapel is thought to be that of the canons graveyard, where several headstones were recovered, suggesting the graves of the canons was marked (Brown and Howard-Davis 2008). However, this area was not excavated and unfortunately any comparisons between known ecclesiastics from the canons cemetery, with suggested lay burials within the church cannot be made.

3.4.2.4 Burials in the Cloister and Chapterhouse

The majority of burials in the north cloister walk were adult males and dated to the 13th to 15th centuries. It has been suggested the male burials from this area were canons at Norton (Brown and Howard-Davis 2008), although the only burial suggested to have been within a wooden coffin (Greene 1989), was that of a probable female. This may suggest a high status individual who had considerable influence and had made appropriate donations to afford a burial within an area that was usually reserved for ecclesiastics. From the east cloister walk, two male and two female burials were recovered, which were within stone coffins and date to around the 13th to 14th century. These burials are suggested to represent high status lay individuals (Brown and Howard-Davis 2008), although whether they are associated with a particular family group, such as the Dutton's, cannot be determined.

From the chapterhouse (vestibule), an important cluster of burials was discovered, which included an adult male and three sub-adults, all buried around the same time in monolithic stone coffins. The adult burial was dated to the 14th century from a pottery shard, although this was possibly a displaced piece from later extension work, and the burial may even pre-date the fire of 1236. This is evidenced from extensive layers of burnt material around the area, with the nearby cloister having been severely affected (Greene 1989; Brown and Howard-Davis 2008). It has been suggested that the adult male buried in the chapterhouse (vestibule) was Richard of Chester (d.1211), who was a wealthy lay benefactor and became a canon at Norton shortly before his death. This may explain why this group was buried within an area that was usually only reserved for high status ecclesiastics. Evidence of infectious disease was discovered on this individual and evidence of nutritional stress on two of the sub-adults (see section 8.4.4).

Within the chapterhouse (proper), which is situated directly east to the chapterhouse (vestibule), only one burial was discovered, although extensive excavation was not undertaken. The burial was that of an adult male within a stone-slabbed coffin with a wooden base, dated to the 14th century (Brown and Howard-Davis 2008). Burial within the chapterhouse was usually reserved for senior ecclesiastics, which suggests this individual may have been one of the last priors at Norton before it received abbey status.

3.4.3 Faunal Remains at Norton Priory

The faunal data from Norton was originally recorded on punch cards, which were not transferred to modern computer software, hence this data is lost. However, Greene (1989: 51) provides a descriptive account of the faunal assemblage at Norton from two main chronological groups: ‘pre-dissolution’ (pre-16th century) and ‘post-dissolution’ (post-16th century). For the purpose of this study, only fauna from the pre-dissolution group is discussed here, to provide a background of the faunal assemblage that was broadly contemporaneous with the human burials at Norton.

The highest percentage of mammals from Norton were found from cattle bones (47%), followed by sheep/goat (31%), and pig (22%). Butchery marks were present on many cattle bones, suggesting slaughter took place on-site. Few extremity bones from cattle were recovered, although bones from the meat yielding parts (e.g. shoulder, hind leg, and rump) were well represented. The majority of cattle bones recovered were aged 4 years or over, which may suggest mature beef was consumed or that mature cattle were kept for dairying. However, it has been suggested that dairy farming was not a primary form of agriculture before the dissolution at Norton (Greene 1989).

There is no evidence for large-scale sheep farming at Norton before the 14th century and wool production was of minimal importance, as evidenced by records of wool exports from the county (Greene 1989). The majority of sheep/goat bones recovered was aged to around 2-3 years, with a lesser number of mature bones recovered. Sheep/goat tibiae and humeri were recovered, which suggests a preference for the consumption of legs of mutton and lamb (Greene 1989).

The majority of pig bones recovered from Norton were aged 1-2 years, with a high proportion of pig mandibles recovered. This may suggest that pigs were cooked whole and focused on young and suckling pigs. Pigs were reared on the demesne of Norton and were allowed to be kept on the land of Roger de Lacy (Baron of Halton, 1190-1211); thereby foregoing any charge that Norton would have had to pay to keep their pigs on royal land (Greene 1989). One important consideration is that pork may have been consumed in the form of bacon, as salt was in plentiful supply in medieval Cheshire. The percentage of pig bones recovered may therefore underrepresent the amount of pork consumed at Norton (Greene 1989).

From the pre-dissolution layers, only four fallow deer and eight red deer bones were recovered. As well as granting free pannage for Norton pigs, Roger de Lacy also granted two deer from his land every year indefinitely to the canons (Greene 1989).

The lack of deer bones suggests that venison was rarely eaten at Norton and may have been reserved for special feasts only.

Very few fish bones were recovered from Norton, which may be due to the lack of preservation or recovery bias as sieving methods were not employed. Greene (1989) reported that eleven fish bones were excavated from the pre-dissolution levels, the majority of them being cod. However, at the time of this study, only one cod bone from Norton remained, which was sampled for isotopic analysis (see chapters 7 and 8). Although the natural habitat for cod is within the marine environment, they can frequent estuarine systems, which suggest they would have been present in the River Mersey and easily available to the canons at Norton. Records of cod being cooked in St Werburgh's Abbey in nearby Chester attest to the availability of this species in medieval Cheshire (Greene 1989). Large quantities of oyster shells were also recovered at Norton, with fewer numbers of mussels and cockles. These shellfish would have been easily accessible to the canons from the nearby mud and sandbanks at the River Mersey and at the Runcorn Gap. One vertebra of a porpoise dated to the 13^{th} century was also recovered. Porpoise have been known to enter the River Mersey and were considered a special delicacy in the medieval period (Greene 1989). The canons at Norton may have therefore acquired such sea mammals for special occasions, hence the scarcity of bones being recovered.

Due to the dearth of fish bones from Norton, those acquired from Chester Cathedral for this study provide an important source of material for marine dietary reconstructions. The fish bones were recovered from medieval layers at the east range of the cathedral cloister, which was excavated in 2000 by the University of

Manchester Archaeological Unit, under the direction of Simon Ward (Chester Archaeology). The earliest phase of the site incorporated a Saxon church around the 9th century. A Benedictine abbey was then formed in 1093 and dissolved in 1540, with the reformation of a cathedral in 1541 (Ward 2000). This site is temporally and spatially comparable to Norton and can therefore provide the only option to corroborate evidence for the interpretation of fish consumption at medieval Norton.

3.4.4 Economic Activity at Norton Priory

There is little evidence for arable farming at Norton and most evidence comes from historical sources, namely, the 1536 record of the Augmentations Office by Thomas Combes. From this documentation, Greene (1989: 55) has estimated that 50% of land at Norton was being used for pasture, 16% for meadow and 34% for arable; although a further 14% from fallow (ley) land would form part of the arable cycle. Therefore arable farming may have been as important as pastoral farming at Norton (Greene 1989). However, there is little evidence of what was grown at Norton, with the 1536 records only mentioning thirteen acres of barley stubble. However, court records report a case of an unpaid bill to the abbot for the procurement of wheat, barley, peas and oats by William Starkey of Northwich, Cheshire (Driver 1971, in Greene 1989: 55). This suggests that surplus crops were being sold from the Priory, as well as being used on site for bread and ale. These two foodstuffs would have formed part of the staple diet at Norton and records attest to those who contributed to the production, such as William the joiner, who baked fortnightly, and his wife who was 'alewife to the abbot' (Heath 1973, in Greene 1989: 55). The bakehouse and brewhouse would have been situated in the outer courtyard; hence close to the kitchen and cellarers range (see Figure 3.6). The discovery of hand mills within and near the kitchen suggest some grain was hand ground at Norton, although the majority would have been processed in the Priory water mill or at nearby Windmill Hill (Greene 1989). The canons or lay workers would have tended the gardens that were situated to the south of the refectory, which provided both culinary and medicinal herbs, the latter of which was possibly used to treat patients in the infirmary (Greene 1989).

Wood would have been greatly utilised at Norton for various uses, such as fuel (along with turf), food and drink vessels, building material and coffins. Wood from water-logged deposits was found dating from the 13th to 16th century, with the types of wood utilised being alder, willow, oak and hazel (Greene 1989). Norton also owned a salthouse in Northwich (Cheshire), which would have been used for producing foods, such as salted fish and bacon. It is unknown if leather would have been processed, although there is evidence for hemp production from a Priory field known as Hemp Yards and from historical documentation that records a John Leftwich as a linen webster (Greene 1989).

The canons from Norton profited from gifts that were listed in the 1115 foundation charter, which included the whole of Runcorn, as well as mills, fisheries, churches, ploughland, rights to woodland and demesne tithes, all around northwest and eastern England (Greene 1989). It appears that the economy at Norton was partly based on a reciprocal arrangement with local businesses and landowners, with land and animals being offered from the Baron of Halton to the Priory, as part of the original charter, and no doubt to ensure religious favour in life and appropriate burial and prayers after his death. By 1847, tithe records state that the extent of Norton's surrounding lands amounted to 1,193 acres (Greene 1989). The 1536 Augmentations Office records valued Norton Priory and its lands at £42 16s 0d, with arable and pasture land that was let out for farming worth a further £3 12s 0d (Greene 1989: 33). The income from the surrounding lands of Norton would have principally come from farming (Brown and Howard-Davis 2008). However, keeping a Priory and later, a mitred abbey, stocked with food, drink and shelter for ecclesiastics, workers and visitors would have been costly. Aside from their farming income, such a drain on resources may have been offset with donations from benefactors and income from visitors and pilgrimages to the Priory. Pilgrims would have travelled to Norton to see the Norton Priory Cross that supposedly contained a fragment of the Holy cross of Christ, a relic brought back from the Crusades by Geoffrey de Dutton (K. Hurlock, *pers.comm*.). As one of the patron saints of Norton, the statue of St Christopher, dated to the 14^{th} century, would also have attracted many visitors (Greene 1989).

3.5 Chapter Conclusion

This chapter has provided background evidence of archaeological excavations at Portmahomack and Norton including the human burials, to illustrate location, period, burial rite and where possible, evidence for ecclesiastical or lay status. Key evidence of the faunal remains recovered was also presented, to provide an understanding of animal exploitation from both sites to facilitate subsequent interpretation, which is discussed in chapter 8. Historical evidence on Norton has provided important information, such as manufacture, the Priory's rise to abbey status, and individuals of high status that were buried at Norton. Archaeological evidence of economic activity from Portmahomack and Norton was also presented, to gain a broad understanding of tasks undertaken that related to manufacture, craft or subsistence. At Portmahomack, vellum making and mercury gilding during the monastic phase suggests a religious focus in some of their manufacturing activities, which shifted to more of a subsistence focus for the laity in the later periods. At Norton, activities centred on subsistence for the ecclesiastics and the Christian community associated with Norton, as well as the upkeep of its buildings and management of its lands. Religious activities are also evidenced from objects that would attract pilgrims to Norton, such as the Holy cross relic and the St Christopher statue.

A general background on socio-economic events that affected health and subsistence in medieval Britain was also presented in this chapter, to provide an insight into the impact that biological and climatic events had during this time. In Europe, such events included a number of cooling periods that affected crop growth, resulting in harvest failures and subsequent famines. Additionally, the spread throughout Europe of the Justinian plague in the 6th century and the Black Death in the 14th century resulted in catastrophic episodes of mortality. These events dramatically changed the socio-economic landscape in Britain and would have had a direct impact on people's lives, which is discussed further in the following chapter.

Chapter 4

LIFEWAYS IN MEDIEVAL BRITAIN

4.1 Introduction

‘Lifeways’ is a term relating to the way in which a person, group or community lived their lives. The use of this term is used in bioarchaeological research, for example to distinguish between groups such as hunter-gatherers and farmers (e.g. Larsen 1999) and when reconstructing aspects of health and disease from human skeletal material (e.g. Buikstra and Beck 2006). The ‘lifecourse’ however, “integrates ageing with embodiment, ritual, memory and material culture” (Gilchrist 2012: 1). This biocultural approach combines disciplines, such as historical and bioarchaeological evidence, to understand individual choices and various perceptions on the living body relating to age, disability or gender in the medieval period (Glencross 2011). In this study, ‘lifeways’ is used to describe multi-faceted aspects of life, such as diet, health, disease, trauma, occupation and belief. It can therefore be applied when reconstructing the life of one individual or of a whole society, to contribute to issues on status, socio-economic, religious and political interactions and the health and well-being of past peoples.

Aspects of medico-dietary culture have rarely been addressed in contemporary scholarship as a separate subject (Lewicka 2014). This chapter will therefore focus on the health and diet of people in medieval Britain, through bioarchaeological and historical sources, to gain a broader perspective on the physical and social impact on the body. Additionally, aspects of disease and trauma in medieval Britain will be discussed in this chapter, although the palaeopathological descriptions of such will be presented in chapter 6.

4.2 Health in Medieval Britain

Evidence for health in medieval Britain may be derived from a range of sources including archaeology, palaeopathology, iconography and literature. As in many other societies and time periods, medieval Britain comprised a number of different social strata and cultural norms. Therefore, health throughout the medieval period fluctuated depending on people's lifeways. For example, the late medieval period had certain aspects of deterioration in health compared to the early medieval period, exacerbated by socio-economic factors, such as population growth and increased urbanisation; epidemics, such as the Black Death, and starvation due to harvest failures (Dyer 1998; Roberts and Cox 2003). A comprehensive discussion of health in medieval Britain, a period which spans over a thousand years, is beyond the remit of this study. However, an understanding of this topic is necessary to gain a broader perspective of medieval lifeways and how they may contribute to contemporary issues on health and disease. The advantage of reconstructing lifeways from the medieval period is that sometimes, both archaeological and historical evidence can be utilised. Hence, by drawing on multiple sources of evidence: historical literature, archaeozoology, chemical and skeletal analysis, for example, a broader perspective is obtained.

The World Health Organisation (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO 2006). This definition, which came into force in 1948, has received increasing criticism recently, with scholars suggesting that it has limitations, hence proposing "the formulation of health as the ability to adapt and to self-manage" (Huber *et al*. 2011: 237). In this respect, the understanding of health in our society is important as ever and one vital way to understand this is to look at aspects of health in the past, one aspect which this study aims to contribute to.

4.2.1 Lifestyle Factors

Where and how we live may influence the types of diseases contracted, whether in polluted urban areas, cold coastal climates or rural environments. Additionally, lifestyle factors, such as the type of work and associated tasks, may result in the development of chronic diseases or risk of trauma (Roberts 2009).

Osteoarchaeological evidence of trauma in medieval Britain may be caused by weapon-related injuries or occupational accidents, although assigning a specific occupation from skeletal material without conclusive contextual evidence cannot be determined (Roberts and Cox 2003: 237). In early medieval Britain, bones most affected by fractures were found on upper long bones, with lower limb bones and skull fractures also commonly affected (Roberts and Cox 2003). The highest rate of fractures in late medieval Britain occurred on the ribs, closely followed by the ulna and radius. For example, at the medieval site of St Helen on-the-Walls in York, fractures rates were most prevalent on the lower arm bones and occurred more in males than females (Roberts and Cox 2003). Additionally, most fractures were well healed with lack of deformity, suggesting even those of low status received medical attention (Grauer and Roberts 1996). Exceptions include skeletal evidence from battlefield sites that show weapon-related injuries as the probable cause of death. Towton in Yorkshire is one such site where in 1461 the War of the Roses battle was fought, resulting in the death of around 28,000 men (Fiorato *et al.* 2007; Novak 2007). Of the 38 individuals recovered from the mass grave excavation, 29 had skeletal evidence of weapon-related trauma (Novak 2007). Weapon-related skeletal trauma however is not just confined to battlefields but from religious sites such as those found in this study (see chapters 7 and 8).

Fractures may be a consequence of disease as suggested from skeletal evidence from the leper hospital of St James and St Mary Magdalene in Chichester. Here, high fracture rates in the clavicles and forelimbs were suggested to be associated with poor and dimly lit living conditions combined with sensory nerve and vision impairment and subsequent loss of proprioception (unaware of movement due to sensory nerve damage) by the leper inhabitants, resulting in a greater susceptibility to fall on unseen or uneven surfaces (Judd and Roberts 1998).

Occupation types in medieval Britain depended on people's location, ability, social class and in some cases were gender-specific, although not always. For example, women would work in the field alongside men; in their husband's absence aristocratic women would run the family estate and townswomen would help with business affairs (Mate 2006). Before AD 800 in England, most families lived in small hamlets and performed agricultural duties of cultivating crops (e.g. sowing and threshing) and tending to livestock (e.g. lambing and slaughtering), often to provide for the lay or monastic land owners, unless the land belonged to a free farmer, who would be self-sufficient and able to utilise surplus stocks for consumption or sale (Fleming 2011). Mate (2006: 279) notes that "the life of rural inhabitants before the Black Death was one of almost constant toil". All family members would have had to contribute; for example, fathers would work the field with their sons, who would also tend the pigs. Mothers and daughters would be in charge of domestic chores, dairying, spinning wool, tending cows, ewes and poultry, as well as maintaining garden crops (Mate 2006). After twelve years of age, children would often go to work on private estates as servants or work in a town nearby (Mate 2006).

By the mid-late medieval period, peasant hierarchy became more varied and ranged from yardlanders (free land holders), *famuli* (manorial servants) or seasonal harvest workers, who were hired specially to harvest an estate and were often fed and treated better than the full-time *famuli* (Dyer 1988a, 1998). Farming duties were still a large part of rural peasant life (Figure 4.1) and monastic life (chapter 2) but occupations in towns were more varied; from butchers, tanners, builders, brewers, cloth-, glass-, leather- and metal-workers, furniture and candle makers to name a few (Roberts and Cox 2003). Many of these occupations, performed by men, women and children, were very arduous and may have subsequently resulted in joint diseases, trauma from work-related accidents, or respiratory problems due to inhaling pollutants (Roberts and Cox 2003). However, when examining degenerative joint disease (DJD) in medieval populations, some scholars have suggested that certain areas of the skeleton, namely the vertebral column, are not ideal to study markers of occupational stress (Knüsel *et al*. 1997). Joint diseases, such as osteoarthritis, have however been used to suggest a gendered-division in labour (e.g. Sofaer Derevenski 2000) and other joint diseases, such as diffuse idiopathic skeletal hyperostosis (DISH) have even been connected to a monastic lifestyle (e.g. Waldron 1985; Rogers and Waldron 2001).

Figure 4.1: Month-by-month scenes of medieval life and work. In: Book of Hours, Calendar (fols. 2r-7v), France, Rouen; *c*.1500.
© Bodleian Library, University of Oxford. **Source**:
http://www.bodley.ox.ac.uk/dept/scwmss/wmss/medieval/mss/buchanan/e/003.a.htm

Inhalation of wood or coal fuels due to poor housing ventilation or occupations such as blacksmithing or tanning in medieval Britain may have exacerbated respiratory problems and could cause sinusitis. An overall higher rate of sinusitis was found in urban late medieval sites, compared to rural early sites in England, which may be linked to an increased population and occupations more susceptible to air pollution in the late medieval period (Roberts 2009).

Lung infections also increased from the early to late medieval periods. Lesions on the visceral surface of ribs have been associated with pulmonary tuberculosis (TB), although this manifestation alone does not provide a conclusive diagnosis, whereas changes to the spine, known as Pott's disease, are more pathognomonic. The occurrence of the human form of TB (*Mycobacterium tuberculosis*) can be traced back to the Iron Age in England; although it is not until the post medieval periods that its prevalence increases dramatically, exacerbated by population growth and poor living and working conditions (Dyer 1989; Roberts 2011). Close proximity to animals, within the living and working environment, increased the risk of contracting zoonotic diseases such as bovine TB (*Mycobacterium bovis*), which affects the gastrointestinal tract through direct contact with cattle or through ingestion of cattle meat or dairy products (Waldron 2000). However, there is little bioarchaeological evidence that has identified human cases of *M bovis* in medieval Britain and further investigations are needed (Roberts 2011).

The plague, also known as the Black Death, was a catastrophic event that first occurred in England in 1348 and caused the death of over 40% of the population within a year (Dyer 1988a: 35). Death was swift and crossed all social strata, resulting in surviving workers acquiring higher wages and subsequently having a better quality diet (Dyer 1988a; Woolgar 2010). Further outbreaks occurred in 1361 and 1369 and although not as catastrophic as the 1348 outbreak, children and adolescents were more susceptible than adults, thereby hindering population recovery for nearly a hundred years (Horrox 1999). Because the Black Death cannot be visually identified on bone, its relevance to this study is limited. However, as one of the most catastrophic epidemics to humankind, its impact on the study of health and disease in medieval Britain is noteworthy. Recent bioarchaeological (e.g. DeWitte 2010) and DNA (e.g. Bos *et al*. 2011) research has contributed greatly to our understanding of the Black Death, in terms of susceptibility to the disease, the demographic impact and contributions to modern medicine to combat pathogenic bacteria.

It has been suggested that the visual deformities of leprosy and putrid smell of ulcerated flesh exacerbated the widespread sense of fear that medieval people had of lepers (Brody 1974; Rawcliffe 2006) and as an example of social control, the Church imposed a rule after 1186 that forbade lepers to marry (Wells 1967, in Roberts and Cox 2003: 269). Certain diseases had similar symptoms to leprosy, such as venereal syphilis (known historically as the great pox), which resulted in the misdiagnosis and treatment of some people as lepers (Rawcliffe 2006). Moreover, depending on an individual's status or circumstances, social attitudes to lepers varied, from being classed as sinful and social outcasts, to God's beloved children (Magilton 2008a); hence the overall description of the outcast and vilified leper is too simplistic. For example, the prestigious burial of a leper from 7th century Edix Hill, Cambridgeshire (Malim *et al.* 1998) and from 13th century Norton Priory (see chapter 8) attests to the care afforded to high status lepers after death. Treating a leper and praying for their soul enabled the carer (often nuns or monks) to have a physical and spiritual connection with the afflicted, subsequently giving them an elevated position in the eyes of God (Lester 2006). In England, between the late-11th to the mid-16th century, around 360 leper houses (*leprosaria*) were founded, although the majority of these were established before 1350. Scotland was similar to England in that around one fifth of hospitals were operating as *leprosaria* (Rawcliffe 2006). On a wider scale, around 19,000 leper houses are documented in medieval Europe (Roberts 1986), with osteoarchaeological research on skeletons from Naevstead, Demark (Møller-Christensen 1953) contributing greatly to what we now know about leprous changes on bone. Evidence of leprosy on human skeletons from the medieval period have been found from a number of archaeological sites around Britain, such as St James and St Mary Magdalene, Chichester (Lee and Magilton 1989), St Nicholas hospital, Fife, (Hall 1987) and more pertinent to this study, at Norton Priory (Roberts 2002). However, not all who suffered from leprosy would have had skeletal changes; hence there may be a greater prevalence than what is reflected in the archaeological record. Therefore, Roberts (2002) has suggested that around 2-3% of individuals may have been affected by leprosy from sites where the disease has been identified.

Skeletal manifestations of treponemal disease, such as venereal syphilis, are only seen in the tertiary stage, which may take two to ten years to develop, although variation can occur (Ortner 2003; Roberts and Cox 2003). Although only a few cases of syphilis have been found from medieval Britain (Roberts and Cox 2003), the study of this disease has received much attention in palaeopathological literature over the last twenty years, with cases from monastic sites being discovered, such as Hull Friary (Holst *et al.* 2001) and Whithorn Cathedral Priory (Cardy 1994, in Roberts and Cox 2003: 273).

Nutritional deficiencies are evident on skeletal remains from medieval Britain, although to a lesser extent from the early medieval periods. For example, a lower crude prevalence rate (CPR) of 7.6% for cribra orbitalia (which may be linked to anaemia) was reported from early medieval Britain compared to a CPR of 10.8% in the late medieval period. Although not a large increase, this may be associated with population growth, urbanisation and a subsequent lack of nutritious food resources within certain groups (Roberts and Cox 2003). However, whether such evidence was the result of people not ingesting enough nutritional foods, or because of a loss of vitamins due to prolonged storage or cooking, is more difficult to reconstruct. Nutritional foods, such as those rich in vitamin A (e.g. carrots, dark leafy greens such as kale, dairy), vitamin C (e.g. spinach, strawberries, oranges), vitamin D (e.g. fatty fish such as salmon, mushrooms, eggs), protein and iron (e.g. meat, fish, nuts) and calcium (e.g. dairy, nuts, kale) were certainly consumed by medieval people (Dyer 1989). However, religious, cultural and economic factors possibly influenced what was consumed, by whom and when or how frequently (see section 4.3). Vitamin C and D deficiencies can result in scurvy and rickets respectively, although there are few of these cases throughout the medieval period, which only occur sporadically throughout the archaeological record (Roberts and Cox 2003). Conversely, there is abundant evidence for dental diseases that reflect aspects of nutritional deficiencies and diet. Dental enamel hypoplasia (DEH), which occurs when there is a disturbance in enamel formation during childhood, has an increased occurrence in the late medieval period (Roberts 2009). This has been associated with various forms of nutritional stress due to illness, poor living conditions or during weaning from breastmilk; although the latter has now been discredited as a direct cause (Larsen 1999). Another probable cause for many of these nutritional deficiencies could be recurrent bad harvests in the 13th and 14th centuries, with the utmost catastrophe being the Great Famine of 1315-18. In total, these harvest failures, combined with consequently high foods prices, are estimated to be responsible for around one million deaths between 1290 and 1325 (Dyer 1998: 61).

4.2.2 Medicine and Surgery

Humoral theory was the dominant medical and dietary doctrine throughout the medieval period. It was established by Empedocles (*c*.500 – 430 BC) and originated from the four elements (and their associated temperaments) of air (coldness), fire (heat), earth (dryness) and water (wetness). Hippocrates (460 – *c*.377 BC) thereafter added the four humours of blood, yellow bile, black bile and phlegm (Adamson 2004; Ellis 2009). This was later developed into a complex medico-dietary system by the Greek physician Galen (AD 131– 201), who added the four qualities of taste: sweet (blood), bitter (yellow bile), sour/spicy (black bile), and salty (phlegm) to the system (Adamson 2004), along with its associated ages, seasons and complexions (Table 4.1).

Table 4.1: Humoral theories and associations
(Sources: Adamson 2004; Gilchrist 2012; Jotischky 2011; Lewicka 2014).

Humours	Elements	Seasons (Planets)	Ages	Temperaments	Complexions
Blood	Air	Spring (Moon, Mercury)	Childhood	Hot/Wet	Sanguine
Yellow bile	Fire	Summer (Venus)	Youth	Hot/Dry	Choleric
Black bile	Earth	Autumn (Sun, Mars)	Adulthood	Cold/Dry	Melancholic
Phlegm	Water	Winter (Jupiter, Saturn)	Old age	Cold/Wet	Phlegmatic

Humoral theory was also adopted throughout the Islamic world, producing health manuals such as the 11th century *Tacinium Sanitatis*, which incorporated the belief of humoral values on diet and health. Such Greco-Arabic works were translated into Latin and thereafter used throughout the western world (Jotischky 2011; Lewicka 2014). Humoral theory was promulgated on the basis that a person retained a healthy disposition when the bodily humours were in balance but an excess or deficit of these humours would result in sickness or disease, caused by inhalation or absorption into the body (Jotischky 2011). ‘Allopathic contraries’ were used to treat this imbalance, in other words, using opposites to counteract, such as using cold remedies to treat “hot diseases” (Lewicka 2014: 609), for example, a cold compress for a fever. Dietetic theories were also ingrained into humoral pathology; lamb (a phlegmatic meat), for example, was to be avoided by those with an excess of phlegm and beef (a cold meat) was to be avoided by those with an excess of black bile, whereas chicken was a humorally safe meat to eat (Hammond 2005; Freedman 2007). Medicine and diet were therefore inextricably linked in the medieval period, summed up eloquently by Hippocrates' famous quote: "*Let food be thy medicine and medicine be thy food*" (Lucock 2004: 214).

Diagnosing an illness due to humoral imbalance was usually obtained through the practice of examining the odour and colour of urine, known as uroscopy (Rawcliffe 2006). Intertwined with such diagnoses were cosmological and seasonal considerations (Figures 4.2 and 4.3), such as the time of the year, the position of the planets and even when an individual was born (Gilchrist 2012). Certain foods were used for their preventative and curative properties (see section 4.3), although the most popular treatment for humoral imbalance in the medieval period was bloodletting. The practice of phlebotomy was used to treat humoral imbalances and a range of conditions, through various bloodletting techniques, such as cupping, leeching or incision. Again, this was linked to cosmological events, with charts being consulted for when to bleed based on the phasing of the moon, which was practiced in 7th century England (Cameron 1993). The risk of infection from bloodletting was high and the earliest reference to this is found in the 9th century medical manuscript, Bald's *Leechbook*, which recommends applying poultices or horse dung to combat infection or haemorrhaging (Cockayne 1864-6, in Cameron 1993: 161*f*.). Bloodletting was also used prophylactically on a periodic basis, around once every season to maintain humoral balance (Green 2010).

Figure 4.2: Uroscopy and ring of flasks. In *Epiphaniae medicorum* by Ulrich, Pinder, 1506. *Slide number 9004, Wellcome Images London, Ref: EPB 866.*

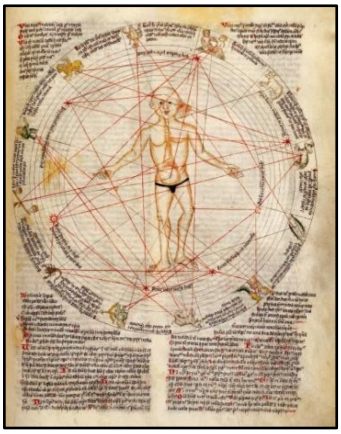


Figure 4.3: Bloodletting man encircled by the influence of the zodiac and planets, *c.1420-30. Folio 41 recto, Wellcome Images, London, Ref: WMS 49.*

Sources: http://wellcomeimages.org/indexplus/page/Home.html.

Monastic brethren would often take a bloodletting 'holiday', allowing them to temporarily become patients of the infirmary, which enabled benefits, such as rest from arduous tasks, and permission to eat meat on fast days in accordance with St Benedict's Rule. Some monastic houses, such as Redbourn Priory in Hertfordshire, which was founded in the late-12th century, were used specifically for this purpose (Heale 2004). Despite the risk of fainting, infection, haemorrhaging and scarring, the practice of bloodletting continued into the late-19th century (Cameron 1993). Only with physicians, such as Rudolph Virchow (1821–1902) who made revolutionary breakthroughs in the understanding of disease pathophysiology (Tan and Brown 2006), was bloodletting finally abandoned.

It was not the primary objective for medieval hospitals to care for the sick, they also provided for the elderly, poor, infirm and travellers. Early medieval hospitals were mainly within religious houses or at royal centres, although not exclusively (Rawcliffe 2011). Hospitals thereafter grew out of monastic infirmaries, many of which followed the Rule of St Benedict and the associated 10th century *Regularis Concordia* that required religious houses to provide care for their community and poor strangers (Roberts and Cox 2003). By the 12th century, the Rule of St Augustine gained favour in larger hospitals, such as St James's, Westminster and St Leonard's, York, and caring for the sick was one of the roles the Augustinian canons undertook as part of their religious duty (Burton 1994; Rawcliffe 2002). Hospitals took the form of places for the long-term infirm, *leprosaria* or alms-houses. In some cities, all types could be found, as in Bristol, which had seven hospitals (two of which were *leprosaria*) and eleven alms-houses (Price and Ponsford 1998). With the Dissolution of the Monasteries between 1536 and 1540, many hospitals associated with religious houses were decommissioned. This led to petitions such as one to King Henry VIII in 1538, which appealed for the refoundation of hospitals to combat '*the miserable people lyeing in the streete, offending every clene person passing by the way*.' (Arnold 2008: 40). Some hospitals were refounded although a shift from a religious focus to a civic one emerged; Bethlem (Bedlam) hospital in London, for example, passed from religious control to the Corporation of London in 1547 (Andrews *et al.* 1997).

Apart from bloodletting, surgery throughout the medieval period was mostly in an external capacity, such as setting broken bones and dislocations, extracting teeth, dressing wounds and lancing haemorrhoids. In medical emergencies, more invasive types of surgery were required, such as amputations (Figure 4.4), which were a common choice of action if gangrene set into a fracture or wound (Porter 1987). Osteoarchaeological examples of amputations have been found dating to the early medieval period at Tean Island in the Scilly Isles (Brothwell and Møller-Christensen

1963, in Roberts and Cox 2003: 216) and from the mid-late medieval period at Blackfriars Friary, Ipswich (Mays 1996). However, a high percentage of cases may go unreported if the individual died during surgery and the bone ends are unhealed (Roberts and Cox 2003). Until the advent of anaesthesia in the 18th century, pain relief was mostly in the form of alcohol, opium, a mixture of the two (laudanum), or mandrake, all of which have narcotic properties (Ellis 2009).

Figure 4.4: 16th century amputation,
Folio 79 recto, Wellcome Images London, Ref 2760.
Source: http://wellcomeimages.org/indexplus/page/Home.html.

Trepanation is one of the oldest surgical procedures, with specimens found dating back to the Mesolithic period (Lille 1998). The procedure involved a portion of the skull being removed either by drilling, scraping or cutting a hole into the bone, whilst avoiding damage to the meninges, blood vessels and brain (Aufderheide and Rodríquez-Martín 1998). Although this procedure would often require a skilled surgeon, it appears that even the poorest classes of medieval society in England had access to this treatment (Mays 2006a). A study by Roberts and McKinley (2003) on trepanation cases from Neolithic to post-medieval sites in Britain found the highest percentage in the 5th to 11th century periods with 24 cases, although this figure was reduced to just 7 cases in the 12th to 16th century periods. The authors also noted that no cases were found in Wales or northwest England (Roberts and McKinley 2003: 61). However, evidence of trepanation has been found at Norton Priory, with three possible specimens identified (B, Connolly, *pers.comm*.), attesting to this procedure being performed in northwest England during the medieval period.

Medical procedures relating to obstetrics and gynaecology were still very much in their infancy in the medieval period, with teachings by the founder of obstetrics, the Greek surgeon Soranus (AD 90-138), still being adhered to. For example, Soranus introduced the birth stool, designed for supporting the back during childbirth and advised expectant mothers to ensure the bladder was emptied before the birth (Ellis 2009). In medieval Christian Britain, the role of delivering the baby was mostly performed by women; the Church being largely indifferent to the lowly status and medical needs of females. Invasive surgery during childbirth, in the form of Caesarean sections, was a last resort and often only performed to save a child after the mother had died. Conversely, it was the mothers' safety that was of primary concern and she would be saved instead of the child if both lives were in danger (Roberts and Cox 2003). A full- or near full-term foetus found within the pelvic cavity of a female skeleton suggests evidence of an obstetric death. Osteological evidence for obstetric deaths has been found from a number of early to late medieval sites in Britain (Roberts and Cox 2003), including one probable case from Norton Priory (Boylston 2008) and from Portmahomack (King 2000).

The use of medicinal herbs was popular throughout the medieval period, with a range of uses for illnesses and pain relief, as well as for their culinary uses (sees section 4.3). Evidence of monastic herb gardens has been found at Westminster Abbey (Jotischky 2011) and possibly at Norton Priory (Greene 1989). Around the early-13th century, Pope Innocent III declared that no ecclesiastic should shed blood or practise medicine for his own gain, which led to some renouncing their vows to practice as laymen (David and Beardshaw 2004). This may suggest that surgical procedures in religious hospitals thereafter were performed by lay brethren, whereas ecclesiastics focused on preventative and palliative care using medicinal herbs. However, to what extent Pope Innocent's rule was obeyed cannot be determined.

Dental surgery in medieval Britain was also in its infancy compared to its contemporaries in Europe. The belief that tooth worms caused dental caries was as prevalent in the medieval period as it was in Greek medical theory. General oral hygiene was lacking although toothpicks were used in an attempt to keep teeth relatively clean (Ring 1985). Dental treatments were largely non-invasive and influenced by humoral theory, with herbal remedies, charms and even pilgrimages and prayer used to cure tooth worms and toothache. Historical evidence from the medieval period documents treatments for the removal of calculus, filling cavities, fitting dentures, as well as procedures to treat oral cancer and mandibular fractures (Anderson 2004). The medical treatise '*Chirurgia Magna*', for example, was written in Latin by Guy de Chauliac in 1363 and translated into Middle English in the late-15th century. In this treatise, many of these treatments were documented as well as recommendations on what instruments to use and forms of pain relief, for example when opium or other herbal remedies fail, the area must be cauterised with hot oil or a hot iron or tooth extraction (Ogden 1971, in Anderson 2004: 423).

By the late medieval period there were a number of different medical practitioners, from physicians, surgeons (and barber surgeons), apothecaries, midwives and nurses, not to mention monk-physicians practising within their own religious communities. Even blacksmiths and farriers would perform tooth extractions and reset broken bones. By 1600 in London, there were around 100 surgeons, 50 physicians, 100 apothecaries and 250 'irregulars' treating the sick and infirm, although the type of practitioner sought would vary greatly depending on a person's position in society (Porter 1987).

Although poor living conditions may have contributed to certain diseases in medieval Britain, immunity overall was stronger than today due to low levels of hygiene. Bathing and washing clothes were a rare activity, resulting in pathogen hosts, such as fleas to live on the body (Roberts and Cox 2003: 256). The difficulty in reconstructing past health from skeletal material is that many diseases do not manifest on the bone. Tuberculoid leprosy, for example, often leaves little visible trace on bone, yet soft tissue damage and overall health is affected (Roberts 2011). An inactive (healed) lesion on bone suggests an individual survived the associated disease, hence having greater immunological strength than somebody who did not and had active (unhealed) lesions on the bone. In other words, evidence of certain pathological lesions on bone does not automatically suggest the individual was unhealthy, but strong enough to survive the disease. This "osteological paradox"

(Wood *et al.* 1992) is of major concern to bioarchaeologists when reconstructing aspect of health and disease in past populations.

Overall, the health of medieval inhabitants in Britain may have been associated with their social status, in terms of their living conditions and susceptibility to disease, along with their economic status, where dangerous occupational hazards resulted in higher rates of trauma. Political consequences were also a factor, where weapon-related trauma on bone was the result of conflict and violence, whether due to attacks on individuals, as at Norton Priory; unforeseen attacks on the community, as at Portmahomack (see chapter 8), or large-scale battles, as at Towton in Yorkshire (Fiorato *et al.* 2007). Medical care was available but the level of care very much depended on what could be afforded or whether one was deemed worthy of Christian care, such as the old, infirm or lepers. As aforementioned, medico-dietary theories were very much at the forefront of medieval healthcare and for many, food was not simply used for culinary purposes but also had preventative and medicinal uses. However, not everyone had the luxury of choosing their diet, hence simply consumed what was available or could be afforded.

4.2.3 Disability and Impairment

Metzler (2011: 45) suggested a clear distinction between impairment and disability; the former being a "biological, physical condition that affects a person's body" and the latter being a "social construct". There is evidence of impairment in the bioarchaeological record, such as amputations (e.g. Mays 1996) or club foot (e.g. Roberts *et al.* 2004), but this evidence alone does not prove an individual was disabled; an amputee may use a crutch for example. It is therefore difficult to reconstruct disability from the archaeological record alone (Dettwyler 1991) and indeed it was not until the 16th century that the word "disabled" was used (Online Etymology Dictionary - disability). Furthermore, how an impaired person was perceived by their community is even more difficult to reconstruct (Knüsel 1999) as it is dependent on a number of factors such as the status and disability of the individual and the beliefs and type of care given (Roberts 2000). Due to associated symptoms or visible manifestations, chronic diseases may overlap with impairment (Metzler 2011), although perceptions of those with syphilis or leprosy, for example, varied. In medieval Scotland, syphilis was referred to as the 'grandgore' (large sore) and its rapid spread led to the '*Ane Grandgore Act'* of AD 1497 (Morton 1962). Under this Act, incurables were ordered to be taken from Leith by boat to the island of Inchkeith, off the Firth of Forth, until such time as they may be cured by God (Jillings 2010). Compassion in this case appears to be lacking yet in the burial record, some individuals with incurable diseases were afforded prestigious burials suggesting some form of care, duty or compassion (e.g. Lee 2008). However, it is prudent to note that in the archaeological record alone 'compassion, cruelty and indifference leave few traces' (Dettwyler 1991: 382). Disability in archaeology has received much attention recently (e.g. Finlay 1999; Hubert 2000), although it is still in its infancy and requires further investigation (Metzler 2011).

4.3 Diets in Medieval Britain

Reconstructing diets from the medieval period is complex, as the types of foods consumed depended on factors such as regional differences, seasonality, social class and religious influences (Dyer 1989; Spencer 2000; Barrett and Richards 2004). Historical sources on medieval food come in the form of manorial and monastic accounts of food acquisitions (e.g. Harvey 1993; Dyer 1989), animal rearing (e.g. Hamerow 2002), penitentials on food and fasting (e.g. Brown 2003) and even literary accounts of medieval society, as in *The Canterbury Tales*, by Geoffrey Chaucer (Wright 2011). Many written sources focus mainly on wealthy or ecclesiastical households and may not reflect the diets of the lower classes or isolated communities (Pearson 1997), or indeed what was consumed and by whom. However, historical evidence such as medieval paintings may elucidate certain aspects of peasant diets (Figure 4.5). Archaeological evidence, such as cookware, flora, fauna and human skeletal remains can overcome this bias and help to reconstruct the types of foods consumed by those from all social strata. Archaeological remains of flora and fauna are best recovered through sieving methods although this is not always done on some sites. Certain areas may yield better recovery such as kitchens, cesspits or drains, although the lack of preservation, of some small animal bones for example, can result in recovery bias (Serjeantson and Woolgar 2006). The size and morphology of pottery can indicate its function, such as cooking, storage or serving (Woolgar 2010). Additionally, lipid residue analysis on pottery can be used to reconstructs its contents. At the 7th to 9th century Anglo-Saxon site of Hamwic (Southampton), lipid residue analysis on twenty-four potsherds revealed evidence of animal fats, leafy vegetables, aquatic foods and even beeswax, suggesting stewing pots or a reuse of some of the vessels (Baeten *et al*. 2012).

Figure 4.5: Peasants breaking bread. In 14th century '*Livre du roi Modus et de la reine Ratio*.' Paris, Bibliothèque Nationale, Département des manuscrits, Français 22545 fol. 72.
Source: http://www.bnf.fr/fr/acc/x.accueil.html

By using stable carbon and nitrogen isotopes, individual or group diets can be reconstructed, thereby providing a greater insight into the diets of the peasantry and the ecclesiastics. 'Peasantry' and 'ecclesiastics' are broad categories to describe a complex social system in medieval Britain. For example, successful farmers or tradesmen, as well as labourers and servants, were all classed as peasantry, and many ecclesiastics often emulated and lived like the aristocracy, especially in terms of their diet. However, in an attempt to contextualise dietary differences in medieval Britain, and pertinent to this study, the following sections will mainly focus on lay peasants and ecclesiastics, using historical and archaeological evidence where available.

4.3.1 Diets of the Peasantry

The earliest forms of written evidence on food, and rules on fasting, in early medieval England are from Latin penitentials, that were brought to England by Irish Christian missionaries around 669, and from Irish legal tracts and Anglo-Saxon law codes (Frantzen 2014). Vernacular penitentials also mention fasting, or fæsten, as it was known in the early medieval *Scriftboc* (*SB*) and *Old English Penitential* (*OEP*), as forms of penance or seasonal Christian fasts (Frantzen 2014). To what extent peasants obeyed fasting rules is unclear although early Anglo-Saxon law codes such as 'Wihtred's laws' (AD 695) which include a clause that punishes a homeowner who gave those within his house, including slaves, meat on fast days. A fine is also recorded under Wihtred's laws to a slave who of their own choice, ate meat during a period of fasting, which suggests a certain element of free will in Anglo-Saxon slaves (Frantzen 2014: 207). Unfortunately, there are no direct historical sources relating to the diet of people in early medieval Scotland although Irish penitentials would have had influence. Some clues are available from ecclesiastical writers such as Adomnán, who emphasised the importance of cattle by describing St Columba's ability to increase people's fortunes by causing their cattle to multiply (Foster 2004). Peasant Christian fasting foods in Anglo-Saxon England appear to have consisted of bread, water and some greens; although documentary sources for the peasantry overall are sparse (Frantzen 2014), hence foods on fast days could have varied greatly throughout the lay social strata. Fagan (2006) states that fish only became a common culinary dish after the 8th century, firstly in wealthy households and more frequently thereafter with the peasantry. Eels were especially common across all social strata and were often used as a form of currency. In his *Historia Ecclesiastica*, Bede documented that bishop Wilfrid of Colchester "found so much misery from hunger, he taught the people to get food by fishing and caught only eels" (Fagan 2006: 34).

The consumption of fish in the medieval period can be difficult to quantify and depends on a number of factors such as origin and access, cost and archaeological preservation. People who lived near coasts or rivers may have had better access to fish resources than inland inhabitants, giving them an advantage of a higher protein diet if they were able to access such resources. Stable isotope analysis suggests that fish consumption in the medieval period increased due to a combination of population growth, increased fishing trades and a widespread adherence to Christian fasting practices (Barrett and Richards 2004). The practice of preserving fish by smoking, salting and pickling grew in the 13th century, enabling the poor to store fish for much longer and access an important source of protein from preserved fish, such as cod or herring, throughout the winter months when other resources were low (Spencer 2000). Where fish could not be substituted for meat on fast days, cheese was included in the diet thereby sustaining a protein source. However, in some Old English texts, such as the 10th century *Capitula* of Theodulf, those [mainly ecclesiastics] who wanted to fast intensely could forego cheese, eggs and fish (Frantzen 2014), although this appears to be an individual choice rather than a compulsory rule. In medieval Britain, fasting was observed up to 3 days a week and around Christian holidays, such as Advent and Lent, totalling around 150 fast days per year (Grant 1988; Fagan 2006). The consumption of fish increased to such a level in the late medieval period that it is mentioned in lay textual evidence. One 15th century schoolboy wrote in his book "*Thou wyll not beleve how wery I am off fysshe, and how moch I desir that flesch were cum ageyn. For I have ete none other but salt fysh this Lent*" (Nelson 1956: 8, in Fagan 2006: 149).

It is not until the 13th century that historical records begin to record the contribution of animal by-products, such as milk, cheese and butter, to the diets of medieval lay people (Woolgar 2006). Many peasant workers were fed well for their labours, no doubt to keep them healthy and strong enough to work. The types of food consumed changed over time however; at Sedgeford in Norfolk, for example, it is recorded that in 1256 harvest workers were fed meat (4%), fish (13%), and dairy (28%), whereas in 1424 food portions changed to 28%, 6% and 9% respectively, showing a reversal of dairy and meat consumption (Dyer 1988a: 25). Before the spread of the Black Death in Britain around 1348-1350 (Benedictow 2004), most peasants relied on cereals foods, the most common being barley bread and pottage. The contents of pottage, a stew with base ingredients of cereals (e.g. oats and pulses) and vegetables (e.g. leeks, onions and cabbage) varied depending on a family's income and the resources available: from cereal grains with green leaves and herbs for the lower classes, to inclusions of animal meat (or fat and bones) or fish for the more fortunate (Spencer 2000; Jotischky 2011). It seems however that even the poorest peasants could still acquire enough ingredients to eat, as attested in 'The Clerk's Tale' in Chaucer's, *The Canterbury Tales*, where humble Giselda supposedly survived on pottages made from the edible greens she gathered from the wayside (Wright 2011: 215). Access to gardens was written into the contracts of maintenance agreements for the peasantry, which suggests they benefited mostly from the consumption and nutritional value of fruit and vegetables. By the 15th century in Britain, peasant diets changed: wheat, ale, fish and meat consumption increased, providing a range of vitamins that were previously deficient in the diet of many people (Dyer 1989).

Farming and subsistence strategies varied greatly throughout the medieval period and evidence of the types of food consumed may be difficult to identify in the archaeological record. Certain fruits and vegetables, for example, are invisible although the presence of grains from barley, wheat and oats suggests successful preservation in both Britain and Ireland (Mytum 1992; Hamerow 2002). These grains were popular in the medieval period for baking bread, for animal fodder and for making ale. Although ale was a popular drink in medieval Britain, water was often drunk too, mostly by the lowest classes of peasantry (Adamson 2004), but also in addition to ale for harvest workers (Dyer 1988a) and as described in the OEP as penance to ecclesiastics and layfolk during fasting (Frantzen 2014). It has often been suggested that water was unsafe to drink during the medieval period, especially polluted water from swamps, snow and rivers (e.g. Magnusson 2001). However, it is now generally accepted that water consumption was not dangerous in medieval Britain and water was readily available and used in many villages (Singman 1999) as well as in large towns, such as London, where wells and nearby springs were utilised (Keene 2001).

In Anglo-Saxon England, wheat was preferred over barley for making bread (Hamerow 2002), although poorer peasants had to make do with cheaper types, such as barley, rye and oat breads (Adamson 2004). Associated tools for cereal production, such as hand querns, have been discovered, at Portmahomack for example, which were later discarded for the more sophisticated method of the watermill, suggesting a shift to large-scale cereal production on the site during the early medieval period (Carver 2008). Windmills were introduced in Britain around the 11th century, which subsequently increased the efficiency of cereal production and contributed to population growth (Jotischky 2011). The increased production and consumption of grains such as wheat and barley resulted in social control over its processing and distribution, with many private and monastic estates employing harvest workers, millers, bakers and merchants and building watermills to accommodate such production. For example, religious estates such as Byland Abbey in Yorkshire, St Mary's Abbey in Winchester and Norton Priory all had watermills for grain production (Greene 2005).

Faunal evidence at medieval sites in Britain reflects a predominance of cattle bones, with sheep and pig bones often following in prevalence. The presence of cut marks on animal bones and the distribution of certain body parts may suggest evidence of past butchery practices, although taphonomic processes such as gnawing, or displacement of body parts due to burrowing animals, may mask such evidence (O'Connor 2000). Evidence of faunal age-at-death may also elucidate the usage of an animal (Spencer 2000; Hamerow 2002). For example, the optimum age for slaughter of all animals for meat would be near maturation (2.5 to 3.5 years); the presence of older female cattle bones may suggest dairying and evidence of lower limb pathology may suggest cattle used for traction (Holmes 2014). Other usages include cattle for breeding and hides; sheep for wool, skins, dairying and pigs for eating waste and foraging. Suckling pig was often regarded as a delicacy in medieval Britain, hence out of reach of the peasantry, although when possible, they could acquire pieces of beef, pork or mutton meat or alternatively, consume eggs, curd or cheese in the absence of meat (Spencer 2000). The types of foods consumed by servants who worked in noble households varied depending on their position and were in some respects healthier than free peasants. In 1363, the *Act on the Diet and Apparel of Servants* stated that servants' food consisted of "meat or fish once a day, the remains of other foods, milk, cheese, and 'other provisions' according to the employee's rank". The 'other provisions' may have referred to bread and ale (Hammond 2005: 57).

Many stable isotope studies relating to medieval diets come from English monastic sites (see section 4.3.2), although a small number of studies have presented evidence on the diets of lay individuals. For example, isotope results from adult skeletons of peasant status at the medieval site of Wharram Percy in Yorkshire revealed a relatively homogeneous terrestrial-based diet with little contribution from marine resources suggesting access to fish was minimal (Mays 1997; Richards *et al*. 2002). Conversely, stable isotope results from the inland battle site of Towton in Yorkshire, revealed that despite coming from various social backgrounds, the male soldiers had a mixed diet of meat and fish (Müldner and Richards 2005), suggesting they benefitted from foods such as imported fish, that we not necessarily available to the peasantry on a regular basis.

Sugar consumption, along with other spices, was largely confined to upper class diets (Spencer 2000). By 1264 for example, the household of Henry III procured sugar at around two shillings per pound; today's equivalent of £50 per pound (Sugar Nutrition UK 2011). By the late 14th century, sugar consumption had become more widespread with the aristocracy, although it was still too costly for many peasant households (Woolgar 1999; Newhauser 2013). Alongside sugar, honey was a regular foodstuff in upper class households and was mainly used as a food sweetener, as the main ingredient for mead, for making candles and also used in medicine. Most beehives were restricted to private lands in manorial and monastic estates (Woolgar 1999; Stavely and Fitzgerald 2004; Dyer 2006), although peasants may have used honey as a sweetener if they had access to either beehives or honey from wild bees (Rigby 2003). Attesting to the importance of honey in the medieval period, law tracts on bees and bee-keeping were written; the *Bechbretha* ('bee judgements') for example, was an Irish tract, which had regulations such as swarms and their maintenance (Ó Cróinín 2013: 106).

Aside from catastrophic events such as starvation, due to harvest failures, and disease epidemics (Dyer 1998; Roberts and Cox 2003), medieval peasant diets were generally healthy. Peasants consumed a range of fresh fruit and vegetables; cereals, dairy and when possible, fish and meat, thereby incorporating a range of dietary essential components such as vitamins A, B, C, D, E and K; carbohydrates, proteins, iron and calcium. Those who worked outdoors would also benefit from boosted levels of vitamin D by exposure to the sun, which accounts for 90% of vitamin D in the body (Holick 2004). Osteological evidence of nutritional stresses, such as rickets (vitamin D deficiency) or scurvy (vitamin C deficiency) are present on medieval skeletons (Roberts and Cox 2003), although whether solely due to a dietary deficiency or other environmental factors, such as lack of exposure to sunlight on the skin, cannot be determined from the skeletal evidence alone. Another consideration regarding overall medico-dietetic status is that an increase in nutritious foods, such as fish, in the later medieval period may be offset by increased urbanisation and poor living conditions, thereby sufficient in one or more vitamins but deficient in others that may have led to a number of health debilitating conditions.

4.3.2 Diets of Ecclesiastics

It has been suggested that the quantity and quality of historical sources from religious (monastic or secular) estates is one of the main advantages when studying the diets of these communities (Bond 1988). Conversely, Harvey (1993) stated that historical sources are reticent and of no use to dietary studies. Religious estates, especially elite ecclesiastical centres such as priories and abbeys, kept records on the acquisition and inventory of foodstuffs (e.g. Threlfall-Holmes 2005). However, they would not have necessarily recorded exactly what foods would have been consumed or by whom.

An example of the wealth of historical evidence comes from the two large ecclesiastical centres of Durham Cathedral Priory (1460-1520) and Westminster Abbey (*c.*1495-*c.*1525). At Durham, barley was the main grain purchased, which was malted for ale. To a lesser degree, wheat was used for making bread and was consumed in greater quantities during Lent and around Christmas. Oats had a number of uses: for making ale, for animal fodder and for human consumption (Threlfall-Holmes 2005). Meat appears to be an important purchase at the Priory, consisting of cattle, sheep, pig, and poultry, with fish species being predominantly of the cod and herring family (Threlfall-Holmes 2005).

At Westminster Abbey, bread was an important part of the daily diet, with a pound loaf supplied to the monks each day (Harvey 1993). The importance of bread in Christianity stems from the Bible, for example during the last supper, where "Jesus took bread, and blessed it, and gave it to the disciples, and said, Take, eat; this is my body" (Matthew 26: 26-28, in Adamson 2004: 183). Mutton was the most common type of meat consumed at Westminster, accounting for 46%, with beef consumption at 24% (Harvey 1993). This pattern is reversed at Durham with 65% of beef and 18% of mutton consumed, which may reflect a difference in farming strategies between the two regions (Threlfall-Holmes 2005).

There is a lack of historical sources on monastic diets in early medieval Scotland, although Adomnán, in his *Life of Columba*, mentions both arable and pastoral farming being practised by the monks at Iona (Graham-Campbell and Batey 1998). Adomnán also writes about two days of fasting each week being part of the monastic regime (Sharpe 1995). However, in the Rule of St. Columba, there is no mention of proscribing meat and food is only mentioned twice: '*Take not of food till thou art hungry*', and '*Every increase which comes to thee in lawful meals…give it for pity to the brethren or to the poor…*' (Menzies 2009: 79).

Aquatic resources were an important inclusion in the ecclesiastical diet, especially freshwater fish at inland settlements, where marine resources were scarce or too expensive for some households. Many later medieval religious estates had their own fishponds, which had strict fishery rights (Bond 1988), and freshwater fish would be a regular inclusion on the tables of the clergy at religious houses such as Durham and Westminster, especially during fasting periods (Threlfall-Holmes 2005). Emulating the aristocracy, abbots and bishops would lavish their important guests with luxury foodstuffs such as game, spices and sweet wines, along with highly prized freshwater fish, such as lamprey. Physicians however warned their patients of the dangers of humoral imbalance from eating cold and moist fish such as lamprey (Woolgar 1999; Freedman 2007), although to what extent their recommendations were adhered is unknown.

As well as climate changes and an increase in population, Fagan (2006: 57) states after the 10th century, "Catholic dietary practices created an insistent demand for fish that turned a subsistence practice into an international industry". However, Frantzen

(2014) suggests that there is no historical textual evidence to suggest that fish was automatically used as a substitute food when meat was proscribed on fast days. Despite this lack of textual evidence, it appears that fish became a popular substitute for meat in the mid-late medieval period in Britain, both with the lay and ecclesiastical communities, although whether through increased demand due to population pressures or as a substitute by choice is unknown. At Westminster Abbey around 1500, meat (17% of the daily diet) was completely replaced by fish (18% of the daily diet) during Lent (Harvey 1993).

Some Ecclesiastics appeared to have found a range of loopholes to avoid the St Benedictine Rule of no meat on fast days. For example, St. Thomas Aquinas stipulated that chickens were aquatic in origin, hence could be eaten (Spencer 2000). Additionally, rabbit embryos were eaten, as well as animal offal and entrails, which were not classed as meat (Harvey 1993; Spencer 2000). Because the Rule only stipulated what food could be eaten in the 'refectory', clergy could in theory eat anything elsewhere within the monastery, hence the emergence of the 'misericord' room where meat, for example, could be consumed. Officially, only the sick in the infirmary could consume meat on fast days to maintain their strength, although as aforementioned, some monks would regularly take a bloodletting holiday and become patients of the infirmary, hence consume meat on fast days (Jotischky 2011; Myers 1995). However, this may not have been the general pattern overall as some monastic orders, such as the Cistercians, practised strict asceticism, with meals consisting of little more than just bread and water on some days (Harvey 2006).

Fresh salad foods, such as parsley, leeks, sage, onions, garlic, watercress and fennel were mentioned in the 14th century English recipe book '*Forme of Cury*' before they were widely known in medieval Europe (Adamson 2004: 98). However, by the early 16th century, raw vegetables were believed by the aristocracy to be disease-ridden, fuelled by texts such as *The Book of Keruynge*, which in 1508 warned its readers to "beware of green sallettes". Some vegetables however, such as cabbage, garlic, leeks and onions were considered safe to eat providing they were cooked properly (Spencer 2000).

Faunal evidence elucidates further the importance of fish consumption at medieval religious houses. At Eynsham Abbey in Oxfordshire for example, large quantities of herring bones were found, minus head bones, suggesting these were preserved fish imported to this inland site. At St Gregory's Priory in Canterbury, fish bones exceeded bird bones by up to nine times (Jotischky 2011: 89*f*.). This suggests that fish were either a preferred foodstuff or more affordable or accessible than game foods, such as geese, peafowl and deer, which were luxury foods for the upper classes (Threlfall-Holmes 2005; Thomas 2007; Jotischky 2011). However, this pattern is not mirrored at early Christian sites such as Iona, where large quantities of deer bones were found (Ralston and Armit 2003). Moreover, around 7.4% of the Iona diet consisted of grey seal, to which the monastery claimed breeding rights (Alcock 2003).

Faunal evidence suggests that cattle bones predominate at many medieval religious sites; the percentages for cattle, sheep and pigs at Kirkstall Abbey (Cistercian) in Yorkshire (75%, 14%, 5%) and also at Portmahomack and Norton Priory (see chapter 3) attest to this. Conversely, sheep predominate at other sites such as Pontefract Priory (Cluniac) in Yorkshire (30%, 45%, 20%) (Greene 1989: 51). This may be due to different monastic orders adopting different farming strategies and dietary practices; the Cistercian diet, for example, was more austere than Cluniac rules on food consumption. Moreover, the high percentage of cattle bones at Kirkstall Abbey may reflect the importance of cattle used for dairying (Figure 4.6) and traction, particularly as the Cistercian order was renowned for their farming strategies (Burton 1994).

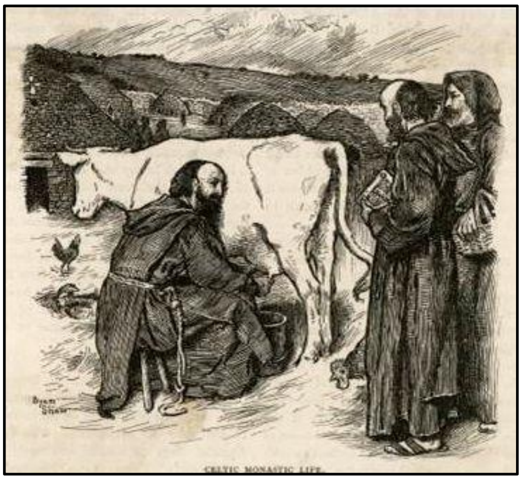


Figure 4.6: Monastic dairy farming by Byam Shaw.
Source: http://www.maryevans.com/search.php?src=look&pic=10050277

Stable isotope analysis has been used to study aspects of social differentiation between monastic and lay populations. From the Gilbertine Priory of St Andrew, Fishergate in York, carbon isotope analysis revealed that the monastic brethren consumed a larger proportion of seafood compared to the layfolk. Moreover, the monks' teeth revealed a lower rate of dental caries compared to the layfolk, supporting the isotope evidence that they consumed a large amount of non-cariogenic foods such as fish (Mays 1997). Müldner and Richards (2007b) built on this study, by analysing both carbon and nitrogen isotopes on a larger sample size from the site.

Although a dietary trend was clear in earlier findings (Mays 1997), no real differences in diet between the monastic community and lay people or indeed between males and females were found (Müldner and Richards 2007b). At the rural hospital of St. Giles in Yorkshire (*c*.12th – 15th centuries) and Warrington Friary in Cheshire (*c*.13th – 16th centuries), stable carbon and nitrogen isotope analysis on human bone collagen revealed little isotopic variation between the hospital patients at St Giles and Augustinian friars at Warrington. This suggests that those in both secular and religious infirmaries consumed similar types of foods, which attest to widespread adherence to Christian diets and fasting practices, reflecting religious influences on diet in medieval Britain.

Stable isotope studies have also been performed on skeletal material from monastic sites in Scotland, to investigate status divisions in diet. At Whithorn Cathedral Priory (Dumfries and Galloway), isotope analysis revealed the diets of lower status males differed significantly from that of the bishops who had a higher intake of marine fish, suggesting a medieval upper class diet (Montgomery *et al.* 2009; Müldner *et al.* 2009). Studies such as these attest to the importance of using stable isotope analyses to complement archaeological and historical interpretations, especially those relating to social and religious differentiation in food consumption. Dietary comparisons to isotope studies from medieval Europe are discussed further in section 8.6.12.4.

Overall, the diet of ecclesiastics in medieval Britain varied due to a number of factors: different monastic orders (hence different food/fasting rules); the wealth and status of a religious house, the geographical location and subsistence strategies, and the temporal difference, from early medieval insular monasteries, such as

Portmahomack, to larger established later medieval estates with commitments to both their monastic brethren and wealthy lay founders or benefactors, as at Norton Priory. The types of food consumed in medieval religious houses therefore depended on its status and obligations, although religious influences resulted in some uniformity. Archaeological and historical evidence suggests that many ecclesiastics enjoyed a rich and plentiful diet, consisting of various meats, fishes, spices and wines (Harvey 1993; Threlfall-Holmes 2005; Jotischky 2011). This wealth of food was used to maintain the social standing of some religious houses, which in turn would appease those who had an interest in maintaining its upkeep and status.

4.4 Chapter Conclusion

This chapter has presented a general description of the lifeways in medieval Britain by providing an overview of the impact of health, disease and trauma on the skeletal body. Lifestyle factors such as poor living conditions or hazardous occupations may have contributed to poor health and susceptibility to certain diseases or trauma. Additionally, an overview of medicine and surgery in medieval Britain has also been presented to understand how those with disease or trauma were treated and whether certain theories, cultural beliefs and attitudes influenced such treatments. Pertinent to this study, this chapter has also presented a selection of archaeological and historical evidence on the diets of the peasantry and ecclesiastics in medieval Britain. This may elucidate how religious and cultural influences had an impact on food consumption and highlight differences in diet, if any, between different social classes. The following chapter will provide background information on stable carbon and nitrogen isotopes in the biosphere and on the structure of human bone to contextualise the issues discussed in this chapter.

Chapter 5

STABLE LIGHT ISOTOPES: PRINCIPLES AND APPLICATIONS

5.1 Introduction

The previous chapter discussed aspects of medieval lifeways including health, disease and trauma, with the latter sections centred on the types of foods consumed in medieval Britain and the social and religious influences therein. To build on this, in terms of dietary reconstructions, this chapter will provide a background on stable isotopes; firstly by discussing the structure and function of bone and the usefulness of bone collagen in isotopic studies. An overview of what isotopes are, the notation and terminologies used and an understanding of fractionation between diet and a consumer will then be presented. Stable carbon and nitrogen isotope values in terrestrial and aquatic ecosystems and their trophic level effects will also be discussed to provide an understanding of the relationship between humans and the biosphere. Finally, some examples of stable isotope applications are presented to contextualise the palaeodietary aspect of this study.

5.2 Bone Structure, Function and Turnover

Bone is a composite material (Figure 5.1) with three components: water, an organic matrix, and an inorganic mineral (carbonated hydroxyapatite) (Schwarcz and Schoeninger 1991; Tuross 2003). By weight, the mineral component of dry bone is around 75%, providing rigidity for the bone, with the organic component being 25%, giving the bone its tensile strength (Lee-Thorp and Sponheimer 2007). The organic mass of bone is formed of 90% Type I collagen, with the remaining 10% consisting of organic molecules such as lipids and other non-collagenous proteins (Tuross 2003; Katzenberg 2000).

Collagen contains three chains in a triple helix, with covalent crosslinks giving its great stability (Welle 1999). Type I collagen has an extremely ordered amino acid composition, including hydroxyproline, proline, and glycine, the latter two of which being unusual among proteins. For example, glycine has only two carbon atoms to one atom of nitrogen, compared to four or more carbon atoms to each atom of nitrogen in most other amino acids (Schwarcz and Schoeninger 1991; Schultz and Liebmann 1997). Because of the percentage of amino acid residues of glycine in collagen, the atom-to-atom ratio of carbon to nitrogen (C:N) is around 3:1, as opposed to 5:1 in other proteins. This low C:N ratio and the aforementioned amino acid composition is considered diagnostic of collagen. These features are therefore used to assess the preservation of collagen prior to stable light isotope analysis (Schwarcz and Schoeninger 1991).

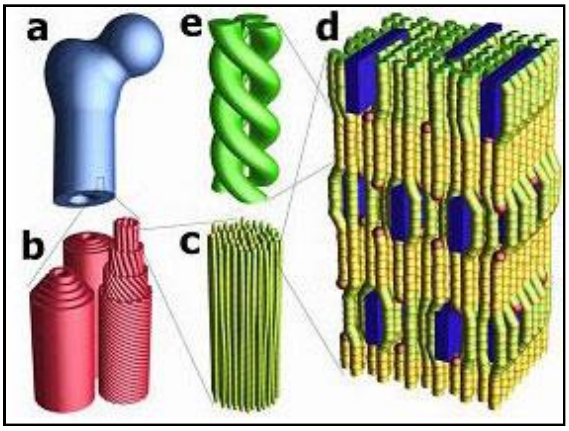


Figure 5.1: Hierarchical structures in bone: **(a)** macroscopic bone, **(b)** osteons, **(c)** collagen fibre, **(d)** striped collagen fibril and **(e)** collagen molecule triple helix. **Source**: *Brookhaven National Laboratory*: www.bnl.gov/nsls2/sciOps/chemSci/softMatter.asp

Bone turns over to provide and maintain tissue strength and to regulate calcium and phosphate homeostasis (Tuross 2003), although bone turnover rates are relatively slow compared to more metabolically active tissues such as liver and fat, which turn over in a matter of days (Tieszen *et al*. 1983). Based on cortical bone collagen turnover rates per year (%/yr) of human femoral mid-shafts, Hedges *et al.* (2007) found that adult female turnover rates were 4%/yr at the age of 20, decreasing to 3%/yr by the age of 80. Adult male bone collagen turnover rates were 3%/yr at the age of 25 and decreased to 1.5%/yr by the age of 80, revealing the lowest bone turnover rate in older males. The rate of adult bone collagen turnover differs greatly between cortical (e.g. femur) and trabecular (e.g. rib) bone, being around 3%/yr and 18%/yr respectively (Valentin 2003), hence isotope ratios from trabecular bone may reflect the diet of an individual over a shorter period of time than from cortical bone (Fuller *et al.* 2006). Therefore, depending on the type of bone analysed, carbon and nitrogen isotopes can reconstruct an adult's diet from the last 10 to 30 years of life (Libby *et al*. 1964; Stenhouse and Baxter 1979). Valentin (2003) also found that cortical and trabecular bone turnover is much greater in sub-adults, which steadily decreases towards adulthood (Table 5.1). Similarly, Hedges *et al*. (2007) suggested a higher cortical bone turnover rate of 10-30%/yr in 10-15 year olds compared to the aforementioned adult rates. Overall, dietary reconstructions in children will therefore reflect a much shorter dietary signal than in adults. Moreover, dietary reconstructions in young adults may be more similar to those of older children than of older adults.

Table 5.1: Bone turnover rates (after Valentin 2003: 188).

Age	**Cortical Bone Rate (%/year)**	**Trabecular Bone Rate (%/year)**
Newborn	300	300
1 year	105	105
5 years	56	66
10 years	33	48
15 years	19	35
Adult	3	18

Past studies suggested that there is no evidence of a physiological correlation between age and sex and $\delta^{15}N$ and $\delta^{13}C$ values. For example, Lovell *et al.* (1986) analysed $\delta^{13}C$ values in 50 humans aged between birth and 60 years at death from a prehistoric Canadian prairie site, the results of which suggested a homogenous diet within the group, hence no correlation. More recent studies have proposed that age may affect the rate of collagen turnover. For example, Hedges *et al.* (2007) found that the ^{14}C content of human femoral mid-shaft collagen revealed that once full maturity is reached, the collagen turnover of an individual is greatly reduced and that although males have a greater rate of turnover than females during adolescence, this is reversed once full maturity is reached. It is therefore important to know the age and sex of an individual when using stable isotope analysis for dietary reconstructions.

It has been suggested that some pathological conditions, such as osteomyelitis, periostitis, bone atrophy and fracture, postpone the normal bone remodelling process, hence altering isotope values. For example, Katzenberg and Lovell (1999) found that pathological bone from one individual had $\delta^{15}N$ values of 2‰ higher than that of the non-pathological segment of the same bone, leading the authors to conclude:

> "…*wasting and the consequent recycling of tissue protein can result in elevated $\delta^{15}N$ values and new tissue deposited during the repair of fracture can register short-term dietary change*."
>
> (Katzenberg and Lovell 1999: 323).

A number of individuals in this study reveal skeletal changes indicative of trauma and pathologies, such periostitis and fractures (see chapter 7). Sampling and analysis of pathological bone was deliberately avoided on the majority of skeletons in this study to obtain isotope results that reflect typical diets. Pathological bone, as well as non-pathological bone from the same individual, was however sampled from a number of skeletons from Norton Priory that had Paget's disease of bone (PDB) to ascertain if any differences in isotope ratios were present (see section 7.4.3.3). Investigating isotopic differences between PDB versus non-pathological bone can prove beneficial by contributing to a greater understanding of PDB as its aetiology is still inconclusive (Tan and Ralston 2014).

5.3 Collagen Degradation, Contamination and Integrity

Before stable isotope ratios can be used for palaeodietary reconstructions, it is imperative that there is an understanding of what diagenetic changes may occur in bone (Sponheimer and Lee-Thorp 1999). Certain indicators and procedures should also be considered to acquire accurate isotope ratios that reflect the *in vivo* composition of collagen (DeNiro 1985). Important reviews have been provided relating to diagenetic changes for the inorganic (e.g. Hedges 2002; Lee-Thorp 2002) and organic (e.g. Collins *et al.* 2002) phases of bone. This section will discuss the processes involved in collagen degradation and contamination, and what indicators are available to assess the quality of collagen.

5.3.1 Collagen Degradation

van Klinken (1999: 688) refers to collagen degradation as a diagenetic alteration (or breakdown) and states that collagen contamination relates to a completely different process, which involves the presence of exogenous contaminants. The collagen content of buried bone appears to be quite low in tropical areas, with more rapid degradation than in temperate areas, where there is better preservation of collagen but more concern for contamination (van Klinken 1999).

Collagen is protected to a degree by the hydroxyapatite component, although once exposed to diagenetic factors, such as low pH, groundwater activity and high temperatures; the mineral component begins to decompose (Hedges 2002). Collagen degradation occurs with the hydrolytic cleavage of peptide bonds between amino acids, followed by the loss of peptides from the right-handed triple-helical collagen structure and loss of bone through leaching (Collins *et al.* 1995; van Klinken 1999). The breakdown of these peptide bonds affects the nitrogen atom due to kinetic isotope effects, which can result in enriched $\delta^{15}N$ values that appear like a trophic level effect. Microbial attack also affects the amino acids that have a high number of carbon atoms (from five to nine), which may result in more negative $\delta^{13}C$ values (Balzer *et al.* 1997; Grupe 2001).

Bone and dentine are similar in that they are both composite tissues of mineral and collagen and are therefore susceptible to diagenesis when dissolution of the mineral phase occurs (Collins *et al*. 2002). Hedges (2002) states that, with increasing research, it is becoming clear that the loss of much collagen is correlated with microbial attack (bacterial and fungal). Additionally, environmental factors favouring microbial attack, such as temperature, hydrology and site geochemistry need to be better understood to provide concise interpretations of diagenetic alterations (Hedges 2002).

5.3.2 Collagen Contamination

Although the climate in temperate Europe does favour better collagen preservation, exogenous contamination of collagen is more of an issue in these areas (van Klinken 1999). Natural exogenous contaminants of collagen mainly derive from humic materials originating from either the soil or from *in situ* humification of collagen through Maillard-type browning, and indeed can derive from both of these simultaneously (van Klinken and Hedges 1995: 264). However, there is great difficulty in detecting humic substances in bone and not much research regarding humic–collagen–hydroxyapatite (HAP) interactions has been performed so far (van Klinken and Hedges 1995). At present, avoiding contaminated samples and adhering to chemical pre-treatments appear to be the only precautions for dealing with humic contamination (van Klinken and Hedges 1995: 269; van Klinken 1999).

5.3.3 Collagen Quality Indicators

A number of methods can be employed to assess the quality of extracted collagen. The term “collagen” (in quotation marks) is used in this section to denote degraded ancient material as opposed to collagen (no quotation marks) in its biochemical sense (van Klinken 1999: 687). Amino acid profiling has been suggested to be a suitable method to rule out collagen alteration (Schwarcz and Schoeninger 1991). However, this method is found to be of little use when assessing “collagen” quality due to its insensitivity to certain molecular species (such as humics) and due to the effort and expense needed (van Klinken 1999: 690).

Post-mortem diagenetic alteration of “collagen” can be detected by measuring the atomic carbon and nitrogen ratios (C:N). C:N ratios between the range of 2.9-3.6 are suggested to represent uncontaminated samples, whereas those outside this range may have been altered diagenetically (DeNiro 1985: 808). van Klinken (1999: 691) noted that the range quoted by DeNiro (1985) is too wide to make this method a sensitive tool in detecting contamination and proposed a shorter range of 3.1-3.5 for acceptable samples. However, to maintain uniformity when comparing to other stable isotope studies, the DeNiro (1985) C:N ratio range of 2.9-3.6 will be used in this study.

Based on European samples, van Klinken (1999) discovered that weight percentages (wt. %) for carbon and nitrogen in intact collagen are around 35 wt.% and 11-16 wt.% respectively. Well-preserved collagen is therefore suggested to be in the ranges of 30-50 wt. % for carbon and 10-20 wt.% for nitrogen (van Klinken 1999). “Collagen” yield, which is expressed as weight percentage, is a well-established method of assessing collagen integrity. Fresh bone contains around 22-25 wt.% collagen, which decreases during burial at a slower rate in temperate zones, such as Europe, than in hotter zones with more precipitation, such as the tropics (van Klinken 1999; Lee-Thorp and Sponheimer 2007). van Klinken (1999) found that once the “collagen” content drops below 0.5 wt. % it is very difficult to remove any contamination. Based on African samples, Ambrose (1990) found that “collagen” yields over 3.5% represented well-preserved “collagen”. Therefore, an acceptable minimum range for “collagen” yields is around 0.5 wt. % to 2 wt. % (van Klinken 1999).

5.4 Why use Collagen?

Type I collagen is relatively insoluble because it is protected by the bone's mineral matrix (hydroxyapatite) and has extensive linkages between each of the three equal-sized chains (Schwarcz and Schoeninger 1991; Grupe *et al.* 2000). By measuring the atomic C:N ratios, collagen samples that have been altered diagenetically can be detected, hence contaminated samples can be omitted from dietary reconstructions (DeNiro 1985). Additionally, adult human collagen does not exchange carbon with air or other organic materials due to its inertness (van der Merwe 1982). Collagen, which contains both carbon and nitrogen, is therefore an extremely useful material for stable isotope dietary reconstruction as it can survive for thousands of years, with the most favourable conditions being cool and stable (Ambrose 1993). Under the right conditions, collagen can survive extremely well and can be used for dietary reconstruction on material as far back as the Late Pleistocene in temperate Europe (Lee-Thorp 2008). Unfortunately, collagen cannot be used for applications further back in time (e.g. > 200,000 years old) as it will begin to denature and dissolve more quickly on geological timescales than the mineral component (Lee-Thorp and Sponheimer 2006; Lee-Thorp 2008; Lee-Thorp and Sealy 2008). Therefore, apatite-based methods are used on early hominin remains, with tooth enamel providing the most reliable material (e.g. Lee-Thorp and van der Merwe 1987; Wang and Cerling 1994; Lee-Thorp 2002; Lee-Thorp 2008). Bone collagen is the preferred material selected for this study because it is relatively recent (~1000 years old) and from a temperate climate, which provides better preservation of collagen than tropical and arid environments (van Klinken: 1999). Additionally, to obtain nitrogen isotope data to reconstruct the types of foods consumed and trophic level effects, bone collagen needs to be analysed because nitrogen is not present in tooth enamel or bone apatite, hence these materials have not been selected for analysis.

5.5 What are Isotopes?

Isotopes are atoms that contain the same number of protons and electrons but different numbers of neutrons, therefore have difference masses (Hoefs 1987; Sharp 2007). Stable isotopes include hydrogen, oxygen, carbon and nitrogen, the latter two of which are used in this study. There are two stable isotopes of nitrogen in the atmosphere: ^{15}N and ^{14}N, which have relative abundances of 0.37% and 99.63% respectively. Carbon has two stable isotopes: ^{12}C, ^{13}C, with abundances of 98.89% and 1.11% respectively (Sharp 2007: 8). Additionally, carbon has an unstable isotope (^{14}C), which is used to date organic materials because it decays radioactively at a set rate over time, which is significant on archaeological time-scales (Aitken 1990). Other unstable isotopes applied to archaeological studies include strontium, ($^{87}Sr/^{86}Sr$), which is often used in conjunction with oxygen isotopes ($\delta^{18}O$) on tooth enamel to reconstruct the provenance and mobility of individuals (e.g. Müldner *et al.* 2009).

5.6 Notation and Terminology

Because isotope differences are small, stable isotope ratios are not normally written as simple ratios of one isotope to another, but as delta (δ) units, which measure deviation in isotope ratios from a particular standard (Hoefs 1987; Sharp 2007). The standard used for nitrogen is atmospheric nitrogen (AIR) and for carbon was PeeDee Belemnite (PDB), which is a marine sediment from the Upper Cretaceous Peedee formation of South Carolina (Sharp 2007. The original supply of PDB is now used up, therefore replacements are now utilised (e.g. Vienna PDB: V-PDB), which are carefully calibrated against the isotopic composition of the original sample (Sharp 2007). Stable isotope ratios are expressed in terms of parts per thousand (per mil) using the symbol ‰ (Hoefs 1987; Sharp 2007). Using carbon isotopes ^{13}C:^{12}C, as an example, they are calculated as:

$$\delta^{13}C = \left[\frac{(^{13}C/^{12}C)_{sample}}{(^{13}C/^{12}C)_{standard}} - 1 \right] \times 1000 ‰$$

If the ratio of heavy to light isotope is higher in the sample than in the standard, the δ value will be positive, whereas if the opposite occurs, the δ value will be negative. For instance, a sample with a $\delta^{15}N$ value of +14.7‰ has a $^{15}N/^{14}N$ ratio that is 14.7 per mil, or 1.47 percent higher than the standard of AIR (0‰) (Sharp 2007: 17). Isotopic differences are usually expressed as Δ (difference) and are variable between diet and particular tissues. For example, the difference in $\delta^{13}C$ between diet and collagen ($\Delta^{13}C_{d\text{-}coll}$) is +5‰ (Lee-Thorp 2008: 928).

5.7 Fractionation

The ratios between naturally occurring stable isotopes of carbon (^{12}C and ^{13}C) and nitrogen (^{14}N and ^{15}N) vary because, in an attempt to preserve energy, all biochemical reactions discriminate against the heavier isotope of a particular element; this process is called isotope fractionation (Ambrose 1993; Hoefs 1987). This occurs because the bond energy and reaction rate of each isotope is slightly different, with heavier isotopes (those with a greater atomic mass) having stronger bonds and slower reaction rates than light isotopes (those with a lower atomic mass)

(Schoeller 1999). Two main occurrences produce these fractionations: 'isotope exchange reactions' (or equilibrium), which occur where the isotope distribution changes between different chemical exchange processes; and 'kinetic processes', which depend on differences in the reaction rates of isotopic molecules (Hoefs 1987: 6). For example, during nitrification (the production of nitrate from organic nitrogen) kinetic fractionation occurs with the conversion of nitrite to nitrate ions (NO_2^- to NO_3^-), whereas the previous conversion stage of organic nitrogen to ammonium (N_2 to NH_4^+) does not cause significant fractionation (Faure and Mensing 2005). Light elements such as carbon and nitrogen are therefore more likely to exhibit isotopic fractionation than heavy isotopes. In plant and animal tissues, a trophic level increase is created when carbon and nitrogen fractionation occurs with each step up the food chain (Schoeller 1999).

5.8 Carbon Isotopes in Terrestrial Ecosystems

During photosynthesis, carbon is fractionated through the absorption of atmospheric carbon dioxide (CO_2) by plants. The $\delta^{13}C$ value of plants is determined by their relative photosynthetic pathways, which are C_3, C_4 and CAM (van der Merwe 1982). C_3 plants, which convert atmospheric CO_2 to a photoglycerate compound with three carbon atoms, are found in most temperate zones and include all trees, bushes, forbes and most shrubs (van der Merwe 1982; Lee-Thorp and Sponheimer 2006). C_3 plants have $\delta^{13}C$ values that range from around -20‰ to -35‰ with a mean $\delta^{13}C$ value of -26.5‰ and are more depleted in ^{13}C than C_4 plants (van der Merwe 1982).

C_4 plants, which convert atmospheric CO_2 to dicarboxylic acid with four carbon atoms, include tropical vegetation such as sugar cane, maize, millet and sorghum.

The $\delta^{13}C$ values of C_4 plants range from around -9‰ to -16‰, averaging -12.5‰. Fortunately, these values do not overlap with those of C_3 plants, hence a useful tool to distinguish isotopically, the types of plants consumed (van der Merwe 1982). No native C_4 vegetation exists in Europe and before foods like sugar cane were imported into Britain in the late medieval period, this dietary component was very rare (Mays 1997; Spencer 2000). In arid environments, CAM (Crassulacean acid metabolism) plants, such as pineapple and cacti, fix CO_2 through phosphoenolpyruvate carboxylase and can alternate between C_3 and C_4 pathways and mirror their $\delta^{13}C$ values (van der Merwe 1982; Lee-Thorp and Sponheimer 2007).

Carbon isotope variation occurs depending on environmental and climatic effects, such as the availability of light, nutrients and temperature (Heaton 1999). For example, the *canopy effect* occurs in dense forests where large amounts of isotopically light CO_2 are released due to decomposing ground vegetation. The forest canopy traps the air and prevents it from mixing with the free atmosphere, resulting in more negative $\delta^{13}C$ values with decreasing height (van der Merwe 1982). Variations in $\delta^{13}C$ values may also be due to temporal changes, such as the *fossil fuel effect*, which is caused by the admixture of anthropogenic (fossil fuel) CO_2. This has resulted in an increase in $\delta^{13}C$ values during the last 150 years by 1.5‰, which needs to be added to modern $\delta^{13}C$ values when comparing to pre-industrial values (van Klinken *et al*. 2000). Average $\delta^{13}C$ values for humans, herbivores, omnivores and carnivores from Holocene Europe are -19.9‰, -20.6‰, -20.1‰ and -19.7‰ respectively, suggesting a diet of C_3 terrestrial foods (van Kinken *et al*. 2000). However, not all animals are fed a uniform diet and husbandry strategies may be affected by a number of factors such as climate, location and seasonality, resulting in variable isotope values that may subsequently affect human isotope values. Therefore, analysing animal bone from the same site as human bone is needed to obtain conclusive results and aid dietary interpretations.

Carbon isotopes studies have questioned whether dietary proteins are preferentially routed to collagen (the *protein routing* model) or whether all dietary components contributed to the construction of collagen, known as the *scrambled egg* model (Ambrose and Norr 1993). Pioneering studies discovered that dietary protein is preferentially routed to collagen, whereas bone apatite carbonate reflects the entire diet (Krueger and Sullivan 1984; Lee-Thorp *et al.* 1989; Ambrose and Norr 1993; Tiezsen and Fagre 1993). Conversely, Schwarcz (2000) rejected the protein routing model, based on Mayan groups consuming a low protein C_4 diet (in this case, maize) and protein from animals that were fed C_3 plants. Other scholars (e.g. Ambrose and Norr 1993; Jim *et al.* 2004) also found that only in low or poor quality protein diets are significant amounts of carbon to collagen contributed from dietary carbohydrates and lipids.

5.9 Nitrogen Isotopes in Terrestrial Ecosystems

Nitrogen isotopes are fractionated primarily during the conversion of atmospheric N_2 into organic compounds by the metabolism of certain algae and bacteria. This process consists of *fixation, nitrification*, and *denitrification*, which together constitute the exogenic nitrogen cycle (Faure and Mensing 2005). The roots of most terrestrial plants (e.g. grasses, and trees) take up nitrogen from the soil, which is used as a nutrient element for growth. In the ocean, phytoplanktons (producers) obtain their nitrogen for growth from nutrients in the water, whereas animals (consumers) receive the nitrogen they need when plants (or other animals) are eaten (Mackenzie 1998).

Because nitrogen gas is inert, most plants and animals cannot use it directly from the air as they can do with carbon dioxide and oxygen. Instead, most organisms must wait for the nitrogen to be fixed, that is, pulled from the air and bonded to hydrogen or oxygen to form inorganic compounds, which contain mainly ammonium (NH_4^+) and nitrate (NO_3^-) ions (Vitousek *et al*. 1997). However, some plants, such as legumes (e.g. peas and beans) are able to 'fix' nitrogen, either from the NO_3^- and NH_4^+ ions in the soil or directly from atmospheric N_2. Nitrogen-fixing plants therefore have $\delta^{15}N$ values closer to atmospheric nitrogen (0‰), while non-leguminous plants have higher $\delta^{15}N$ values (DeNiro 1987; Katzenberg 2000).

In plants, many factors affect $\delta^{15}N$ values. These include temperature, altitude, rainfall, soil salinity, and the application of natural fertilisers such as manure. For example, van Klinken *et al.* (2000: 49) suggest that a 'manuring effect' on plants would increase $\delta^{15}N$ values in humans who consume these plants. This is supported by experiments on modern European cereal grain and chaff that suggest manuring significantly increases $\delta^{15}N$ values (Bogaard *et al.* 2007). Soil condition may be another factor affecting $\delta^{15}N$ values, such as soils on lower slopes and near saline seeps, which have higher $\delta^{15}N$ values than well-drained soils due to greater denitrification in more boggy areas, resulting in heavy residual NO_3^- ions (Karamanos *et al.* 1981).

Climatic influences and physiological factors are a consideration for palaeodietary reconstructions as different mechanisms and processes in the body affect $\delta^{15}N$

values. Heaton *et al.* (1986) demonstrated that $\delta^{15}N$ in human and animal bones from South Africa are sensitive to climate and elevated in arid regions. Minagawa and Wada (1984) discovered ^{15}N enrichment in animals depends on the excretion mechanism, where nitrogen is excreted as ammonium ions in aquatic animals or as urea (e.g. mammals or amphibians) or uric acid (e.g. birds or reptiles). Ambrose (2000) tested the excretion mechanism on heat and water stressed rats, although no difference was found, suggesting that the physiology of such species were not useful comparisons with humans. Human $\delta^{15}N$ values have also been found to be altered in pathological bone and during times of nutritional stress. For example, $\delta^{15}N$ values from the hair of pregnant women were found to increase during nutritional stress and decrease towards full term, suggesting that tissue protein became ^{15}N-enriched during bouts of morning sickness (Fuller *et al.* 2005).

Nitrogen metabolism and other environmental and physiological factors need consideration prior to analysis. For example, foregut fermenters (e.g. cattle, goats), are suggested to have higher $\delta^{15}N$ values than hindgut fermenters (e.g. rabbits) (Sponheimer *et al.* 2003). Studies have also suggested that high protein consumers, such as browsers, have higher $\delta^{15}N$ values than grazers, possibly relating to low protein consumers being less able to excrete urea to retain water, because sufficient nitrogen must be retained for the animal's gut flora (Sealy *et al*. 1987; Ambrose 1991). Sealy *et al.* (1987) did not detect distinctions between grazers and browsers under arid conditions and found that increased $\delta^{15}N$ values may be caused by the re-synthesis of nitrogen by the gut flora. This theory was later criticised by Ambrose (1991) who stated that the use of ^{15}N depleted urea would decrease, rather than increase $\delta^{15}N$ values in body tissue.

Herbivore $\delta^{15}N$ values from the British Holocene vary from around +4‰ to +7‰ (Müldner and Richards 2005; Richards *et al.* 2006; Jay and Richards 2007), possibly due to differences in regional resources and husbandry practices. For example, in transitional zones, such as salt marshes, certain plants may have higher $\delta^{15}N$ values than more inland terrestrial plants. Britton *et al*. (2008) discovered that Bronze Age herbivores that grazed on salt marshes in the Severn Estuary had significantly higher $\delta^{15}N$ values than other fauna data-sets from the UK. Such evidence may reveal important implications where high $\delta^{15}N$ values are automatically interpreted to reflect a marine signal without evidence of site-specific faunal baseline data (Britton *et al*. 2008).

5.10 Carbon and Nitrogen Trophic Level Effects

Carbon and nitrogen is incorporated into a consumer through the food chain and the foods consumed. This has been summarised as 'you are what you eat, plus a few per mil', which basically means your body reflects what is consumed, plus a fractionation value (DeNiro and Epstein 1976: 834). However, certain factors may alter $\delta^{15}N$ values beyond the norm (see sections 5.9 and 5.12). A number of systematic changes in $\delta^{15}N$ ratios have been observed when organic matter is passed upwards in the food chain, for example, from plants to herbivores to carnivores (Figure 5.2). This 'trophic level effect' is estimated at +3-5‰ enriched in ^{15}N for each trophic level (Schoeninger and DeNiro 1984; Schoeninger 1985; Sealy *et al.* 1987; Sponheimer *et al.* 2003).

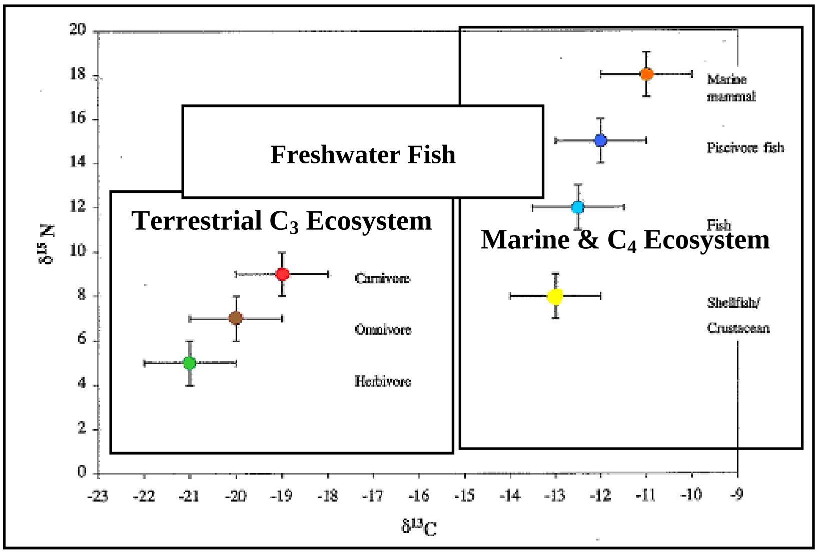


Figure 5.2: Stable $\delta^{13}C$ and $\delta^{15}N$ isotope plot illustrating terrestrial and aquatic trophic level systems (modified from Richards 2000).

Importantly, the consumption of meat and milk, or milk-derived products is indistinguishable in the isotope record because there is no fractionation between body tissue and fluid (Schutkowski 2008). Additionally, the proportion of protein consumption is impossible to differentiate isotopically, especially if the main protein source is from meat (van Klinken *et al.* 2000), therefore, using $\delta^{15}N$ values to determine trophic level effects in this respect would be ineffective.

Certain studies have suggested $\delta^{13}C$ values reflect trophic level effects (e.g. Wada and Hattori 1976; McConnaughey and McRoy 1979). However, other studies suggest bone collagen $\delta^{13}C$ values do not seem to reflect a trophic level increase “to any useful degree”, with only a small (<1‰) increase (Schoeninger and DeNiro 1984: 636). van Klinken *et al.* (2000) reported that $\delta^{13}C$ values of most plant tissues are closer to those of carbohydrates (-25‰ to -27‰), which are less pronounced than animal bone collagen (around -20‰). Plant consuming herbivores should have less pronounced $\delta^{13}C$ trophic level shifts than carnivores, although measuring plant-herbivore shifts is difficult due to variability in plants and collagen-diet spacing. Therefore, the authors suggest that "this makes the use of the term 'carbon trophic level effect' in herbivores of little value, and consequently it would be clearer to use the term 'carnivore effect' for the carbon trophic level effect in carnivores." (van Klinken *et al*. 2000: 47). Moreover, it appears that $\delta^{13}C$ trophic level shifts are indistinguishable when animals from multiple food webs are analysed, as opposed to a possible observation in animals from single food webs (Schoeninger 1985).

5.11 Carbon Isotopes in Aquatic Ecosystems

Like terrestrial plants, marine plankton derives its carbon from the photosynthetic fixation of atmospheric CO_2, although other aquatic plants fix carbon from dissolved bicarbonate (HCO_3^-), which has less negative $\delta^{13}C$ values (0‰) relative to atmospheric CO_2 (Tauber 1981; Sharp 2007). Aquatic (both marine and freshwater) foodwebs have highly varied $\delta^{13}C$ values due to carbon originating from various sources (e.g. atmospheric/aquatic CO_2, carbonate and aquatic detritus) and depending on the types of plant, such as plankton (-31‰ to -18‰) and algae (-22‰ to -10‰) (Sharp 2007). Marine plants tend to have $\delta^{13}C$ values intermediate between those of terrestrial C_3 and C_4 resources, whereas freshwater foodwebs reflect more of a C_3-like carbon isotope composition (Katzenberg 1989). In temperate Europe, $\delta^{13}C$ values for marine fish are generally around -12‰ (Tauber 1981) and species that inhabit deep, open waters have lighter $\delta^{13}C$ values than those inhabiting shallow waters (Fry and Sherr 1988; Sealy 2001).

Problems may arise when distinguishing between marine and terrestrial diets if the latter is dominated by C_4 plant consumption, because they have similar $\delta^{13}C$ values to marine organisms (Tauber 1981; Katzenberg 2000). However, as this study is based on medieval British diets, where the consumption of C_3-based foods was dominant, this caveat may be excluded.

5.12 Nitrogen Isotopes in Aquatic Ecosystems

The major inputs of nitrogen in the ocean are river runoff, rain, and the fixation of molecular N_2 by marine blue green algae (Sharp 2007). Dietary studies using nitrogen isotopes on aquatic organisms are well known and report larger food chains than in terrestrial ecosystems, resulting in aquatic organisms having higher $\delta^{15}N$ values (Minagawa and Wada 1984; Shoeninger and DeNiro 1984). Certain fish however, reflect unusually low $\delta^{15}N$ values that do not appear to correlate with their marine dependence. For example, Schoeninger and DeNiro (1984) discovered coral reef fish had $\delta^{15}N$ values as low as +3.9‰, suggesting low levels of nitrogen, fixed by blue green algae, being carried up the food chain. In marine plants, $\delta^{15}N$ values are around +4‰ higher than in terrestrial plants, although considerable overlap can occur (Shoeninger and DeNiro 1984). Humans who feed on marine resources should have higher $\delta^{15}N$ values than those who consume mainly terrestrial foods, providing a useful indicator of distinguishing between marine and terrestrial diets (Schoeninger *et al.* 1983; Schoeninger and DeNiro 1984).

Nitrogen in freshwater foodwebs is derived from various sources, including terrestrial and aquatic detritus. Variation in $\delta^{15}N$ values occur in freshwater foodwebs, and to some extent with more variation in isotope composition than in marine foodwebs (Fry 2006). Distinguishing trophic level effects between freshwater and terrestrial foodwebs can be complex as some freshwater fish have been found to have $\delta^{15}N$ values similar to that of terrestrial carnivores (Shoeninger and DeNiro 1984: 631). An understanding of the local terrestrial and aquatic resources available to the area under investigation is therefore needed.

5.13 Previous Isotope Applications: An Overview

Pioneering studies, using stable isotopes for palaeodietary reconstructions, appeared with the discovery of early maize cultivation amongst prehistoric Eastern Woodland Americans, detected by differences in $\delta^{13}C$ values through the different C_3 and C_4 photosynthetic pathways (Vogel and van der Merwe 1977; van der Merwe and Vogel 1978). The adoption and consumption of maize has since been the focus of a number of studies, with successful results (*cf*. Katzenberg *et al*. 1993, 1995; Schurr and Schoeninger 1995).

Research in the late 1970s and 1980s included controlled feeding studies to detect influences of carbon (DeNiro and Epstein 1978) and Nitrogen (DeNiro and Epstein 1981) in animals for dietary reconstructions. In 1984, Mingawa and Wada measured $\delta^{15}N$ ratios in aquatic animals from the East China Sea and revealed a trophic level increase in aquatic foodwebs. Trophic level effects were also identified by Schoeninger (1985) on $\delta^{15}N$ ratios in animal bone collagen, although no detection was found in $\delta^{13}C$ ratios. Much research has been performed on faunal remains from African sites, ranging from physiological effects to climatic influences, which are discussed in a number of review publications (e.g. Sillen *et al.* 1989; Schwarcz and Schoeninger 1991; Lee-Thorp 2008). More recent studies have focused on using stable isotope analysis to reconstruct aspects of social differentiation, reflected through burial practices and food consumption, as at the Neolithic site of Çayönü Tepesi, southeastern Anatolia (Pearson *et al.* 2013). Such studies attest to the usefulness of applying stable isotope analysis to provide a bioarchaeological perspective on past societies.

5.14 Previous Isotope Applications: A European Perspective

Tauber (1981) was the first to study $\delta^{13}C$ values in European coastal populations and discovered a distinction between marine and terrestrial consumption in prehistoric Denmark. Murray and Schoeninger (1988) were the first to discover how social and/or gender distinctions were reflected through the consumption of millet (a C_4 plant) in Iron Age Slovenia. Other isotope studies on European sites support archaeological evidence of social variation, as at the early medieval cemetery site of Weingarten, Germany (Schutkowski *et al.* 1999); the La Tène period sites of Kutná Hora-Karlov and Radovesice, Bohemia (Le Huray and Schutkowski 2005) and multi-period sites in Orkney, Scotland (Barrett and Richards 2004).

Religious and social influences on diet have also been a focus of palaeodietary reconstructions in Europe. For example, dietary differences at a 12th – 15th century Cistercian monastery at Koksijde (Polet and Katzenberg 2003) and also at a post-medieval Carmelite friary at Aalst (Quintelier *et al.* 2014), both in Belgium, were suggested to reflect social differentiation between monastic and lay brethren, and between low and high status groups. Monastic and lay dietary differentiation was also found on 13th and 14th century individuals from Whithorn Cathedral Priory, Scotland (Müldner *et al.* 2009).

Previous isotope studies in Britain have provided important data on past medieval diets. However, as stated in chapter 1, most research in England has centred on Yorkshire (e.g. Müldner and Richards 2005, 2007a, 2007b; Richards *et al.* 2002) and mostly from the Orkneys in Scotland (e.g. Richards *et al.* 2006), with a few studies spread sporadically around southeast (e.g. Jay and Richards 2007) and southwest Scotland (e.g. Müldner *et al.* 2009). However, only a handful of these studies are from medieval religious sites and focus primarily on dietary reconstructions. Moreover, a negligible amount of these studies have combined stable isotope analysis with osteoarchaeological and palaeopathological methods (e.g. Spencer 2008, 2009), giving us few details about the impact of social and religious influences on human diet and health overall. The skeletal and stable isotope data in this study will therefore aim to contribute towards a greater understanding of the lifeways of Christian communities from medieval Britain.

5.15 Chapter Conclusion

This chapter has provided information drawn from multiple disciplines such as geochemistry, archaeology, plant and animal physiology and palaeopathology to provide a synthesis of understanding stable isotopes and their applications in palaeodietary studies. More pertinent to this study, stable isotope analysis combined with osteoarchaeological and palaeopathological studies provide a comprehensive understanding, thereby reconstructing the lifeways and the lifecourse of past individuals. The dearth of stable isotope studies on medieval religious sites in Britain has been noted (section 5.14); hence the usefulness of its application in this study, combined with skeletal investigations is noteworthy. The following chapter will discuss the osteological, palaeopathological and stable isotope methods used in this study to provide a context in which to present the overall results (chapter 7) and interpretations (chapter 8).

Chapter 6

MATERIALS AND METHODS

6.1 Introduction

This chapter will present the materials used and methodologies applied in this study. Osteological, palaeopathological and stable isotope methodologies represent those that are routinely applied in bioarchaeological studies, hence a range of key texts and established methods are presented here.

Guidelines for the ethical treatment of human remains were consulted and adhered to, such as those from the Church of England and English Heritage (CofE/EH 2005) and the British Association of Biological Anthropology and Osteoarchaeology (BABAO). Evidence of disease or violence in palaeopathology studies can be regarded as a sensitive topic (Lambert 2012), which needs to be considered when reporting such cases. Therefore in this study, all efforts were made to treat the human skeletal remains with care and respect and report sensitive topics, such as violence, in an appropriate way.

6.2 Skeletal Materials

Macroscopic assessments on human adult and sub-adult skeletons were performed in this study, as well as stable isotope analysis on a selection of human and sub-adult bone collagen, to reconstruct aspects of medieval lifeways at Portmahomack and Norton Priory. From Portmahomack, 178 human skeletons were osteologically assessed, which comprised of 138 adults and 40 sub-adults and from Norton, 128 human skeletons, comprising 115 adults and 13 sub-adults. The number of human and sub-adult bone samples selected for isotope analysis is presented in section 6.5.1. Demographic profiles from these skeletal assemblages are presented in section 7.2.1 and osteology catalogues are presented in Appendices 2a-c.

Faunal remains from Portmahomack and Norton were selected for isotope analysis, to provide a faunal baseline to reconstruct human diets; hence bones from a range of terrestrial and aquatic species were sampled. Additionally, marine fish bones were also sourced from Chester Cathedral to substitute those lacking from Norton, as discussed in chapter 3. The number of faunal bones and species selected for isotope analysis are presented in section 6.5.2.

6.3 Osteology Methods

The first practical stage in this study was to apply osteological methods (see sections 6.3.1 to 6.3.6) to assess sex, age-at-death, stature, metric analysis and non-metric traits. Evidence of pathological markers of disease and/or trauma on bones and teeth was then investigated (see sections 6.4.1 and 6.4.2) to build a biological profile and to reconstruct and interpret past lifeways of individuals from Portmahomack and Norton. An expert review of the proposed osteological recording system (Appendices 1a-q), that incorporated methodologies discussed in the following sections, was sought from Clark Spencer Larsen and Simon Mays at the beginning of this study, both of whom agreed to its validity and relevance (C.S. Larsen, *pers.comm*; S. Mays, *pers.comm*).

6.3.1 Determination of Sex

The sex of adult skeletons was determined on the basis primarily of Phenice (1969), from morphological traits of the os pubis, namely the ventral arc, sub-pubic concavity and ischiopubic ramus ridge. The greater sciatic notch, sub-pubic angle and pre-auricular sulcus of the os coxae were also assessed as were the nuchal crest, mastoid process, supraorbital margin and ridge and the mandibular area (gonial flare, mental eminence) from the skull (Phenice 1969; Buikstra and Ubelaker 1994). Following Bass (1995), post-cranial measurements were also used where necessary from the clavicle (maximum length), scapula (glenoid cavity width), humerus and femur (maximum head diameter and epicondylar breath). Those with measurements in the upper range are generally assigned as male (*cf*. Bass 1995). Following Buikstra and Ubelaker (1994: 21), adults were assigned to one of five sex categories: 1 = female (F), 2 = probable female (?F), 3 = ambiguous sex (?), 4 = probable male (?M), 5 = male (M) and Adult = (?Sex). Additionally, those assigned probable male or probable female were included in male and female categories as appropriate for subsample analyses (see chapter 7). Given the difficulties in sexing juveniles (e.g. Scheuer and Black 2000; Saunders 2008; Lewis 2007), sub-adults were not assigned to a sex category in this study to avoid bias and inaccuracies.

6.3.2 Age-at-Death: Categorisation

Age-at-death of the Portmahomack adult skeletons was originally assigned by King (2000) using the age categories recommended by the Calvin Wells laboratory (now known as the Biological Anthropology Research Centre (BARC)) at the University of Bradford. Boylston (2008) also assigned age categories to the Norton adult skeletons based on those from BARC. At the beginning this study, these age groups were re-categorised by BARC to provide more refined age ranges in the middle adult categories, including a separate 'old adult' category that allows for identification of adults aged 60+ years (H.Schutkowski, *pers.comm*.). The osteological age categories used in this study (Table 6.1) are not definite ages from lived years but are used as a guide to investigate and reconstruct results from age-specific groups (see chapter 7).

These age ranges represent life stages such as ‘child’, ‘adolescent’, ‘young adult’, or ‘old adult’. Sub-adult age-at-death categories in this study were based on those proposed by Lewis (2008: 174), who stated that such age categories were used to “reduce the errors introduced by inter- and intra-population variability.” The term ‘sub-adult’ will be used in this study as a collective descriptor for those from perinate to adolescent; hence all skeletons aged less than 18 years. However, age categories may relate to biological ages rather than the social age of an individual, especially older children (10.6 – 14.5 years) and adolescents (14.6 – 17.0 years) who may have been regarded as an adult within their community.

Table 6.1: Age-at-death categories relating to this study.

Portmahomack (King 2000)	Norton Priory (Boylston 2008)	Portmahomack and Norton Priory (this study)
Pre-term	Foetus	<38 weeks gestation: Perinate
0-0.5 yrs	<1 yr: Infant	0-1 yr: Infant
0.6-2.5 yrs	<6 yrs: Child	1.1 - 2.5 yrs: Child
2.6-6.5 yrs		2.6 - 6.5 yrs: Child
6.6-10.5 yrs	<11 yrs: Child	6.6-10.5 yrs: Child
10.6-14.5 yrs		10.6-14.5 yrs: Older Child
14.6-17 yrs	14-17 yrs: Adolescent	14.6-17.0 yrs: Adolescent
17-25 yrs: Young adult	18-25: Young adult	18-25 yrs: Young adult
26-45 yrs: Middle adult	26-35: Young/middle adult	26-35 yrs: Young middle adult
	36-45: Middle adult	36-45 yrs: Old middle adult
46+ yrs: Old adult	46+ yrs: Old adult	46-59 yrs: Mature adult
		60+ yrs: Old adult

6.3.3 Assessing Age-at-Death

Adult age-at-death was assessed using diagnostic methods primarily from the os coxae (Brooks and Suchey 1990; Buckberry and Chamberlain 2002) and teeth (Brothwell 1981), and thereafter from the crania (Meindl and Lovejoy 1985), and ribs (İşcan and Loth 1986).

From the ox coxae, adult age was firstly assessed using the Suchey-Brooks pubic symphysis method (Brooks and Suchey 1990). The auricular surface ageing method (Buckberry and Chamberlain 2002) was also applied. This method, which was derived from assessing skeletons from 17th to 19th century London, has been suggested to be more accurate and less complex than the previous auricular method by Lovejoy *et al.* (1985) (Buckberry and Chamberlain 2002; Mulhern and Jones 2005). Dental attrition was assessed for adult ageing following Brothwell (1981), who examined degrees of dental attrition on permanent molars from the Neolithic to Medieval period in Britain, hence a useful method for the medieval material in this study and when ossa coxae were absent. Adult age assessments using ectocranial suture closure (Meindle and Lovejoy 1985) and sternal rib ends (İşcan and Loth 1986) were only used in this study as secondary methods. This is due to inaccuracies in ectocranial suture ageing (e.g. Hershkovitz *et al*. 1997) and the often fragmentary nature of ribs from archaeological contexts (Cox 2000); hence these methods were only used where the aforementioned primary methods could not be applied, due to absence or damage.

Sub-adult age-at-death was based primarily on the formation and development of deciduous and permanent teeth (Moorrees *et al.* 1963a, 1963b, Smith 1991); tooth eruption stages (Ubelaker 1989), measurement of the pars basilaris (Scheuer and MacLaughlin-Black 1994), long bone diaphyseal lengths and epiphyseal fusion stages (Scheuer *et al*. 1980; Scheuer and Black 2000; Schaefer *et al*. 2009).

For sub-adult ageing from the dentition, loose teeth were examined macroscopically and mandibles were x-rayed at the Royal Liverpool University Hospital, to provide a radiographic image of the dentition for ageing, following the methods of Moorrees *et al*. (1963a) for deciduous teeth and Smith (1991, after Moorrees *et al.* 1963b) for permanent mandibular teeth. Radiographs and macroscopic examinations were also used when applying the tooth eruption method (Ubelaker 1989). This method is based on tooth eruption stages through the gum, not the bone, and on combined male and female data from American Indians, hence a certain degree of variability is suggested. Overall however, this method consistently correlated with the other sub-adult dental ageing methods.

Sub-adult humeri, radii, ulnae, femora, tibiae and fibulae were measured on an osteometric board for maximum diaphyseal length and an age assigned following the regression method by Scheuer *et al.* (1980) for foetal and perinatal ageing, and by Scheuer and Black (2000; after Maresh 1970) for sub-adult age estimations. To avoid inaccurate age calculations, measurements were not taken from bones that had breakage or taphonomic erosion to bone ends. The pars basilaris method was also used, which is a useful method for foetal and infant (up to 6 years) ageing and especially useful for distinguishing between early and late infant ages (Scheuer and MacLaughlin-Black 1994). Finally, epiphyseal fusion stages following Schaefer *et al.* (2009) were applied for perinatal to post-adolescent ageing. Each fusion centre on the bone was scored as either 'open', 'partial' or 'complete' and ages were assigned from those provided by Scheuer and Black (2000). In order to gain overall sub-adult age-at-death, all methods were compared and assigned an age category. Where wide variables occurred between age estimations, the most reliable method (e.g. Moorrees *et al.* 1963a or Smith 1991) was used.

6.3.4 Stature Estimation

Adult stature was estimated using the regression formulae devised by Trotter and Gleser (1952, 1958) and Trotter (1970) from measurements primarily of the left (or right if left was absent) femur and tibia, which are the most reliable when measured together (Trotter 1970). Regression formulae for estimation of stature based on those applied by Trotter (1970) from American White individuals were used primarily from the femur (F) and tibia (T): 63.29 + 1.30 x (F+T length) ± 2.99cm for males and 53.20 + 1.39 x (F+T length) ± 3.55cm for females. In the absence of the femur and/or tibia, measurements were taken from the humerus (males: 70.45 + 3.08 x (H length) ± 4.05cm), (females: 59.97 + 3.36 x (H length) ± 4.45cm); radius (males: 79.01 + 3.78 x (R length) ± 4.32cm, (females: 54.93 + 4.74 x (R length) ± 4.24), or ulna (males: 74.05 + 3.70 x (U length) ± 4.32cm, (females: 57.76 + 4.27 x (U length) ± 4.30cm). Although using this method may not be ideal for British samples (Brothwell and Zakrzewski 2004), it is an established method used in osteological studies on British collections (e.g. Vincent and Mays 2009; Clough and Boyle 2010), hence appropriate for this study.

6.3.5 Osteometric Analysis

Apart from genetics, diet, activity and the environment are factors that can affect metric and non-metric skeletal traits and should therefore be considered when discussing biological or familial affinities (Larsen 1999; Zakrzewski 2011). In this study, 32 cranial and 53 post-cranial points or anatomical landmarks on the adult skeleton were measured, following Buikstra and Ubelaker (1994). However, not all these points could be measured from each individual skeleton due to post-mortem breakage or absence of skeletal elements. From these measurements a number of indices were calculated following Bass (1995), namely, cranial, upper facial height, orbital and nasal, to assess craniofacial morphology.

Post-cranial measurements were taken from the femoral and tibial shafts and used to calculate platymeric and platycnemic indices respectively, to determine lower limb shape, which has been found to vary among populations (Brothwell 1981; Bass 1995). Certain lower limb shapes may indicate stress-related factors, either biomechanical or disease related. For example, a high platymeric index (stenomeric: less than 100mm) from the femur may be associated with pathological changes on the bone, such as osteoperiostitis or osteomyelitis. Additionally, a platycnemic index (less than 62.9mm) from the tibia is attributed to a biomechanical response to prolonged sitting or squatting positions (Brothwell 1981; Bass 1995).

6.3.6 Non-metric Analysis

Non-metric traits (NMT) manifest as additional sutures, ossicles, foramina, facets, bony processes and canals on the skeleton (Brothwell 1981; Buikstra and Ubelaker 1994). A hereditary connection has been suggested where some traits are present on skeletons (e.g. cranial ossicles), although environmental or biomechanical factors may be the cause for other traits, such as squatting facets (Saunders 1989; Brothwell and Zakrzewski 2004). It has been suggested (Finnegan 1978) that assessing postcranial NMT may prove more beneficial than cranial NMT for population comparisons and that their durability in the archaeological record enables more precise outcomes. However, more recently, it has been suggested that cranial NMT are preferred because “cranial development is more canalised than the development of the infra-cranial skeleton" (Brothwell and Zakrzewski 2004: 28). It is therefore prudent to assess both where possible, to provide a broad representation of biological adaptability or familial affinity. There are approximately 20 cranial and 10 post-cranial NMT (*cf*. Brothwell 1981) that are assessed in osteoarchaeological studies. However, due to the fragmentary state or absence of relevant bones, some of these traits could not be identified on all skeletons in this study. Furthermore, as certain NMT that occur in childhood disappear by adulthood (Vincent and Mays 2009); only adult NMT results were assessed in this study.

6.4 Palaeopathology Methods

Macroscopic assessment of skeletal remains may yield evidence of disease and/or trauma, which can contribute to reconstructing past lifeways and provide a greater understanding of the lives of individuals within their cultural context. Identification and diagnoses of pathologies were made in this study following criteria from key palaeopathological texts, mainly Aufderheide and Rodríguez-Martín (1998), Ortner (2003) and Roberts and Manchester (2005), although other sources were consulted (e.g. Waldron 2009; Grauer 2012). Due to a number of skeletons being incomplete, conclusive diagnosis could not be obtained in certain cases, where a full distribution of pathological markers on the skeleton would be needed, as with leprosy or syphilis for example (Steinbock 1976).

Data recording for all pathologies following standards by Buikstra and Ubelaker (1994) was considered and tested at the beginning of this study. However, it was decided that their coding system for potentially numerous markers of disease and/or trauma on one or more bones of each skeleton would be irrelevant in some cases and far too time consuming and cumbersome to carry out in this study, a problem which has also been highlighted by Roberts and Connell (2004). Moreover, these standards were written in response to the Native American Graves Repatriation Act (1990) and include palaeopathology not often observed on British skeletal collections, such as cranial modification. However, a selection of Buikstra and Ubelaker (1994) guidelines were used for recording certain pathologies, such as cribra orbitalia and porotic hyperostosis. Guidelines for recording human remains by Brickley and McKinley (2004) were also followed. These guidelines are aimed at those assessing British skeletal collections, hence suitable for this study.

6.4.1 Dental Pathologies

The presence of dental diseases from archaeological remains can provide evidence of diet, activity, oral hygiene or cultural behaviour (Roberts and Manchester 2005). However, dental pathologies can have multiple causes, for example a granuloma may be caused by a carious lesion, which subsequently may have been caused by high levels of cariogenic foods such as bread or sugar. In this study, human dentition was assessed to identify the presence of dental calculus, caries, enamel hypoplasia, periodontal disease, granulomas, abscesses, ante-mortem tooth loss and occlusal wear. Each tooth was scored (after Brothwell 1981; Buikstra and Ubelaker 1994) mainly by presence/absence and position of dental pathology, and any other dental anomalies of interest were also noted.

6.4.1.1 Dental Calculus

Dental calculus (tartar) occurs when the plaque that forms on the surface of the tooth mineralises and because of its mineral composition, it survives in all but acid burial environments. Calculus has been associated with a high protein diet and can induce periodontal disease resulting in resorption of bone (Hillson 1996). Calculus is one of the most common dental pathologies found in the archaeological record; although taphonomic processes may cause calculus deposits to break off the tooth. Therefore, the amount of calculus recorded may not be an accurate representation of presence during life; hence the degree of calculus was not scored in this study, only the presence or absence.

6.4.1.2 Dental Caries

Dental caries is the most common dental pathology found in both modern and archaeological human populations. Carious lesions on teeth range from spots on the tooth surface to large pulp-invading cavities (Hillson 1996). Caries occur when bacterial infection, caused by fermentable carbohydrates (e.g. wheat and barley) and foods high in sugar, degrade the enamel, dentin and cementum of the tooth (Aufderheide and Rodríguez-Martin 1998).

6.4.1.3 Dental Enamel Hypoplasia

Dental enamel hypoplasia (DEH) is caused by the disruption of amelogenesis (enamel formation), which manifests as linear grooves or pits on the tooth and is associated with various metabolic diseases, with poor childhood nutrition or illness being the main causative factors (Aufderheide and Rodríguez-Martin 1998; Larsen 1999). Although microscopic methods to measure DEH are suggested to be highly beneficial, in reconstructing childhood health (e.g. Hassett 2014), only macroscopic identification could be applied in this study.

6.4.1.4 Periodontal Disease

Periodontal disease occurs initially with inflammation to the gingival soft tissues and ultimately to the bone, causing alveolar bone resorption, exposure of the tooth root and ante-mortem tooth loss. Differential diagnosis for periodontal disease includes compensatory eruption, which occurs due to severe tooth wear (Roberts and Manchester 2005). Periodontal disease can be caused by dental calculus, poor oral hygiene and foods rich in sugars and carbohydrates (Hillson 1986). Periodontal disease is sometimes difficult to identify or quantify in skeletal material as taphonomic damage to alveoli may hinder accurate assessment.

6.4.1.5 Dental Abscesses and Granulomas

Dental abscesses occur when the pulp chamber of a tooth is exposed to infection from bacteria in the mouth. This can be caused by advanced caries, dental trauma, periodontal disease, or severe wear (Hillson 1996). Once the infection has killed the pulp cavity it may then spread through the root canal and eventually result in pressure caused by a build-up of infectious fluid, causing a fenestration (hole) in the bone for the fluid to escape (Hillson 1986, 1996; Roberts and Manchester 2005). Voids that have rounded or thickened margins are identified as chronic abscesses rather than granulomas (Ogden 2008).

Dental granulomas occur when bacteria enters the pulp chamber, either due to caries, trauma or severe attrition. Thereafter, inflammation results in obstructed blood supply, subsequently leading to death of the pulp and pus production (Hillson 1996). Reactive inflammation then affects the periodontal tissue and the affected bone becomes resorbed by granulation tissue. Granulomas can become cystic, the size of which can increase over a number of years, especially if the corresponding tooth has not been removed (Ogden 2008). Voids with sharp margins of approximately 2-3mm are recognised as granulomas and those greater than 3mm are considered to be cystic (Dias and Tayles 1997; Dias *et al*. 2007).

6.4.1.6 Ante-mortem Tooth Loss

The loss of teeth during life can be due to a number of factors including trauma, dental disease (e.g. periodontal, caries or abscess) or severe wear (Roberts and Manchester 2005). Ante-mortem tooth loss (AMTL) was identified where the tooth socket had evidence of full or partial bone remodelling. In some cases, the maxilla and/or mandible may be fully edentulous (complete AMTL) and further resorption of the surround bone structure may be evident.

6.4.1.7 Dental Wear

Dental wear can be caused by attrition (e.g. tooth on tooth contact) or abrasion (e.g. coarse food or activity-related wear); hence factors that influence dental wear may include food preparation, diet, lifestyle or dental pathologies (Hillson 1986). Occlusal wear was scored using a modified Smith (1984) and Brothwell (1981) method, the latter of which has been suggested to be very useful in skeletal collections where many of the anterior teeth were absent (Ogden 2008), as is the case in a number of skeletons in this study.

6.4.1.8 Dental Anomalies

Dental anomalies include imbrication (overcrowding), impaction (failure to erupt or partial angled eruption), hypodontia (one or more teeth absent), hyperdontia (more teeth present than normal), retention of deciduous teeth and atypical rotation of teeth. These anomalies can be due to congenital defects or physiological consequences, such as the dental arcade being too small to accommodate full dentition (Hillson 1996). In this study, dental anomalies were identified following key texts (Hillson 1996) and clinical publications (e.g. Dhanrajani 2002), then described and noted on the dental recording sheet.

6.4.2 Skeletal Pathologies

Markers of pathology on bone can provide a wealth of information relating to aspects of health, disease and trauma, thereby enabling the reconstruction of past lifeways. In this study, human skeletal material was examined for evidence of a number of bone pathologies, including infectious and respiratory diseases, developmental or congenital conditions, neoplasms, circulatory disorders, joint diseases and trauma. Identification, diagnoses or differential diagnoses of bone pathologies were made following criteria from key palaeopathological texts, mainly Aufderheide and Rodríguez-Martín (1998), Ortner (2003) and Roberts and Manchester (2005), although other palaeopathological and clinical publications were also consulted (e.g. Grauer 2012).

6.4.2.1 Infectious and Respiratory Diseases

A number of infectious or respiratory diseases can be identified on the skeleton and may contribute to interpretations of past lifeways, including aspects of occupation and environmental influences. Moreover, when compared with burial evidence, such diseases may infer aspects of the society in which an individual lived, for example, how they were treated in death despite their affliction in life (see chapter 8).

6.4.2.1.1 Treponemal Disease

Treponemal diseases, such as venereal syphilis, yaws, bejel (*Treponema pallidum*) and pinta (*Treponema carateum*) can be acute, subacute or chronic and can be transmitted by human to human contact (Aufderheide and Rodríguez-Martín 1998; Ortner 2003; Roberts and Cox 2003). Skeletal changes include destructive lesions and irregular repair, known as *caries sicca*, most commonly on the parietal and frontal bones of the skull. Facial bones, such as the nasal aperture and palate may also undergo destructive changes and associated pathological lesions may occur on the lower limbs, such as osteomyelitis, periostitis and osteitis (Roberts and Cox 2003; Roberts and Manchester 2005). It has been suggested that a distribution of periosteal new bone on the tibiae and distal femora, and to a lesser extent on the arm bones is associated with venereal syphilis (Steinbock 1976). However, periosteal manifestations on limb bones can also occur from other diseases, such as leprosy. Therefore, without changes to the skull, which are more suggestive of venereal syphilis than non-specific periosteal new bone (Roberts and Manchester 2005), diagnosis is tentative.

6.4.2.1.2 Leprosy

Lepromatous leprosy is a chronic infectious disease caused by *Mycobacterium leprae*, which is spread by human to human contact and may result in peripheral nerve damage, widespread ulceration, blindness, severe deformation to the extremities and facial disfigurement (Aufderheide and Rodríguez-Martin 1998; Rawcliffe 2006). As opposed to tuberculoid leprosy (TL), lepromatous leprosy (LL) is a slow-acting, low resistance disease that can take over a decade for visual changes to occur. Similar to treponemal disease, periosteal new bone formation on the tibiae and fibulae is associated with LL. Pathognomonic skeletal changes associated with LL (but not TL) include bone resorption to the metatarsals, metacarpals and to the phalanges of the hands and feet (Roberts and Manchester 2005). Changes to the facial bones, including resorption of the maxillary alveolae, anterior nasal spine and aperture, and pitting of the palate, are pathognomonic of rhinomaxillary syndrome, which is only present in the chronic low resistance form of LL or near-lepromatous leprosy (Andersen and Manchester 1992). Evidence of LL was therefore identified in this study where skeletal changes to the hands and feet and/or rhinomaxillary syndrome were identified.

6.4.2.1.3 Tuberculosis

The human form of tuberculosis (TB) is caused by *Mycobacterium tuberculosis*, with pulmonary TB being the common type, caught from human to human contact of saliva or mucosa. Animal to human TB infection is caused by *Mycobacterium bovis*, which often affects the gastrointestinal tract. Skeletal changes associated with human TB include lesions on visceral ribs, osteomyelitis and septic arthritis and possible ankyloses of the joints, with the hip and knee joints mostly affected (Aufderheide and Rodríguez-Martin 1998; Roberts and Manchester 2005). However, it is changes to the spine, known as Pott's disease, which is the most pathognomonic of TB, and also tuberculosis dactylitis, which is an inflammation of the hand or foot bones (Roberts and Cox 2003; Roberts and Manchester 2005). In this study, TB is diagnosed where there is evidence of Pott's disease and/or dactylitis. A combination of rib and limb periosteal new bone is diagnosed as possible TB.

6.4.2.1.4 Periosteal New Bone

Although the term 'periostitis' is widely used to describe certain changes to archaeological bone, it is not as such a disease of the bone but an inflammation of the periosteum, a layer of connective tissue that surrounds the bone. Moreover, the term 'non-specific infection' is used to describe infective changes to bone where the aetiology is unknown (Weston 2012). The description of periosteal new bone (PNB) will therefore be used here to describe these changes specifically to bone. PNB manifests as bony changes that cover the normal bone cortex and in chronic stages may result in expansion of the shaft (Ortner 2003). PNB initially manifests as woven bone (active at time of death) and over time as lamellar bone (healed at time of death) and can have different forms such as pitted or striated (Weston 2012). PNB can be caused by trauma or infection to the soft tissue (Roberts and Manchester 2005); due to infectious diseases such as leprosy, syphilis or tuberculosis (Roberts and Cox, 2003), or associated with metabolic diseases such as scurvy (Ortner *et al*. 2001). The cause of PNB can be complex and its presence cannot be used to diagnose a specific disease if no other indicators are evident on the skeleton. In this study, PNB on ribs that cannot be associated with TB is reported separately to PNB on other skeletal elements, to identify possible association with respiratory disease.

6.4.2.1.5 Sinusitis

Sinusitis is an inflammation of the facial sinuses (ethmoidal, frontal, maxillary), which manifests as new bone formation, most commonly affecting the maxillary sinuses. The aetiology can be either through invasive dental or respiratory infections, the latter being caused by exposure to dry, smoky, overheated and poorly ventilated atmospheres. Allergies and infectious diseases that involve the nasal mucosa can also be the cause (Roberts 2007, 2009; Roberts and Cox 2003). Sinusitis could only be identified macroscopically in this study, where sinus bones were broken post-mortem; hence the observed prevalence may not reflect the actual prevalence of this pathology.

6.4.2.1.6 Nasal concha bullosa

Nasal concha bullosa is an expansion of the inferior nasal conchae, which are situated perpendicular to the left and right ethmoid plates (Mays *et al.* 2014). It has been suggested that this is an anatomical variant that can vary in size, although it is also thought to predispose paranasal sinus infection (Kwiatkowska *et al*. 2011). However, no evidence has been found to link nasal concha bullosa to sinusitis (Mays *et al.* 2014), although due to the lack of this pathology in the palaeopathological literature, its presence is noteworthy. This condition was identified macroscopically by inspecting the nasal cavity.

6.4.2.2 Metabolic Diseases

Certain metabolic diseases can be associated with nutritional problems, either due to diet or physiological anomalies (Ortner 2003) and are often described as 'indicators of stress' (Roberts and Manchester 2005: 222). However, it is worth noting that the presence of stress markers on bone may suggest than an individual was strong enough to survive the disease, at least long enough for it to manifest on the bone (Wood *et al*. 1992).

6.4.2.2.1 Rickets and Osteomalacia

Rickets is caused by a deficiency of vitamin D, which is essential for the absorption of calcium and phosphorus to facilitate the mineralisation of bone, hence its strength. Only around 10% of Vitamin D is sourced from food, such as fish oils and animal fats, with the remaining 90% from sunlight on the skin (Holick 2004; Giuffra *et al*. 2013). This may suggest why few cases are seen from rural medieval Britain, where outdoor life was more prevalent (Lewis 2007). However, although sunlight is of primary importance for vitamin D absorption, the contribution from diet is paramount when access to sunlight is limited (Roberts and Cox 2003). Skeletal manifestations include thinning of bones or deposits of PNB on the skull and softening and subsequent bent and misshapen long bones (Aufderheide and Rodríguez-Martin 1998; Ortner 2003), hence a diagnosis of rickets was made in this study following these descriptors.

Healed rickets can be identified on adult bones if for example; the bowing effects from childhood have not been reconciled throughout the growth period (Ortner 2003; Roberts and Manchester 2005), and were identified as such in this study. Osteomalacia, which is a vitamin D and calcium deficiency, is the adult version of childhood rickets, although the skeletal manifestations of osteomalacia may differ as limb bowing is rarely seen, although vertebral compression, pelvic deformity and pseudo-fractures can occur (Aufderheide and Rodríguez-Martin 1998; Roberts and Manchester 2005; Brickley and Buckberry 2015).

6.4.2.2.2 Scurvy

Scurvy is caused by a deficiency of vitamin C (ascorbic acid), which is found in fresh fruit, vegetables and to a lesser extent in animal foods (Ortner 2003; Mays *et al.* 2013). Vitamin C deficiency occurred in sedentary communities with the advent of agriculture and prolonged food storage (Roberts and Manchester 2005). However, a low occurrence of scurvy and rickets throughout the medieval period suggests that access to fresh foods was adequate (Roberts and Cox 2003). Scurvy manifests as pitting and/or new bone formation, mostly affecting the skull, although the ribs and long bones can also be affected. Scorbutic lesions are more visible on infant bones, although adult bone lesions may occur on the mandibular or maxillary alveoli due to inflammatory changes (Aufderheide and Rodríquez-Martín 1998; Ortner 2003).

Aufderheide and Rodríguez-Martin (1998: 313) have noted that “scurvy and rickets superficially share several features: widened metaphyses of long bones (especially those of the lower limbs), and prominent ‘knobby’ costochondral rib junctions.” For this reason, and for diagnosing ambiguous pathological markers on bone, differential or possible diagnosis may be presented.

6.4.2.2.3 Internal Frontal Hyperostosis

Internal frontal hyperostosis (IFH) is a metabolic disorder that commonly affects post-menopausal women. Pathological bone changes involve nodular bone deposits and thickening of the endocranial (inner) surface of the cranium, most commonly occurring on the frontal bone, although the parietal and temporal bones may also be affected (Ortner 2003). As this condition can only be macroscopically identified on the inner surface of crania, many more cases may be overlooked on skeletons with complete skulls.

6.4.2.2.4 Osteoporosis

Like IFH, Type I osteoporosis is also common in post-menopausal women and Type II osteoporosis can occur in both sexes, known as senile osteoporosis, although there are few examples of both types in the archaeological record (Ortner 2003; Roberts and Manchester 2005). Bone loss is the main factor, which can lead to thinning of the bone and fractures, with cancellous bones such as the ribs, pelvis, vertebrae and sternum most affected. Bilateral atrophy of cranial bone can also occur although this is very rare in the archaeological record (Aufderheide and Rodríguez-Martin 1998).

6.4.2.2.5 Cribra Orbitalia and Porotic Hyperostosis

Cribra orbitalia (CO) and porotic hyperostosis (PH) manifest as porosity on the orbital roof and outer cranial vault respectively. They are most commonly thought to be caused by iron-deficiency anaemia (Stuart-Macadam, 1985; Roberts and Manchester 2005), although recent studies suggest a vitamin B_{12} deficiency during infancy, with nutrient losses from gastrointestinal infections (Walker *et al.* 2009). Buikstra and Ubelaker (1994: 151*ff.*) recommended both CO and PH bone changes to be identified as being either active (score 1) or healed (score 2) at the time of death, with varying degrees of porosity (scores 1-3).

6.4.2.2.6 Paget's Disease of Bone

Paget's disease of bone (PDB) is a chronic, progressive skeletal disorder that is caused by a disruption in normal bone turnover, resulting in excessive bone destruction, and softer bone formation. Bones become thickened and misshapen and can be susceptible to fractures (Aufderheide and Rodríguez-Martin 1998; Roberts and Manchester 2005). Although this condition was discovered over 130 years ago, by Sir James Paget, its aetiology is still unknown. It is often suggested to have a slow-acting viral origin (Aufderheide and Rodríguez-Martin 1998; Tan and Ralston 2014), although other factors including a genetic predisposition (Visconti *et al*. 2010), childhood vitamin D deficiency (Barker and Gardner 1974), and exposure to environmental pollutants (Lever 2002) have also been suggested. A high prevalence of PDB in contemporary northwest England has been found centred on Lancashire towns, with a noticeable prevalence also found in Cheshire (Barker *et al*. 1980; Cooper *et al.* 2006), which is pertinent to this study. PDB was identified in this study by the presence of excessive thickening of bone, and in some cases where reduction of the medullary cavity and disorganised new bone formation was present. X-rays were not taken, although for one extreme case, x-rays were obtained from the University of Bradford, where a previous osteological assessment (Boylston 2008) on the Norton assemblage had taken place.

6.4.2.3 Developmental and Congenital Anomalies

Developmental anomalies on human skeletons may be caused by either intrinsic (genetic) or extrinsic (environmental) factors, some of which, such as sacralisation, are commonly seen in the archaeological record, although they can be more difficult to detect in delicate sub-adult bones (Roberts and Manchester 2005; Barnes 2012b). A number of anomalies were identified in this study (see chapter 7), all of which were identified macroscopically. Some challenges were encountered, specifically with vertebral border shifting, where all vertebrae from the skeleton were not present, hence the full extent of the anomaly could not be ascertained in some cases.

6.4.2.4 Neoplasms

Neoplasms are new bone growths or destructive lesions that manifest in either a benign (e.g. button osteomas) or malignant (e.g. metastic carcinoma) form (Aufderheide and Rodríguez-Martín 1998; Ortner 2003). Button osteomas are commonly found on archaeological skeletons, although malignant neoplasms are rare, especially types such a Ewing’s sarcoma and primary malignant lymphoma (Brothwell 2012). In this study, neoplastic diagnoses were obtained based on descriptions of lesion morphology from Aufderheide and Rodríguez-Martin (1998), Ortner (2003), Roberts and Manchester (2005) and Brothwell (2012). X-rays were obtained, from the Royal Liverpool University Hospital Radiography Department, on two possible cases of neoplasm to aid diagnosis, although other cases had sufficient evidence on the bone to enable macroscopic identification.

6.4.2.5 Circulatory Disorders

Circulatory disorders can be caused by vascular deficiency, infection, genetics or cancer (Aufderheide and Rodríguez-Martin 1998). However, trauma is gaining predominance in the palaeopathological literature as a causative factor. For example circulatory disorders, such as Osgood-Schlatter's disease, Scheuermann’s disease, slipped femoral capital epiphysis and intervertebral osteochondrosis are suggested to be linked with trauma, especially in males. However, apart from Osgood-Schlatter's, all these conditions may also be linked to a genetic predisposition, making conclusive diagnosis difficult (Aufderheide and Rodríguez-Martin 1998; Ortner

2003; Roberts and Cox 2003). In this study, circulatory disorders were identified from skeletal changes to the vertebrae (Scheuermann's disease and intervertebral osteochondrosis), femur (slipped femoral capital epiphysis) and tibia (Osgood-Schlatter's), following diagnostic criteria (*cf.* Aufderheide and Rodríguez-Martin 1998; Ortner 2003).

6.4.2.6 Joint Diseases

Although some scholars suggest vertebral degenerative joint disease (DJD) is inconclusive when considering stress factors relating to activity (e.g. Lovell 1994; Knüsel *et al.* 1997), other scholars associate joint disease with strenuous occupation and a gendered-division in labour (Sofaer Derevenski 2000; Roberts and Cox 2003). The term 'DJD' has been avoided in this study, as joint disease is multifactorial and is not just associated with age, but with sex, environment, genetics, and even joint stress, due to obesity (Waldron 1994, 2012; Brandt *et al*. 1998). Moreover, the intervertebral bodies degenerate differently to the vertebral facets; hence the umbrella term 'vertebral osteoarthritis' can also be misleading when reporting overall vertebral joint disease (Rogers and Waldron 1995). Therefore, vertebral joint disease is presented in this study separately as vertebral body joint disease (VBJD) and vertebral facet joint disease (VFJD) and elsewhere as extra-vertebral osteoarthritis (EVOA). VBJD, VFJD and EVOA were scored using a modified grading system devised by Sager (1969, in Brothwell 1981) as 0: normal bone surface, 1: slight intermittent osteophytes and/or porosity, 2: moderate continuous osteophytes and/or porosity, and 3: considerable osteophytic lipping, porosity and/or eburnation and joint contour change. Miscellaneous joint diseases in this study include septic arthritis, psoriatic arthritis, gout, seronegative spondyloarthropathies (e.g. ankylosing spondylitis) and os acromiale, which were identified from key palaeopathological text (Aufderheide and Rodríguez-Martín 1998; Ortner 2003; Roberts and Manchester 2005).

6.4.2.6.1 Diffuse idiopathic skeletal hyperostosis (DISH)

DISH is often linked to Type II diabetes and obesity, exacerbated by a rich diet, although the exact aetiology is still debated (Waldron 1985; Rogers and Waldron 2001). DISH is usually diagnosed when the anterior longitudinal ligament on four or more continuous vertebrae are fused, although if fewer than four vertebrae show signs of fusion, this may be diagnosed as early DISH (Waldron 2009). This manifestation usually occurs on the right side of the thoracic vertebrae, although the lumbar vertebrae and extra-vertebral bones can also be affected, thereby distinguishing it from ankylosing spondylitis (Roberts and Manchester 2005; Waldron 2009). These skeletal indicators were therefore used to diagnose DISH or probable DISH in this study.

6.4.2.6.2 Schmorl's Nodes

Schmorl's nodes are often characterised as depressed or linear lytic lesions on the vertebral body, most commonly found in the lower thoracic and lumbar vertebrae. They occur due to herniation of the nucleus pulposus, a soft substance found in the centre of the intervertebral disc, which distributes pressure under compressed loads (Ortner 2003; Roberts and Manchester 2005). Although grouped with joint disease, this pathology can have an underlying aetiology linked to osteoporosis, neoplastic disease, trauma or genetics (Dar *et al.* 2010; Jiménez-Brobeil *et al.* 2012; Novak and

Šlaus 2011). Following Knüsel *et al.* (1997) a scoring system of 1 to 3 for slight, moderate and severe nodes was used on the upper and lower vertebral bodies.

6.4.2.7 Fractures and Trauma-related Pathologies

Fractures can be caused by accidents, inflicted trauma or as a secondary complication due to disease-weakened bone (Aufderheide and Rodríguez-Martin 1998; Novak 2007; Martin *et al.* 2013). Fractures and dislocations were recorded following recommendations by Lovell (1997) and Roberts and Connell (2004), including bone and location affected, fracture type, size and evidence of healing. Other types of trauma assessed in this study included spondylolysis, myositis ossificans traumatica, vertebral compression and osteochondritis dissecans. Causative factors other than trauma need to be considered, such as osteoporosis in vertebral compression or a congenital predisposition for spondylolysis (Turkel 1989), although the latter is now believed to be caused by repetitive stress on the neural arch of the spine (Lovell 1997; Mays 2006c). Miscellaneous trauma was diagnosed from skeletal indicators presented in Aufderheide and Rodríguez-Martin (1998) and Roberts and Manchester (2005).

6.4.2.8 Sharp-force Trauma

Sharp-force trauma on bone is often indicative of violence or conflict, although other types of blade wounds may imply surgical procedures, such as amputation or trepanation (Aufderheide and Rodríguez-Martin 1998). In this study, sharp-force trauma on bone was identified by its morphology, such as a linear wound with a well-defined clean edge; a smooth surface on the sloped side and rough flaking on the other (Boylston 2004). The presence or absence of healing was also recorded to diagnose a probable cause of death and where possible, to differentiate between inflicted peri-mortem trauma and post-mortem damage, during excavation for example.

6.5 Stable Isotope Methods

Stable isotope analysis has become an important tool in bioarchaeology, not only to reconstruct past diets but to form part of a multidisciplinary approach, to reconstruct past lifeways and to address issues relating to cultural, religious and socio-economic influences therein.

6.5.1 Human Sample Selection

From Portmahomack human bone, a sub-sample of 97 adult individuals was taken for isotope analysis. Additionally, isotope data from 40 adult samples, which were analysed prior to this study (Curtis-Summers *et al.* 2014), were included to provide a complete dietary reconstruction of the Portmahomack adult population. The age categories for these samples were based on those provided by King (2000), which have now been re-categorised (section 6.3.2) to correspond with adult ages assigned in this study. Samples were also taken from 8 sub-adults from the early medieval monastic phase (n=1) and late medieval lay phase (n=7) at Portmahomack, to provide a case study to investigate if childhood diets differed to adult diets.

From Norton, a sub-sample was selected of 114 adults. However, collagen was only successfully extracted from 84 samples; hence the samples that had failed are not considered further in this study. Due to funding restrictions, no sub-adults from Norton were sampled for isotope analysis. Additionally, pathological bone was extracted from 5 adult males with Paget's disease and a pilot study was conducted to enable comparisons between the isotope results of normal and pathological bone from the same individual (see section 7.4.3.3). The affected individuals from Norton represent high status lay people from a Christian community, hence reflecting an important aspect of past Christian lifeways.

Where possible, rib samples were taken from Portmahomack and Norton human skeletons, avoiding any pathological markers that may alter normal isotope values. If ribs were absent, samples were taken from the hands or feet to minimise destruction of larger bones. This sampling strategy was also adopted for fauna; although preferred skeletal elements were not always available, hence other skeletal elements (e.g. pelvis) were sampled from the Portmahomack and Norton faunal remains.

6.5.2 Faunal Sample Selection

Bone samples were taken from 55 fauna from Portmahomack, comprising a range of terrestrial (cattle, sheep/goat, pig, red deer, roe deer and dog), marine (cod, haddock, horse mackerel, saithe, pollack, otter and eel) and freshwater (char) species. Additionally, isotope results for 16 faunal samples from a previous study (Curtis-Summers *et al.* 2014) were included in the overall Portmahomack faunal isotope results.

From Norton, 36 faunal bone samples were selected, comprising cattle, sheep/goat, pig, red deer and bear. Because only one fish (cod) sample was available from Norton, 9 marine fish bone samples (cod and eel) were sourced from Chester Cathedral to represent marine fish consumption within medieval religious houses in

Cheshire, England. Species identification of a number of Portmahomack and Norton faunal samples were required and confirmed for terrestrial (D.Orton, *pers.comm*.; K.Seetah, *pers.comm*.; S.Stallibrass, *pers.comm.*), marine and freshwater species (M.Holmes, *pers.comm.;* H.Russ, *pers.comm.*).

Faunal species selected for this study, were mainly those that would provide an isotopic baseline to reconstruct human diets, including terrestrial herbivores (cattle, sheep/goat and deer), omnivores (pig, dog and bear), marine (e.g. cod and eel) and freshwater (char) fish. Faunal bone samples were selected with the aim to represent as many chronological and/or occupational phases as possible. Faunal bones from periods 1 to 4 (6^{th} to 16^{th} centuries) at Portmahomack were selected and at Norton, from the 14^{th} and 15^{th} centuries and from the pre-dissolution group. Fish bone samples selected from Chester Cathedral was reported to be from within medieval layers (Ward 2000).

When selecting faunal bone samples, those with visible pathological markers, butchery marks or charred/burnt bones were avoided to minimise atypical isotope results. Only adult faunal bones were selected to avoid suckling and/or weaning isotopic signatures, hence bone elements with un-fused or partially fused epiphyses (indicating juvenile stages) were not selected.

6.5.3 Sample Preparation for Isotope Analysis

Bone samples were removed with bone clippers, which were cleaned with acetone between each sample to avoid cross-contamination and all work surfaces were kept clean with purified water. Bone samples were cut transversely and then longitudinally. Cutting the bone longitudinally also has the benefit of preserving the length of the collagen fibrils and therefore its strength (Buehler 2006). Where faunal bone samples were too difficult to be cut with bone clippers, they were cut with a stainless steel, flexible dental saw with a diamond cutting edge. A section of bone was cut, where possible, longitudinally and the saw was cleaned in between each sample with acetone to minimise contamination.

Sample preparation and isotope analysis procedures were performed similarly to that of Richards and Hedges (1999), from a modified Longin (1971) method. This method uses diluted aqueous hydrochloric acid ($HCl_{(aq)}$) to minimise collagen destruction that may occur when using more concentrated HCl (Pearson 2004). All sample preparation was performed following stable isotope palaeodiet laboratory procedures set down by the Department of Archaeology, Classics and Egyptology, at the University of Liverpool, under the supervision of Dr Jessica Pearson.

6.5.3.1 Demineralisation

Approximately 200-500mg of bone was weighed and placed into labelled test tubes. Each test-tube was filled with 0.5M $HCl_{(aq)}$ and placed in a refrigerator at 4°C until the sample had demineralised. Well-preserved samples that took longer to demineralise were kept at room temperature. If demineralisation was not complete after around 5 days, the $HCl_{(aq)}$ was changed. Once demineralisation was complete, each sample was rinsed three times with ultrapure H_2O (18.2MΩ.cm) to neutralise the pH. Samples were then prepared for gelatinisation or stored in the refrigerator until this stage could be completed.

6.5.3.2 Gelatinisation and Filtering

The final H_2O rinse was discarded and pH3 H_2O (HCl) was added to each test-tube and a lid placed on each. The samples were then transferred into a heating block at 70ºC, wrapped in aluminium foil for insulation, and left for 48 hours or until all bone mineral was dissolved. After removal from the heating block, the solution from each sample was fed through an EZee™ 9ml (60-90µm pore size) filter and transferred to a clean test-tube, with the insoluble residue retained in the filter, which was discarded.

6.5.3.3 Lyophilisation and Sample Weighing

After filtering, each test-tube was sealed with perforated Parafilm and transferred to a -35ºC freezer until fully frozen. Once frozen, the samples were then transferred immediately to a freeze-dryer until dry (lyophilisation). The bulk yield of extracted collagen from each sample was weighed and from this, duplicate samples weighing between 0.580-0.625mg were weighed and secured into tin capsules for mass spectrometric analysis.

6.5.4 Analysis by Mass Spectrometry

All prepared samples were measured by Continuous-Flow Elemental Analysis-Isotope Ratio Mass Spectrometry (CF-EA-IRMS) at the NERC (Natural Environment Research Council) NIGL (NERC isotope Geoscience Laboratory) stable isotope facility, Nottingham, UK. NERC NIGL standards used were M1360p (powdered gelatine from BDH chemicals, UK) with expected values of -20.32‰ for $\delta^{13}C$ (against the carbon standard of Vienna-PDB) and +8.12‰ for $\delta^{15}N$ (against the nitrogen standard of AIR). These were run at intervals of five samples. The mass spectrometry analytical precision is ± 0.1‰ at one standard deviation (1σ). All stages of mass spectrometry analysis were carried out under the supervision of Dr Angela Lamb at NERC NIGL.

6.6 Statistical Analysis

Chi-squared tests were used to analyse osteological data to investigate if statistical differences were present between age and sex groups, archaeological periods, diet, and disease types within Portmahomack and Norton Priory. Two-sample *t*-tests were also used to compare means of adult stature and of carbon and nitrogen isotope values of age- sex- and period-specific groups. In all cases variances were unequal; therefore *t*-tests assuming unequal variance were used. A Shapiro-Wilk test for normality was done for the isotope data and in no case was the null hypothesis of normality rejected. Statistical results with a 'p-value' less than 0.05 (i.e. 5%) are reported in this study as having a statistical difference, hence rejecting the null hypothesis of there being no difference between groups tested. Additionally, bar charts and bi-plots were used to provide descriptive statistics of the skeletal and isotope data. All data and statistical tests were processed on Microsoft Excel, except for the test for normality, which was processed in SPSS. By testing category-specific groups, it is anticipated that differences in past lifeways may be detected, with those that are statistically different reported (see chapter 7).

6.7 Chapter Conclusion

This chapter has presented the materials used and methodologies applied in this study. Osteological methods of ageing, sexing, stature and metrics were discussed, as well as palaeopathology methods to identify dental and skeletal pathologies. The methodology for stable carbon and nitrogen isotope and mass spectrometry analysis was also presented, along with the protocols used therein. Finally, the types of statistical tests used for skeletal and isotope data in this study were indicated. The results of assessments and analyses discussed here will be reported in the following chapter.

Chapter 7

RESULTS

7.1 Introduction

This chapter presents the results of analyses on human skeletons from Portmahomack and Norton Priory using methodologies outlined in the previous chapter. The first section begins by presenting the results of osteological assessments to determine sex, age, stature, osteometric and non-metric traits (section 7.2). The following section presents the results of investigations for evidence of dental and bone pathologies (section 7.3). The final section presents results from stable carbon and nitrogen isotope analysis on human and faunal bone collagen (section 7.4). Results presented here will provide a basis for discussion in chapter 8.

The various periods from Portmahomack that are presented in this chapter represent groups that had different religious foci (see chapter 3). To reiterate, these chronological periods represent the earliest lay proto-monastic group (*period 1*: *c*.550 – *c*.700), the monastic phase (*period 2-3*: *c*.700 – *c*.1100), the lay parish church phase (*period 4*: *c*.1100 – *c*.1600), and the lay post-reformation group (*period 5*: *c*.1600 – *c*.1700). In contrast, burials from all periods at Norton (12th to 16th century) represent those of ecclesiastical and lay status that followed the Augustinian religion. In this chapter, results from different groups at Portmahomack will be referred to by their period and those from Norton within their respective century.

7.1.1 Presentation of Summary Data

Osteological and stable isotope data were recorded in Microsoft Excel. Unfortunately, data on overall health and disease in medieval Britain has not been uniformly recorded, and category-specific prevalence is not often presented, making direct comparisons difficult. Roberts and Cox (2003) identified this problem and consequently reported many of their results by crude prevalence rates. However, when referring to disease prevalence, it has been suggested the term ‘rate’ should be avoided, as disease prevalence is strictly a proportion with no time element (Dolin 1997). Osteological data is presented here as crude prevalence and expressed as a percentage (CP%), which was calculated by the number of individuals affected by the total group scored. Where relevant, age-, sex- or period-specific prevalence (ASP%, SSP%, PSP%) is also presented, which was calculated by the number affected by the number scored in each group. Total sample size is denoted by ‘N’ and by ‘n’ for affected sub-samples. Descriptive statistics in the form of bar charts for osteology data and bivariate plots for stable carbon and nitrogen isotope data are used. Where statistically significant ($p < 0.05$), the results of paired *t*-test to compare mean values and chi-squared test to identify differences, will also be presented.

7.2 Osteology Results

Osteology results presented here are from skeletal assessments performed to determine adult sex, age, stature, osteometric and non-metric traits. Sub-adult age was also assessed to provide a demographic profile of both sites. Apart from perinatal skeletons (<38 weeks gestation), all age categories presented in this chapter refer to age in years.

7.2.1 Demographic Overview

Osteological methods to assess age and sex (see chapter 6) have been used to provide a demographic profile for Portmahomack and Norton. It has been suggested that predominantly male burials within religious sites represent a male ecclesiastical community (Carver 2008; Gilchrist and Sloane 2005). Such evidence has been found from period 2-3 burials at Portmahomack. Lay burials, such as those of wealthy benefactors at Norton, were found within the same cemetery as ecclesiastics, making it difficult to differentiate between the two. However, segregation of burials, depending on status, is evident in some circumstances at Norton, as presented in chapter 3.

From Portmahomack, 178 articulated skeletons were assessed in this study, comprising 138 adults and 40 sub-adults. Burials are assigned to periods 1 (6^{th}-7^{th} century), 2 (8^{th} century), 3 (9^{th}-11^{th} century), 4 (12^{th}-16^{th} century) or 5 (17^{th} century). Radiocarbon dates have been provided from 1 sub-adult and 31 adult skeletons (Carver 2008; Carver *et al*. forthcoming). From Portmahomack (Table 7.1), the majority of adult burials overall were male, with the highest percentage from periods 2 (96%) and 3 (100%). Both of these periods represent the monastic phase (period 2-3) and shall therefore be considered together in this study, unless discussing period-specific individuals. The greatest number of males from period 2 were aged 46-59 (n=23), which supports the demographic of a middle-aged male religious community during this time. Only two females were present from the monastic-phased burials; one being aged 46-59, the other of undetermined age (Figure 7.1). From lay period 4, adult males and females occurred in equal numbers within the 26-35 and 60+ age categories and the highest number of adults overall were aged 46-59 (n=20). A higher percentage of males (61%) compared to females (39%) was found in period 4, although not to the extent from the monastic phase, hence reflecting more of a family group pattern, with male, female and child burials present.

Table 7.1: Portmahomack adults per age, sex and period.

	Period 1			Period 2			Period 3			Period 4			Period 5		
	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?
18-25				5 (1)						6 (2)	2 (1)	1			
26-35	3	1		5			1			5	5				
36-45	2 (1)			8 (4)			2			10	4		1		
46-59		2		23 (3)	1					11 (1)	9 (2)			1	
60+	1			5						2	2				
Adult	3 (1)	1 (1)		5 (3)	1	2				5 (3)	3 (1)				
Total	**9**	**4**	**0**	**51**	**2**	**2**	**3**	**0**	**0**	**39**	**25**	**1**	**1**	**1**	**0**
Sex ratio (%)	69	31		96	4		100			61	39		50	50	

Numbers in parentheses represent probable male or female that are included in total individuals present.
Shaded areas = not applicable.

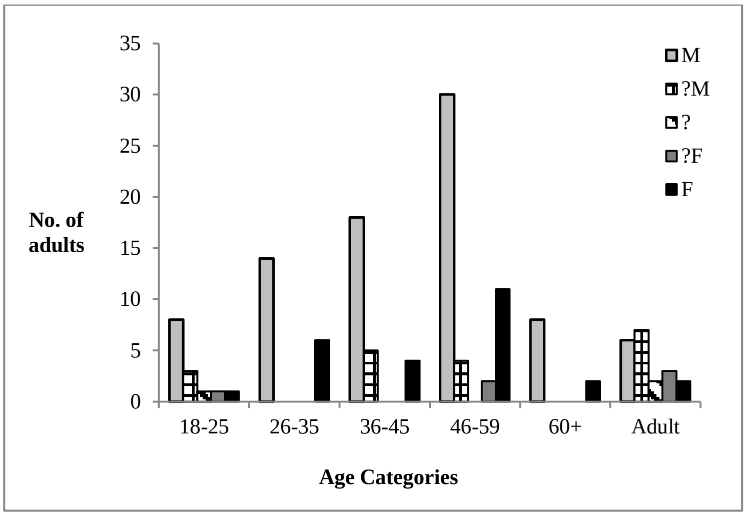


Figure 7.1: Portmahomack adult age categories.

Sub-adults from Portmahomack mostly belong to periods 4 and 5 (Table 7.2), with the highest number aged 2.6-6.5 (n=6) in period 4 and 0-1 (n=10) in period 5 (Figure 7.2). Only one sub-adult, aged 10.6-14.5, was present from monastic period 2. This individual may have been an oblate at the monastery or at least closely associated to the religious community at Portmahomack.

Table 7.2: Portmahomack sub-adults per age and period.

	Period 1	Period 2	Period 3	Period 4	Period 5
Perinate				1	
0-1				2	10
1.1-2.5				3	4
2.6-6.5				6	1
6.6-10.5				5	
10.6-14.5		1		5	
14.6-17.0				2	
Total	**0**	**1**	**0**	**24**	**15**

Shaded areas = no sub-adults present.

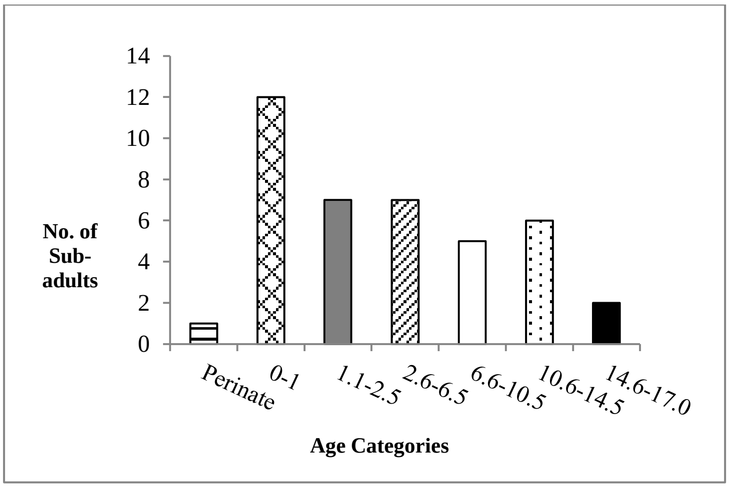


Figure 7.2: Portmahomack sub-adult age categories.

From Norton, 128 articulated skeletons were assessed, comprising 115 adults and 13 sub-adults. The majority of adult burials at Norton were male, with the greatest number belonging to those aged 26-35 (n=32). The highest number of adult female burials (n=11) were also aged 26-35 (Figure 7.3). The greatest number of adult male burials belongs to the 14th and 15th centuries, with female burials occurring equally across the 13th and 14th centuries (Table 7.3). No female burials were found from the 12th and 16th centuries and male burials dominate compared to female burials in the 14th (82% to 18%) and 15th centuries (79% to 21%). However, the sex ratio of burials is similar in the 13th century (56% to 44%). This variation in male and female burials reflects a priory cemetery that contained both ecclesiastical and lay burials. Fifteen adult burials have not been assigned to a period, although they are believed to belong to pre-dissolution levels, possibly within the late 15th century (Greene 1989). They are included here for continuity, although direct comparisons with period-specific groups cannot be made.

Table 7.3: Norton adults per age, sex and period.

	12th C			13th C			14th C			15th C			16th C			?period		
	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?	M (?M)	F (?F)	?
18-25	(1)							3		1	1					1		
26-35				5 (1)	(2)		15	2		9 (1)	4					3	3	
36-45	1			1	(1)		8			11 (1)	1		1			(1)	1	
46-59	1			3	4		8 (2)	1	1	6						5	1	
60+							1			2	1							
Adult								(1)		1	1	2						
Total	**3**	**0**	**0**	**9**	**7**	**0**	**32**	**7**	**1**	**30**	**8**	**2**	**1**	**0**	**0**	**10**	**5**	**0**
Sex ratio (%)	100			56	44		82	18		79	21		100			67	33	

Numbers in parentheses represent probable male or female that are included in total individuals present.
Shaded areas = not applicable.

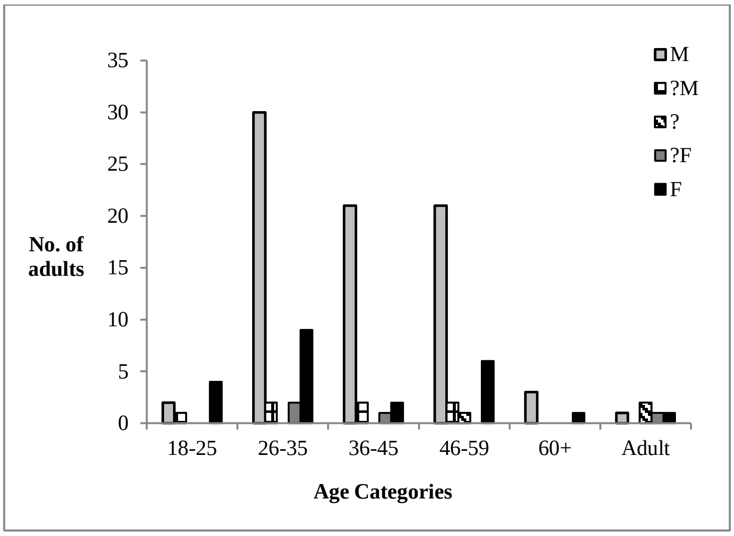


Figure 7.3: Norton adult age categories.

The greatest number of sub-adult burials occurs in the 2.6-6.5 age category (Figure 7.4). Overall however, the number of child burials at Norton is low (Table 7.4), suggesting the majority of children in this community had for example, adequate nutrition or immunity, thereby reducing child mortality or that children were buried elsewhere.

Table 7.4: Norton sub-adults per age and period.

	12th C	**13th C**	**14th C**	**15th C**	**16th C**	**?period**
Perinate				1		
0-1			1			
1.1-2.5			1			
2.6-6.5			3	1		
6.6-10.5						3
10.6-14.5						
14.6-17.0			1	1		
Sub-adult						1
Total	**0**	**0**	**6**	**3**	**0**	**4**

Shaded areas = no sub-adults present.

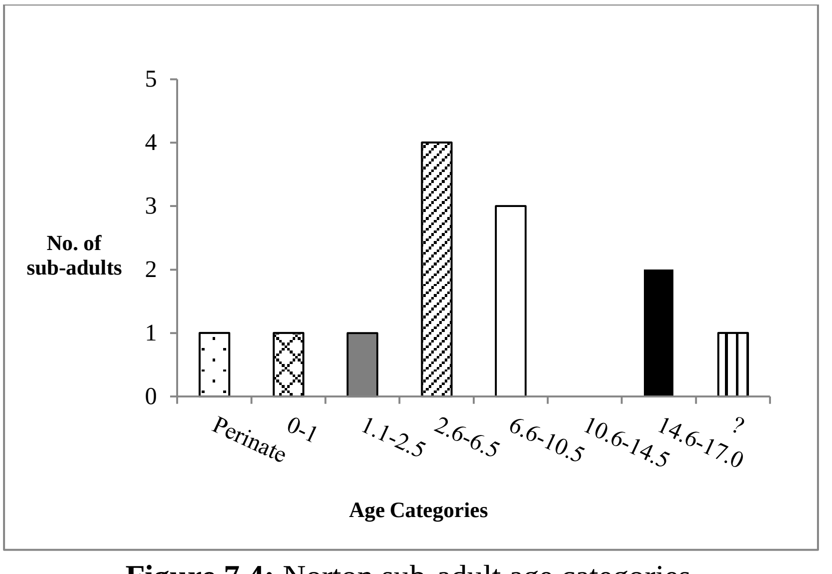


Figure 7.4: Norton sub-adult age categories.

7.2.2 Stature estimation

Portmahomack adult male stature ranged from 156cm to 180cm, with an overall average of 170cm, which is similar to national averages reported by Roberts and Cox (2003). There is a slight decrease in average male stature from periods 1 (n=7), 2-3 (n=44) and 4 (n=47) at 172cm, 170cm, and 169cm respectively. Stature for the individual male from period 5 (16th century) was 168cm. Female stature from Portmahomack ranged from 146cm to 166cm with an average of 156cm. Average female stature for periods 1 (n=3), 2-3 (n=2) and 4 (n=21) are 158cm, 157cm and 156cm respectively, again revealing a decrease in stature over time. A significant difference was found between males from period 1 and those from period 4 ($t(13) = 2.16$, $p = 0.039$), with males from period 1 having greater stature.

Adult male stature from Norton ranged from 162cm to 183cm with an overall average of 173cm. Average male stature from the 13th, 14th and 15th centuries were 173cm, 172cm and 174cm respectively, hence no significant decrease in male stature over time. Female stature from Norton ranged from 149cm to 162cm with an overall average of 156cm. Average female stature from the 13th, 14th and 15th centuries was 159cm, 158cm and 153cm, which does suggest a slight decrease in female stature over time, although not to a significant level. Overall, Norton male and female stature differs slightly to those reported by Roberts and Cox (2003: 248), for late medieval Britain of 171cm for males and 159cm for females. Therefore, Norton average stature for males is 2.5cm taller and for females, 2.5cm shorter than the national average for this period. Despite the slight variation in adult stature at Norton, no significant differences were found.

7.2.3 Osteometric Analysis

Results from measurements (in mm) of the skull, femora and tibiae are reported here to describe physical characteristics and to ascertain if any similarities in craniofacial morphology are present to interpret biological or familial affinities of human groups. Where relevant, average measurements were recorded with one standard deviation (1σ) to illustrate craniofacial and lower limb shape between different periods.

Crania from 31 males and 6 females from Portmahomack were measured for selected craniofacial indices (Tables 7.5 and 7.6). Portmahomack male cranial shape (Table 7.7) of the dolichocrany (narrow) and mesocrany (average) ranges occurred in most periods, especially in periods 2 and 4. Brachycrany (broad) cranial shape was found in males from lay periods 1 (n=1) and 4 (n=2).

The upper facial and nasal indices for Portmahomack males suggests a meseny (average) facial shape and leptorrhiny (narrow) nasal apertures in all periods where measurements taken. A difference in orbital shape for males was present, with those in periods 1 (n=1) and 2 (n=5) revealing hypsiconchy (narrow) orbits, whereas those from period 4 (n=13) had mesoconchy (average) shaped orbits.

Table 7.5: Cranial indices for Portmahomack males.

	Period 1			Period 2			Period 3			Period 4			Period 5		
Index	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**
Cranial	2	77.0	1.1	13	72.4	6.7	0			13	74.8	5.3	0		
Upper facial	0			2	54.8	2.8	0			6	53.4	4.0	0		
Nasal	1	41.5		6	45.5	5.0	0			12	46.2	5.1	0		
Orbital	1	96.1		5	92.0	5.6	0			13	86.6	6.5	0		

Shaded areas = not applicable.

Table 7.6: Cranial indices for Portmahomack females.

	Period 1			Period 2			Period 3			Period 4			Period 5		
Index	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**
Cranial	1	70.6		0			0			3	72.9	8.4	1	76.7	
Upper facial	0			0			0			3	48.3	5.3	1	57.4	
Nasal	0			0			0			3	52.3	6.4	1	43.3	
Orbital	1	89.9		0			0			4	92.1	5.8	1	86.1	

Shaded areas = not applicable.

Overall, Portmahomack females had similar cranial morphology to their male counterparts, although 1 female from lay period 1 had a narrower head shape (doliocrany) than the 2 males from the same period who had a mesocrany (average) head shape. Two females from lay period 4 had broader (euryeny) faces and nasal (platyrrhiny) apertures and 3 females had narrower (hypsiconchy) orbits than the males from the same period. No statistical difference in craniofacial morphology was found at Portmahomack.

Table 7.7: Portmahomack cranial index ranges.

Ranges	**Period 1**		**Period 2**		**Period 3**		**Period 4**		**Period 5**		**Totals**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Dolichocrany		1	7				6	1			13	2
Mesocrany	2		5				5	2		1	12	3
Brachycrany			1				2				3	
Hyperbrachycrany												
Totals	**2**	**1**	**13**	**0**	**0**	**0**	**13**	**3**	**0**	**1**	**28**	**5**

Cranial index ranges (mm): Dolichocrany: <74.99 (narrow or long headed), Mesocrany: 75.0 - 79.99 (average or medium), Brachycrany: 80.0 - 84.99 (broad or round headed), Hyperbracycrany: >85.0 (very broad headed).
Shaded areas = no indices present.

To assess lower limb shape at Portmahomack (Tables 7.8 and 7.9), femora were measured for antero-posterior flattening (meric index) and tibiae were measured for the degree of medio-lateral flattening (cnemic index) (Brothwell 1981; Bass 1995). Measurements were taken from 106 femora (81 males, 24 females and 1 adult) and 81 tibiae (63 males and 18 females).

Table 7.8: Portmahomack male platymeric and platycnemic averages.

Index	Period 1			Period 2			Period 3			Period 4			Period 5		
	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD
Platymeric	7	80.9	3.3	37	79.8	7.3	1	79.6		35	83.0	8.3	1	86.9	
Platycnemic	5	70.1	6.1	23	71.1	7.3	1	58.8		31	72.5	9.0	1	75.2	

NB: One adult (?Sex) from period 2 with platymeria of 79.1. No platycnemic measurement.
SD = one standard deviation (1σ). **Shaded areas** = not applicable.

Table 7.9: Portmahomack female platymeric and platycnemic averages.

Index	Period 1			Period 2			Period 3			Period 4			Period 5		
	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD
Platymeric	3	73.6	13.1	1	82.2		0			19	76.9	7.1	1	86.4	
Platycnemic	3	71.4	6.7	1	78.2		0			13	68.3	6.9	1	65.4	

SD = one standard deviation (1σ). **Shaded areas** = not applicable.

The greatest occurrence of femoral shape for both sexes from periods 1 to 4 at Portmahomack was found in the platymeric range, suggesting a broad or flat femoral shape (Table 7.10). Additionally, some males from lay period 4 (n=15) differed from their counterparts and had eurymeric (rounded) femora, as did adults from period 5 (n=2). A significant difference was found over time, with platymeric and eurymeric femora found most within periods 2 and 4 (χ^2 (3) = 8.91, p = 0.031). Such variation may be due to biological responses from extrinsic (e.g. environment) or intrinsic (genetic) factors.

Table 7.10: Portmahomack platymeric (femora) index ranges.

Ranges	Period 1		Period 2		Period 3		Period 4		Period 5		Totals	
	M	F	M	F	M	F	M	F	M	F	M	F
Platymeric	6	3	29	1	1		21	17			**57**	**21**
Eurymeric	1		7				15	2	1	1	**24**	**3**
Stenomeric											**0**	**0**
Totals	**7**	**3**	**36**	**1**	**1**	**0**	**36**	**19**	**1**	**1**	**81**	**24**

Platymeric ranges (mm): Platymeric: <84.9 (broad or flat), Eurymeric: 85.0 - 99.9 (rounded), Stenomeric: >100.0 (usually found in pathological cases). **Shaded areas** = no indices present.

From the platycnemic index (Table 7.11), the majority of Portmahomack adults (n=43) had eurycnemic tibiae (rounded), although some males from periods 2 (n=7) and 4 (n=12) had mesocnemic (average) tibiae. Females from period 4 had observed eurycnemic (round) and mesocnemic (average) tibiae equally (n=5). Overall, no significant difference in tibial shape from periods 1-5 was found at Portmahomack.

Table 7.11: Portmahomack platycnemic (tibiae) index ranges.

Ranges	Period 1		Period 2		Period 3		Period 4		Period 5		Totals	
	M	F	M	F	M	F	M	F	M	F	M	F
Hyperplatycnemic							1				**1**	**0**
Platycnemic	1		4		1		2	3			**8**	**3**
Mesocnemic		1	7				12	5		1	**19**	**7**
Eurycnemic	4	2	13	1			17	5	1		**35**	**8**
Totals	**5**	**3**	**24**	**1**	**1**	**0**	**32**	**13**	**1**	**1**	**63**	**18**

Platycnemic ranges (mm): Hyperplatycnemic: <54.9 (very flat), Platycnemic: 55.0 - 62.9 (flat), Mesocnemic: 63.0-69.9 (average/normal proportions), Eurycnemic: >70.0 (rounded shaft).
Shaded areas = no indices present.

From Norton, crania from 20 males and 6 females were measured for selected craniofacial indices (Tables 7.12 and 7.13). The greatest number of Norton male (n=7) and female (n=2) crania had mesocrany (average) or brachycrany (broad) head shapes (Table 7.14), although in the 15th century, 3 males had a dolichocrany (narrow) head shape. Hyperbrachycrany (very broad) head shape was found in 1 male from the 12th century and 1 female from the 14th century. Differences in head shape suggest no familial links, particularly in the 15th century where the most variation occurs.

Table 7.12: Cranial indices for Norton males.

	12th C			13th C			14th C			15th C			16th C			?Period		
Index	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**
Cranial	2	83.8	7.2	2	79.5	2.0	6	80.3	2.6	6	75.9	3.1	0			2	82.6	3.3
Upper facial	1	45.3		1	47.8		3	55.8	2.7	0			0			0		
Nasal	1	49.1		1	51.6		4	44.0	2.3	2	49.8	2.7	0			0		
Orbital	1	81.1		2	92.7	5.7	4	82.9	2.9	0			0			0		

Shaded areas = not applicable.

Males from the 12th (n=1) and 13th (n=1) century had a euryeny (broad) facial shape, whereas males from the 14th (n=3) century had a lepteny (narrow) facial shape. Mesorrhiny (average) nasal apertures were found in males from the 12th (n=1), 13th (n=1) and 15th (n=2) centuries. Males from the 14th (n=4) century had a leptorrhiny (narrow) nasal aperture as did both females from the 14th and 15th century. For orbital shape, males from the 12th (n=1) and 14th (n=4) century had chamaeconchy (wide) orbits, whereas males from the 13th (n=2) century had hypsiconchy (narrow) orbits.

Table 7.13: Cranial indices for Norton females.

	12th C			13th C			14th C			15th C			16th C			?Period		
Index	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**	**N**	**Ave**	**SD**
Cranial	0			0			2	85.2	2.3	2	81.0	4.3	0			1	75.4	0
Upper facial	0			0			0			0			0					
Nasal	0			0			1	41.9		1	45.7		0					
Orbital	0			0			1	89.3		2	98.8	4.9	0					

Shaded areas = not applicable.

No upper facial indices could be measured for the Norton females and only cranial indices from the 14th and 15th century females were available. Females from the 15th (n=2) century also had hypsiconchy (narrow) orbits whereas 1 female from the 14th century had mesoconchy (average) orbits. There are some similarities in the craniofacial shape of Norton individuals, although there is variation across different periods. Overall, no significant difference in craniofacial morphology was found at Norton.

Table 7.14: Norton cranial index ranges.

Ranges*	12th C		13th C		14th C		15th C		16th C		?Period		Totals	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Dolichocrany							3						**3**	
Mesocrany	1		1		3		2	1				1	**7**	**2**
Brachycrany			1		3	1	1	1			2		**7**	**2**
Hyperbrachycrany	1					1							**1**	**1**
Totals	**2**	**0**	**2**	**0**	**6**	**2**	**6**	**2**	**0**	**0**	**2**	**1**	**18**	**5**

*****See table 7.7 for cranial index ranges. **Shaded areas** = no indices present.

To assess lower limb shape at Norton (Tables 7.15 and 7.16), measurements were taken from 82 femora (66 males and 16 females) and 73 tibiae (60 males, 12 females and 1 undetermined).

Table 7.15: Norton male platymeric and platycnemic averages.

Index	12th C			13th C			14th C			15th C			16th C			?Period		
	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD
Platymeric	0			5	84.9	8.0	28	89.6	7.0	26	89.6	8.1	1	78.9		6	92.7	7.1
Platycnemic	0			5	69.9	6.5	27	24.4	5.7	23	72.1	6.7	1	73.2		4	73.9	0.8

NB: One adult (?Sex) from 15th C with platycnemia of 73.2. No platymeric measurement.
SD = one standard deviation (1σ). **Shaded areas** = not applicable.

Table 7.16: Norton female platymeric and platycnemic averages.

Index	12th C			13th C			14th C			15th C			16th C			?Period		
	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD	N	Ave	SD
Platymeric	0			5	89.5	2.1	3	91.1	4.6	6	89.6	4.4	0			2	93.7	1.4
Platycnemic	0			2	71.9	0.7	3	77.0	6.7	4	73.6	3.2	0			3	79.3	17.1

Shaded areas = not applicable.

The majority of males and females from Norton had eurymeric (rounded) femora (Table 7.17), especially in the 14th and 15th century. Variation does occur, with 15 males from the 13th to 16th century and 1 female from the 15th century having platymeric (broad or flat) femora. However, no significant differences were found in femoral shape at Norton, suggesting that any variation could be in response to extrinsic factors, such as environmental or biomechanical stresses.

Table 7.17: Norton platymeric (femora) index ranges.

Ranges*	12th C		13th C		14th C		15th C		16th C		?Period		Totals	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Platymeric			3		6		4	1	1		1		15	1
Eurymeric			2	5	22	3	22	5			5	2	51	15
Stenomeric														
Totals	**0**	**0**	**5**	**5**	**28**	**3**	**26**	**6**	**1**	**0**	**6**	**2**	**66**	**16**

***** See table 7.10 for platymeric ranges. **Shaded areas** = no indices present.

The majority of Norton adults, mostly from the 14th and 15th century, had eurycnemic (rounded) tibiae (Table 7.18), although variation does occur with 16 males from the 13th to 15th century and 1 female from the 15th century within the mesocnemic (average) range. Three males from the 13th to 15th century and 1 female (unknown period) had platycnemic (broad) tibiae. This variation may be due to biomechanical plasticity, from either environmental or genetic influences.

Table 7.18: Norton platycnemic (tibiae) index ranges.

Ranges*	12th C		13th C		14th C		15th C		16th C		?Period		Totals	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Hyperplatycnemic														
Platycnemic			1		1		1					1	3	1
Mesocnemic			2		5		9	1					16	1
Eurycnemic			2	2	21	3	13	3	1		4	2	41	10
Totals	**0**	**0**	**5**	**2**	**27**	**3**	**23**	**4**	**1**	**0**	**4**	**3**	**60**	**12**

***** See table 7.11 for platycnemic ranges. **Shaded areas** = no indices present.

7.2.4 Non-metric Analysis

From Portmahomack, the greatest prevalence (CP%) of cranial non-metric traits included zygomaticofacial and supraorbital foramina (Table 7.19), which also dominated when period-specific prevalence (PSP%) was taken into account

(Appendix 3a). These non-metric traits (NMT) were found solely on males from monastic period 2-3 and on males from lay period 4, with cranial NMT observed on only a small number of females from lay periods 1 (n=1), 4 (n=7) and 5 (n=1). No evidence of bregmatic bone was found and the least prevalence overall was found in coronal ossicle, epipteric bone, foramen of Huschke and double condylar facets. Again, this pattern was found when PSP% was taken into account.

Table 7.19: Cranial non-metric traits for Portmahomack adults.

Trait	**N (CP%)**			
Ossicle at lambda	13 (9.4)			
Bregmatic bone				
Metopism	6 (4.3)			
	Right		**Left**	
	N	**CP%**	**N**	**CP%**
Lambdoid ossicles	19	13.8	24	17.4
Parietal foramen	29	21.0	25	18.1
Coronal ossicle	0		2	1.4
Epipteric bone	1	0.7	0	
Parietal notch bone	3	2.2	5	3.6
Ossicle at asterion	7	5.1	11	8.0
Foramen of Huschke	1	0.7	1	0.7
Posterior condylar canal	23	16.7	25	18.1
Condylar facet double	1	0.7	2	1.4
Precondylar tubercle	12	8.7	13	9.4
Foramen ovale incomplete	3	2.2	1	0.7
Accessory lesser palatine foramen	11	8.0	9	6.5
Zygomaticofacial foramen	49	35.5	44	31.9
Supraorbital foramen	37	26.8	39	28.3
Frontal foramen	9	6.5	8	5.8
Accessory infra-orbital foramen	8	5.8	10	7.2

Shaded areas = no traits present.

From Portmahomack, the greatest CP% of postcranial NMT was trochanteric fossa exostosis and lateral tibial squatting facets (Table 7.20). These NMT were also the highest when PSP% was taken into account (Appendix 3b). No evidence of hypotrochanteric fossa or third trochanter was found and the lowest percentage occurred from Allen's fossa, septal aperture and absence of anterior calcaneal facet. The least PSP% of postcranial NMT was found in Allen's fossa and medial tibial squatting facets. In contrast, a high occurrence of lateral tibial squatting facets was found from periods 1, 2 and 4, representing those of both lay and monastic status, with the latter most affected. Moreover, all males from monastic period 2 that had avulsion fractures to the 5th metatarsal tuberosity (see section 7.3.9.1) also had lateral tibial squatting facets. This suggests a biomechanical response to repetitive dorsiflexion of the foot from squatting and strenuous pressures on the lateral part of the foot, resulting in trauma.

Table 7.20: Postcranial non-metric traits for Portmahomack adults.

Trait	**Right**		**Left**	
	N	**CP%**	**N**	**CP%**
Allen's fossa	3	2.2	1	0.7
Poirier's facet	19	13.9	21	15.3
Hypotrochanteric fossa	0		0	
Exostosis: trochanteric fossa	47	34.3	48	35.0
Third trochanter	0		0	
Medial tibial squatting facet	4	2.9	4	2.9
Lateral tibial squatting facet	33	24.1	41	29.9
Supercondyloid process	0		1	0.7
Septal aperture	3	2.2	7	5.1
Double anterior calcaneal facet	22	16.1	27	19.7
Anterior calcaneal facet absent	2	1.5	1	0.7

Shaded areas = no traits present.

The greatest CP% of cranial NMT at Norton consisted of zygomaticofacial foramen and supraorbital foramen (Table 7.21). These NMT were also the greatest in occurrence when PSP% was calculated (Appendix 3c), although some variation occurred, with high percentages found predominantly in males, of lambda ossicles (66.7%), lambdoid (right: 52.9% and left: 44.1%) ossicles (Figure 7.5) and parietal foramen (both sides: 42.9%) in the 12th, 14th and 15th century respectively. This high prevalence of cranial ossicles may suggest a familial affinity between some males at Norton (see section 8.3.2). The least CP% overall was found in bregmatic bone and the right side for epipteric bone and parietal notch bone. A similar occurrence was found in PSP%, as well as low percentages of double condylar facets.

Table 7.21: Cranial non-metric traits for Norton adults.

Trait	**N (CPR%)**			
Ossicle at lambda	12 (10.4)			
Bregmatic bone	2 (1.7)			
Metopism	7 (6.1)			
	Right		**Left**	
	N	**CPR %**	**N**	**CPR %**
Lambdoid ossicles	29	25.2	27	23.5
Parietal foramen	34	29.6	37	32.2
Coronal ossicle	4	3.5	3	2.6
Epipteric bone	2	1.7	5	4.3
Parietal notch bone	1	0.9	4	3.5
Ossicle at asterion	10	8.7	10	8.7
Foramen of Huschke	10	8.7	11	9.6
Posterior condylar canal	14	12.2	14	12.2
Condylar facet double	8	7.0	5	4.3
Precondylar tubercle	21	18.3	20	17.4
Foramen ovale incomplete	4	3.5	0	
Accessory lesser palatine foramen	8	7.0	11	9.6
Zygomaticofacial foramen	50	43.5	41	35.7
Supraorbital foramen	47	40.9	39	33.9
Frontal foramen	11	9.6	10	8.7
Accessory infra-orbital foramen	3	2.6	4	3.5

Shaded area = no trait present.

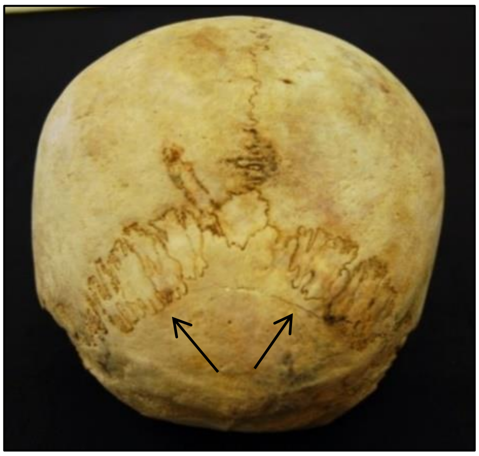


Figure 7.5: Lambdoid ossicles on NP112.

From Norton, the greatest CP% of postcranial NMT were trochanteric fossa exostosis and double anterior calcaneal facets (Table 7.22), observed predominantly on males. This may suggest a biomechanical response to prolonged activity, which may be gender-specific. These NMT also dominated when PSP% was taken into account (Appendix 3d). No evidence of hypotrochanteric fossa was found and no postcranial NMT were found from the 12th century. The lowest CP% overall occurred from Allen's fossa, medial tibial squatting facet and supracondyloid process. When PSP% was calculated, the least occurrences included Allen's fossa, supracondyloid process and septal aperture.

Table 7.22: Postcranial non-metric traits for Norton adults.

Trait	Right		Left	
	N	CPR %	N	CPR %
Allen's fossa	2	1.7	2	1.7
Poirier's facet	15	13.0	10	8.7
Hypotrochanteric fossa	0		0	
Exostosis: trochanteric fossa	16	13.9	21	18.3
Third trochanter	4	3.5	4	3.5
Medial tibial squatting facet	1	0.9	0	
Lateral tibial squatting facet	7	6.1	12	10.4
Supercondyloid process	2	1.7	1	0.9
Septal aperture	6	5.2	6	5.2
Double anterior calcaneal facet	25	21.7	31	27.0
Anterior calcaneal facet absent	9	7.8	7	6.1

Shaded areas = no traits present.

7.3 Palaeopathology Results

The results of skeletal and dental assessments on Portmahomack and Norton skeletons to identify the presence of pathological markers are presented here. Evidence of illness, disease or trauma will be used to reconstruct and interpret aspects of medieval lifeways in chapter 8. Where appropriate, category-specific or crude prevalence's will be presented in this section, as will chi-square results that were found to reveal statistical differences ($p < 0.05$).

7.3.1 Dental Pathologies

At Portmahomack dental pathologies were identified on 64 males and 11 females, with 1248 and 133 teeth observed respectively. No dentition was present on period 2 females; hence comparisons cannot be made with males from this period. For sub-adults (n=20), 193 teeth were observed (110 deciduous and 83 permanent). From Norton, dental pathologies were identified on 72 males, 24 females, with 1005 and 268 teeth observed respectively. On sub-adults (n=10), 81 teeth were observed (44 deciduous and 37 permanent). Summary data is presented here by adult sex-specific prevalence (SSP%) and crude prevalence (CP%) for sub-adults.

7.3.1.1 Ante-mortem Tooth Loss

SSP% of Ante-mortem Tooth Loss (AMTL) affected 33.0% of males and 21.9% of females from Portmahomack (Table 7.23), with the highest occurrences being found in monastic period 2 for males and lay period 4 for females. The highest number of AMTL occurred in the 46-59 age group for both sexes. A highly significant difference was found between males from period 2-3 and those from period 4 (χ^2 (1) = 154.31, $p < 0.001$). This suggests that males from the monastic phase had a greater occurrence of AMTL than those from the later lay phase.

Table 7.23: Dental pathology summary for Portmahomack adults.

Teeth observed	Adults (N=135)			Male (n=103)			Female (n=32)		
	1381			1248			133		
Dental pathology	**Teeth affected**	**Individuals affected**	**CP%**	**Teeth affected**	**Individuals affected**	**SSP%**	**Teeth affected**	**Individuals affected**	**SSP%**
AMTL	393	41	**30.4**	311	34	**33.0**	82	7	**21.9**
Wear	1364	73	**54.1**	1231	63	**61.2**	133	10	**31.3**
Calculus	705	64	**47.4**	632	55	**53.4**	73	9	**28.1**
DEH	145	31	**23.0**	135	28	**27.2**	10	3	**9.4**
Caries	70	29	**21.5**	51	22	**21.4**	19	7	**21.9**
Abscess	46	22	**16.3**	43	20	**19.4**	3	2	**6.3**
Granuloma	58	27	**20.0**	53	24	**23.3**	5	3	**9.4**
Periodontitis	310	30	**22.2**	273	25	**24.3**	37	5	**15.6**

From Norton, 47.1% of males and 70.4% of females were affected by AMTL (Table 7.24), with the highest occurrences being found in the 14th and 15th century for both males and females. The highest number of AMTL occurred in the 46-59 and 60+ age groups for females and 36-45 and 46-59 for males. Overall, a highly significant difference was found, with females more affected than males (χ^2 (1) = 8.37, p = 0.004). A period-specific significant difference from the 15th century was found (χ^2 (1) = 7.80, p = 0.005), again with females being more affected than males.

Table 7.24: Dental pathology summary for Norton adults.

Teeth observed	Adults (N=112)			Male (n=85)			Female (n=27)		
	1273			1005			268		
Dental pathology	**Teeth affected**	**Individuals affected**	**CP%**	**Teeth affected**	**Individuals affected**	**SSP%**	**Teeth affected**	**Individuals affected**	**SSP%**
AMTL	257	59	**52.7**	186	40	**47.1**	71	19	**70.4**
Wear	1239	90	**80.4**	979	66	**77.6**	260	24	**88.9**
Calculus	837	80	**71.4**	683	61	**71.8**	154	19	**70.4**
DEH	43	11	**9.8**	36	8	**9.4**	7	3	**11.1**
Caries	96	36	**32.1**	61	26	**30.6**	35	10	**37.0**
Abscess	13	10	**8.9**	13	10	**11.8**	0		
Granuloma	20	16	**14.3**	10	10	**11.8**	10	6	**22.2**
Periodontitis	37	6	**5.4**	33	4	**4.7**	4	2	**7.4**

Shaded areas = no pathology.

7.3.1.2 Dental Wear

Although dental wear is not technically a dental disease, it can be associated with other pathologies, such as caries, that manifest when extreme wear exposes the pulp chamber (Lukacs, 1989). Therefore, prevalence of dental wear will be provided here.

Dental wear was observed on 61.2% of males and 31.3% of females from Portmahomack. The most severe wear (score 3) was found on the dentition of 43.7% of males (Figure 7.6) and 15.6% of females across all periods, although the highest prevalence was observed in moderate wear (score 2), with 56.3% for males and 28.1% for females. The highest occurrence of moderate wear for males was found in periods 2 and 4 and for females in periods 1 and 4. The majority of severe wear on males and females was found in the 46-59 age group, with males from monastic period 2-3 affected significantly more than those from lay period 4 (χ^2 (1) = 23.41, p < 0.001). This correlates with males most affected by AMTL being from the monastic phase.

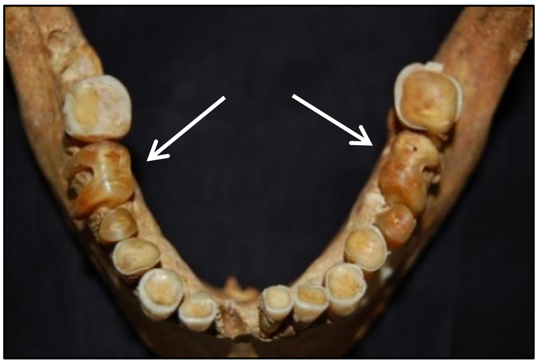


Figure 7.6: Severe dental wear on PMK164.

Dental wear was observed on 30.0% of Portmahomack sub-adults (Table 7.25), with the majority of individuals (27.5%) with slight wear (score 1). Moderate wear occurred on 17.5% of sub-adults, mostly on individuals aged 6.6-10.5 from period 4. No severe wear was observed on the Portmahomack sub-adult dentition and no significant differences were observed.

Table 7.25: Portmahomack sub-adult dental pathology summary.

	Sub-adult (N=40)		
Deciduous teeth observed	110		
Permanent teeth observed	83		
Dental pathology	**Teeth affected**	**Individuals affected**	**Individuals affected CP%**
Wear	117	12	**30.0**
Calculus	39	7	**17.5**
DEH	5	1	**2.5**
Caries	2	1	**2.5**
Abscess	1	1	**2.5**
Granuloma	1	1	**2.5**

From Norton, 77.6% of males and 88.9% of females had observed wear, the majority being moderate wear, which was found in 74.1% of males and 85.2% of females. The most severe wear occurred in 32.9% of males, mostly from the 12th to 15th century and in 29.6% of females mostly from the 13th to 15th century and in the 46-59 age group. Females from the 14th century were found to be more significantly affected by severe wear than females from the 15th century (χ^2 (1) = 4.35, p = 0.037). One male aged 46-59 from the 15th century (NP71), had the greatest occurrence overall with the majority of teeth affected by severe wear.

Dental wear was observed on 61.5% of Norton sub-adults (Table 7.26), with the same percentage having slight wear. Moderate wear occurred on 30.8% of sub-adults, mostly from 2.6-6.5 and 6.6-10.5 age groups. Severe wear was observed on one sub-adult aged 6.6-10.5 (7.7%) from the pre-dissolution phase (period unknown). No statistical differences were observed.

7.3.1.3 Dental Calculus

Calculus was observed on 53.4% of males (n=55) and 28.1% (n=9) of females from Portmahomack. In males, the highest percentage (42.7%) occurred on the buccal aspect, mostly from periods 2 and 4 and in the 36-45 and 46-59 age groups, although three males from period 1, aged 26-35 and 60+, were also affected. In females, the highest percentage (15.6%) of calculus was found equally on the interproximal aspects and on all surfaces across most age groups within period 4. Chi-squared tests revealed no statistical relationships for calculus on adult dentition from Portmahomack. Calculus occurred on 17.5% (n=7) of sub-adults from Portmahomack, with the highest percentages found on the buccal (12.5%), lingual and external (both 10.0%) aspects, across most age groups (except 0-1 years), from lay periods 4 and 5.

From Norton, calculus occurred on 71.8% (n=61) of males and 70.4% (n=19) of females. The highest percentage in males (57.6%) occurred on the interproximal aspect in the 26-35 age group, mostly from the 13th, 14th and 15th centuries, and in females (Figure 7.7), on the lingual aspect (48.1%) across all age groups, mostly from the 14th and 15th centuries. A highly significant difference was found between males and females overall (χ^2 (1) = 10.35, p = 0.001), with males being more affected. Males were also affected more than females in the 14th century (χ^2 (1) = 5.42, p = 0.020) and 15th century (χ^2 (1) = 5.56, p = 0.018). A statistical difference was also found between males, with those from the 15th century more affected than those from the 14th century (χ^2 (1) = 3.69, p = 0.054).

Calculus was observed on 23.1% (n= 3) of Norton sub-adults, equally present on the lingual, external and interproximal aspects (15.4%), on one aged 6.6-10.5 years (period unknown) and two from the 14th and 15th century, aged 14.6-17.0 years. No statistical differences were observed.

Figure 7.7: Dental calculus on NP120.

Table 7.26: Norton sub-adult dental pathology summary.

Sub-adult (N=13)			
Deciduous teeth observed	44		
Permanent teeth observed	37		
Dental pathology	**Teeth affected**	**Individuals affected**	**Individuals affected CP%**
Wear	59	8	**61.5**
Calculus	14	3	**23.1**
DEH	0		
Caries	3	3	**23.1**
Abscess	0		
Granuloma	0		

Shaded areas = no pathology.

7.3.1.4 Dental Enamel Hypoplasia

Dental Enamel Hypoplasia (DEH) was observed on 27.2% (n=28) of males and 9.4% (n=3) of females from Portmahomack, the highest percentage of which occurred as lines (as opposed to pits or grooves) on the buccal aspect (26.2%) of males, mostly from periods 2 and 4 and across all age groups. DEH occurred only on the buccal aspect of all females observed in the 36-45 and 46-59 age groups from lay periods 4 and 5. A highly significant difference was found between males from monastic period 2-3 and lay period 4 (χ^2 (1) = 41.75, $p < 0.001$), with those from the latter being more affected. Within period 4, males were significantly affected more than females (χ^2 (1) = 8.16, $p = 0.004$). Only one sub-adult (2.5%) from Portmahomack aged 6.6-10.5 from period 4 had DEH lines affecting three teeth on the buccal aspect and two teeth on the external aspects.

From Norton, 9.4% (n=8) of males and 11.1% (n=3) of females had evidence of DEH. The highest percentage for males (7.1%) and females (7.4%) occurred as lines on the buccal aspect, with those in males (Figure 7.8) occurring mostly within the 26-35 and 46-59 age groups from the 13th, 14th and 15th centuries. DEH occurred in females, from the 14th and 15th centuries, with two of the three individuals affected being of unknown age, the other aged 18-25 years. A statistical difference between males from the 14th and 15th centuries was found (χ^2 (1) = 6.17, $p = 0.013$), with the former being more affected. No evidence of DEH was observed on any sub-adult dentition from Norton.

Figure 7.8: Dental enamel hypoplasia on NP38.

7.3.1.5 Dental Caries

Caries was observed on 21.4% (n=22) of males and 21.9% (n=7) of females from Portmahomack. The highest male percentages occurred within the 26-35 and 46-59 age groups as interproximal (5.8%) and cervical (6.8%) caries on the mesial and distal aspects from lay period 4, with males from monastic period 2 being most affected, although not to a significant level. Female percentages were highest as interproximal caries on the mesial (6.3%) and distal (9.4%) aspects and cervical caries on the mesial aspect (6.3%) from all age groups observed. A statistical difference was found between males and females from period 4 (χ^2 (1) = 6.08, p = 0.014), with females being more affected. No caries were observed on adults from lay period 1. Caries were only observed on one Portmahomack sub-adult (2.5%) aged 6.6-10.5 years from period 4. These manifested as lesions on two teeth: one on the occlusal aspect and one on the distal interproximal aspect.

From Norton, 30.6% (n=26) of males and 37.0% (n=10) of females (Figure 7.9) had evidence of caries. The highest percentage of caries in males manifested as interproximal lesions on the mesial and distal (12.9%) surfaces across all age groups and periods. Female caries percentages were also highest in interproximal lesions on the mesial (22.2%) and distal (18.5%) surfaces, mostly in the 26-35 group from the 14^{th} and 15^{th} centuries. A highly significant difference was found, with females being more affected by caries than males overall (χ^2 (1) = 14.83, p < 0.001); in the 14^{th} century (χ^2 (1) = 9.48, p = 0.002), and more significantly in the 15^{th} century (χ^2 (1) = 20.58, p < 0.001).

Figure 7.9: Carious lesions on NP120.

Three sub-adults from Norton had evidence of caries (23.1%); one aged 2.6-6.5 from the 14^{th} century with interproximal caries on the mesial aspect of one tooth. Two sub-adults, aged 6.6-10.5 from an unknown period, were also affected, one of whom had a gross carious lesion on the interproximal aspect of the right maxillary second deciduous molar. This may suggest a high carbohydrate diet as a contributory factor.

7.3.1.6 Dental Abscesses and Granulomas

Abscesses were observed on 19.4% (n=20) of males and 6.3% (n=2) of females at Portmahomack. On male dentition, the highest percentage of abscesses (17.5%) occurred on the buccal/labial aspect. These abscesses occurred mostly on males in the 46-59 age group from monastic period 2-3. Males from this period were affected more than males from lay period 4 (χ^2 (1) = 11.42, p < 0.001). Abscesses were observed on the buccal/labial aspect of two females, aged 46-59 from lay periods 4 and 5. A statistical difference was observed between male and female dentition from period 4 (χ^2 (1) = 24.67, $p < 0.001$), with males most affected by abscesses.

From Portmahomack, evidence of dental granulomas was found on 23.3% (n=24) of males and 9.4% (n=3) of females. In males, the highest percentage (21.4%) occurred on the buccal/labial aspect, mostly in the 46-59 age group from period 2 (Figure 7.10). As with abscesses, a notable difference was also found between periods, with monks from period 2-3 being more affected than lay males from period 4 (χ^2 (1), = 10.98, $p < 0.001$). Females affected by granulomas included one aged 36-45 (period 4) and two aged 46-59 (periods 4 and 5), with only the buccal/labial aspect affected.

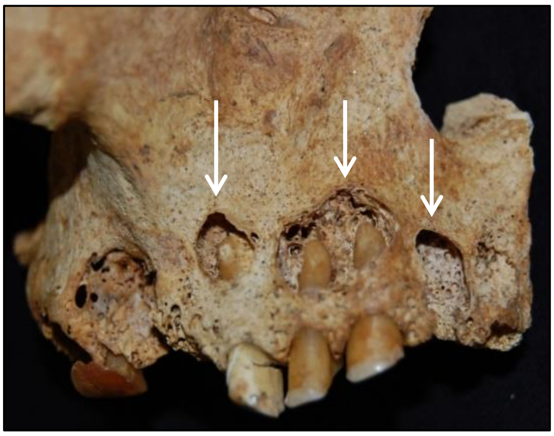


Figure 7.10: Apical granulomas on PMK173.

The occurrence of both dental abscesses and granulomas on the same individual from Portmahomack was found on one female aged 46-59 (period 5) and 13 males, mostly aged 46-59 from monastic period 2, although individuals aged 26-35 to 60+ from periods 1-4 were affected. An abscess was observed on one Portmahomack sub-adult (3%), aged 2.6-6.5 (period 4) on the buccal/labial aspect of the right mandibular central incisor. Evidence of granulomas on one Portmahomack sub-adult, aged 10.6-14.5 (period 4) was observed on the lingual aspect of the mandibular central incisors.

At Norton, dental abscess were observed on 11.8% (n=10) of males, although none were observed on adult females. The highest percentage (9.4%) of abscesses on males occurred on the buccal/labial aspect within most age groups (apart from 18-25) and across most periods (apart from the 13th century). Males from the 14th and 15th centuries were most affected, although no statistical difference was found. No abscesses were observed on sub-adults from Norton.

Dental granulomas occurred on 11.8% (n=10) of males and 22.2% (n=6) of females from Norton. As with abscesses, the highest percentage (9.4%) of granulomas in males occurred on the buccal/labial aspect within the 26-35 to 46-59 age groups from all periods, although none were observed in the 18-25 or 60+ age groups. The highest percentage (14.8%) of granulomas on four females occurred on the buccal/labial aspect, comprising three females from the 13th century (one aged 36-45 and two aged 46-59) and one female from the 15th century aged 60+. A statistical difference was found overall, with females more affected than males (χ^2 = (1) = 10.24, p < 0.001), although when period-specific data was calculated, a statistical difference was only found in the 15th century group (χ^2 = (1) = 91.77, p < 0.001). No granulomas were observed on the Norton sub-adults.

7.3.1.7 Periodontal Disease

Periodontal disease was observed on 24.3% (n=25) of males and 15.6% (n=5) of females from Portmahomack. On males, the highest percentage (47.6%) occurred as mild periodontitis, mostly within the 46-59 age group from periods 2-3 and 4. Only mild periodontitis was observed on the female dentition, occurring in age groups 26-35, 36-45 and 46-59, all from period 4. A notable difference was observed between males and females from period 4 (χ^2 (1), = 10.80, $p < 0.001$), with female dentition more affected.

Figure 7.11: Periodontal disease on NP52.

From Norton, periodontal disease was observed on 4.7% (n=4) of males (Figure 7.11) and 7.4% (n=2) of females. Of the four males affected, mild periodontitis was observed on one male aged 26-35 (15th century) and three males aged 36-45 (13th and 14th century). One male, aged 36-45 from the 13th century also had moderate periodontitis observed on the left mandibular second molar. Only mild periodontitis was observed on two females from Norton; one aged 36-45 from the 15th century and one aged 46-59 from the 13th century. No statistical differences were found in age-, sex- or period-specific groups.

7.3.1.8 Miscellaneous Dental Pathologies and Anomalies

A number of anomalies and additional dental pathologies to those aforementioned have been observed on the Portmahomack and Norton skeletons. The majority of these are oral fistulas, cysts or congenital anomalies, which are summarised in Table 7.27.

Table 7.27: Miscellaneous dental pathologies and anomalies from Portmahomack and Norton.

SK No	Sex	Age	Period	Pathology/Anomaly	Tooth*/ area affected
PMK35	M	18-25	4	Nasopalatine cyst	Palate
PMK85	M	18-25	4	Hypodontia	41
				Distal rotation	11, 21
PMK109	M	46-59	4	Oro-antral fistula	16, 26
				Hypercementosis	38
PMK127	M	36-45	2	Impaction	13, 33
				Hypercementosis	37
NP1	M	18-25	12th C	Hypodontia	12, 22
				Distal rotation	25
				Impaction	48
NP6	M	46-59	?	Mesial fracture	23
NP8	M	36-45	12th C	Oro-antral fistula	Left maxillary sinus
NP34	F	26-35	14th C	Oro-antral fistula	Distal right maxilla
NP37	M	46-59	14th C	Hypodontia	37, 47
NP40	?F	36-45	13th C	Unerupted tooth	23
NP43	F	26-35	14th C	Oro-antral fistula	Right maxilla
NP44	M	26-35	15th C	Retained deciduous tooth	63
				Unerupted permanent tooth	23
				Distal rotation	24
NP59	M	26-35	?	Short roots	11, 21
				Impaction	38
NP61	M	36-45	15th C	Imbrication	32, 33, 42, 43
NP70	M	60+	15th C	Hypercementosis	16
				Oro-antral fistula	Distal left maxilla
NP72	F	18-25	14th C	Hypodontia	12, 22, 35, 45
				Retained deciduous teeth	75, 85
NP75	M	36-45	14th C	Mesial rotation	18
NP78	F	46-59	13th C	Periapical cyst?	27-28/ buccal
NP80	M	26-35	15th C	Imbrication	43
				Mesial rotation	23
NP81	M	26-35	15th C	Over-eruption	37
NP83	M	26-35	13th C	Distal rotation	15
				Periapical cyst	16
NP86	M	36-45	15th C	Hypodontia	16, 26, 36, 46
				Taurodontism,	17, 37
				Mesial rotation	15, 35
NP93	M	26-35	15th C	Enamel pearl	27
NP97	M	46-59	14th C	Imbrication	32, 33, 42, 43
NP99	M	36-45	15th C	Activity notches?	11, 21, 22
NP110	M	36-45	14th C	Impaction	38, 48
				Over-eruption	37
NP111	M	36-45	15th C	Palatial eruption	23 (33)
				Hypercementosis	17, 26
				Malocclusion (overbite)	
NP120	F	26-35	15th C	Cyst	24/buccal and palatial

* FDI notation used (see dental recording sheet in Appendix 1m).

Figure 7.12: Hypodontia of 2nd premolars and 1st molars, with retained 2nd deciduous molars (arrowed) on NP72.

From Norton, dental anomalies occurred across all periods, with hypodontia (Figure 7.12) observed on four adults (3 males, 1 female), rotation on six males, oro-antral fistulas on four adults (2 males, 2 females), cysts on three adults (1 male, 2 females), impaction and imbrication on three males, and hypercementosis on two males. These anomalies, apart from imbrication, also occurred on four males from Portmahomack (Figure 7.13), one being from monastic period 2 and three from lay period 4. Anomalies such as hypodontia, may suggest familial affinity, as discussed in section 8.3.3.

Figure 7.13: Oro-antral fistula on PMK109.

7.3.2 Bone Pathologies

Pathological markers on bone were observed on 69 adults and 7 sub-adults from Portmahomack and on 89 adults and 7 sub-adults from Norton. As stated in section

7.1.1, data are presented either as crude prevalence (CP%) (Tables 7.28 and 7.29) or as category: age- (ASP%), sex- (SSP%), or period-specific (PSP%) prevalence, for health indictors and where large numbers of individuals are affected.

Table 7.28: Adult bone pathologies from Portmahomack (PMK) and Norton (NP).

Pathology	PMK (N=138)			NP (N=115)	
	N	CP%		N	CP%
Treponemal	0			1	0.9
Leprosy	0			2	1.7
Tuberculosis	1	0.7		5	4.3
Rib periosteal new bone	2	1.4		2	1.7
Periosteal new bone	14	10.1		51	44.3
Sinusitis	5	3.6		3	2.6
Nasal concha bullosa	2	1.4		1	0.9
Rickets	1	0.7		4	3.5
Scurvy	2	1.4		0	
Cribra orbitalia	3	2.2		8	7.0
Osteoporosis	2	1.4		0	
Porotic hyperostosis	0	-		7	6.1
Internal frontal hyperostosis	0			7	6.1
Paget's disease	0			9	7.8
Congenital/Developmental	1	0.7		5	4.3
Axial anomalies	13	9.4		11	9.6
Spina bifida occulta	2	1.4		9	7.8
Neoplasm	4	2.9		7	6.1
Circulatory	9	6.5		3	2.6
DISH	2	1.4		5	4.3
Septic arthritis	0			1	0.9
Psoriatic arthritis	0			1	0.9
Gout	0			1	0.9
Seronegative Spondyloarthropathy	0			1	0.9
Ankylosing spondylitis	1	0.7		1	0.9
Fractures/Trauma	29	21.0		12	10.4
Blade injuries	5	3.6		1	0.9
Os acromiale	5	3.6		0	
Schmorl's nodes	52	37.7		63	54.8
Vertebral body joint disease	69	50.0		77	67.0
Vertebral facet joint disease	61	44.2		54	47.0
Extra-vertebral OA	62	44.9		66	57.4
Other	0			11	9.6

Shaded areas = no pathology.

Table 7.29: Sub-adult bone pathologies from Portmahomack (PMK) and Norton (NP).

Pathology	PMK (N=40)		NP (N=13)	
	n	CP%	n	CP%
Tuberculosis	1	2.5	0	
Rib PNB	1	2.5	0	
PNB	5	12.5	0	
Sinusitis	0		1	7.7
Rickets	3	7.5	1	7.7
Scurvy	6	15	1	7.7
Cribra orbitalia	5	12.5	4	30.8
Porotic hyperostosis	1	2.5	1	7.7
Congenital/Developmental	1	2.5	0	
Circulatory	0		1	7.7
Fractures/Trauma	0		0	
Blade injuries	1	2.5	0	

Shaded areas = no pathology.

7.3.3 Infectious and Respiratory diseases

7.3.3.1 Treponemal

From Norton, a possible case of treponemal disease was observed on one adult male (NP58), aged 26-35, from the 15th century. Periosteal new bone was present on the ulnae, femora, tibiae and fibulae, a distribution suggestive of venereal syphilis (Steinbock 1976). However, the diagnosis for this case is inconclusive as such manifestations can also occur from other diseases such as leprosy, although no bone changes, such as rhinomaxillary syndrome, occurred to suggest this diagnosis. A differential diagnosis of non-specific infection is therefore considered.

7.3.3.2 Leprosy

Evidence of lepromatous leprosy was found on one adult male from Norton (NP50), aged 26-35, from the 14th century. Skeletal changes manifested as rhinomaxillary syndrome and bone resorption on the hands (right proximal 4th and 5th phalanges) and foot (left 2nd and 3rd metatarsals) (Figure 7.14). A second possible case of leprosy was observed on another adult male (NP47) aged 26-35 from the 14th century. Extreme bone resorption to the left 4th metacarpal and proximal phalanx and periosteal new bone (PNB) on the right fibula was observed. However, this is not enough evidence for a conclusive case of leprosy; hence non-specific infection is suggested as a differential diagnosis.

Figure 7.14: Leprosy changes: rhinomaxillary syndrome (left), nasal floor porosity (middle) and left metatarsal resorption (right) on NP50.

7.3.3.3 Tuberculosis

One probable case of Tuberculosis (TB) was observed on a male from Portmahomack (PMK54), aged 18-25 from monastic period 2. PNB was present on the proximal ulnae, right pelvis and proximal femur and on a number of right and left ribs. One sub-adult from Portmahomack aged 10.6-14.5 from lay period 4 had PNB on the humeri, radii, ulnae, scapulae, hands and right femur, which was suggested to be a possible case of TB (S. Mays, *pers.comm.*).

From Norton, a definite case of TB was diagnosed on one adult male (NP38), aged 26-35 from the 14th century. Dactylitis of the right 2nd metacarpal (Figure 7.15) was observed and PNB on the ribs, right clavicle, hands, feet, right tibia and fibula. Possible cases of TB are also suggested on three males (3.5%) and one female (3.7%) from Norton, aged 26-35 to 60+ from the 14th and 15th centuries. A combination of rib, limb, and on one male (NP37), pelvic PNB was observed, however, without conclusive evidence, a differential diagnosis of non-specific infection may be offered for these cases. No evidence of TB was found on any sub-adults from Norton.

Figure 7.15: Dactylitis of the right 2nd metacarpal on NP38.

7.3.3.4 Periosteal New Bone

The presence of rib Periosteal New Bone (PNB) alone is not pathognomonic of TB but can be associated with other respiratory diseases (Roberts *et al.* 1998; Roberts and Buikstra 2003), hence it is reported here as a separate pathology. Rib PNB was observed on two adults (1.4%) from Portmahomack. On one male aged 26-35 from lay period 4, this manifested as lamellar bone on the visceral surface and on one female, aged 46-59 from lay period 5, as a mixture of lamellar and woven bone on the visceral rib surface. This may suggest a pulmonary infection for both sexes that was active at the time of death for the female. Rib PNB was also present on one sub-adult from Portmahomack, aged 0-1 from period 5.

From Norton, rib PNB was present on two adults (1.7%): one male aged 46-59 from the 14th century and one female aged 18-25 from the 15th century. Lamellar PNB was present on the visceral surface of 5 right and 4 left ribs of the female and on the visceral surface of 3 rib shaft fragments of the male.

For PNB on bones other than the ribs, CP% for Portmahomack adults was 10.1% (n=14), the majority belonging to period 4, although the number of males affected from periods 2 and 4 were the same. When separated into periods, PSP% of PNB (Table 7.30) was 7.7% for lay period 1 (n=1), 9.1% for monastic period 2 (n=5) and 12.3% for lay period 4 (n=8), with the leg bones most affected. No statistical differences were found between periods. Five sub-adults (periods 4 and 5) from most age categories (apart from 1.1-2.5 years) also had evidence of PNB, which mostly occurred on the leg bones.

Table 7.30: Period-specific prevalence of PNB on Portmahomack adults.

SK No.	Sex	Age	Period	Location
PMK187	?M	36-45	1	Right ulna
		n affected	1	
		PSP% (N=13)	**7.7%**	
PMK38	M	46-59	2	Left tibia, calcaneus and talus
PMK52	M	46-59	2	Right fibula
PMK154	M	46-59	2	Right tibia
PMK143	M	60+	2	Right tibia
PMK148	M	60+	2	Left femur
		n affected	**5**	
		PSP% (N=55)	**9.1%**	
PMK114	F	18-25	4	Left fibula
PMK92	F	26-35	4	Right fibula
PMK105	F	46-59	4	Left femur
PMK134	M	18-25	4	Femora, tibiae and fibulae
PMK108	M	36-45	4	Tibiae and fibulae
PMK104	M	Adult	4	Left tibia
PMK150	M	Adult	4	Femora, tibiae and fibulae
PMK1	?M	Adult	4	Tibiae and fibulae
		n affected	**8**	
		PSP% (N=65)	**12.3%**	

From Norton, CP% for PNB was 44.3% (n=51). When separated into periods, the greatest to the least PSP% occurred in the 14^{th} century (50.0%), 15^{th} century (47.5%) and the 13^{th} century (43.8%), although no statistical differences were found between periods. The majority of bones affected were the tibiae, fibulae and femora and the majority of individuals affected were male (Table 7.31).

Table 7.31: Period-specific prevalence of PNB on Norton adults.

Sk.no	Sex	Age	Period	PNB Location
62	F	46-59	13th C	Tibiae
77	F	46-59	13th C	Tibiae
78	F	46-59	13th C	Fibulae
65	?F	26-35	13th C	Left tibia
83	M	26-35	13th C	Tibiae and fibulae
89	M	26-35	13th C	Tibiae
102	M	26-35	13th C	Tibiae
		n affected	**7**	
		PSP% (N=16)	**43.8%**	
43	F	26-35	14th C	Right fibula
98	F	26-35	14th C	Tibia fragments
66	?F	Adult	14th C	Tibiae
9	M	26-35	14th C	Left femur and tibia
47	M	26-35	14th C	Right fibula
48	M	26-35	14th C	Right tibia
91	M	26-35	14th C	Left femur, tibiae and right fibula
104	M	26-35	14th C	Right pubis and S3-S4
52	M	36-45	14th C	Left tibia, fibulae and right 3rd prox phalanx
67	M	36-45	14th C	Left mandible
73	M	36-45	14th C	Tibiae and fibulae
76	M	36-45	14th C	Right tibia
90	M	36-45	14th C	Tibiae
110	M	36-45	14th C	Tibiae
29	M	46-59	14th C	Tibiae and fibulae
35	M	46-59	14th C	Right 2nd metatarsal
55	M	46-59	14th C	Left tibia
106	M	60+	14th C	Tibiae
7	?M	46-59	14th C	Left tibia
10	?M	46-59	14th C	Right tibia
		n affected	**20**	
		PSP% (N=40)	**50.0%**	
79	?	Adult	15th C	Tibiae
128	?	Adult	15th C	Tibiae and right fibula
118	F	26-35	15th C	Tibiae and right fibula
120	F	26-35	15th C	Tibiae
30	M	18-25	15th C	Right tibia and left femur
88	M	26-35	15th C	Tibiae
12	M	36-45	15th C	Tibiae
19	M	36-45	15th C	Right tibia
20	M	36-45	15th C	Right femur and left tibia
61	M	36-45	15th C	Tibiae and fibulae
96	M	36-45	15th C	Left 4th and right 2nd prox hand phalanges
99	M	36-45	15th C	Tibiae and right fibula
103	M	36-45	15th C	Tibiae
111	M	36-45	15th C	Right tibia
14	M	46-59	15th C	Femora
33	M	60+	15th C	Left 1st metatarsal
82	M	Adult	15th C	Right tibia and fibula
13	?M	36-45	15th C	Tibiae
25	?M	26-35	15th C	Left tibia
		n affected	**19**	
		PSP% (N=40)	**47.5%**	

7.3.3.5 Maxillary Sinusitis

Maxillary sinusitis was observed on five adult males (3.6%) from Portmahomack, comprising two aged 26-35 (periods 2 and 4), two aged 46-59 (period 2) and one aged 60+ (period 1). From Norton, three adults (2.6%) had sinusitis comprising one probable male aged 18-25 (12th century); two females aged 26-35 (14th century) (Figure 7.16) and 46-59 (13th century). One sub-adult, aged 6.6-10.5 (unknown period), was also affected. Additionally, on one adult male, aged 36-45 (14th century) from Norton, an exostosis in the left maxillary sinus was observed. This is described as an idiopathic condition, with the maxillary sinus being an atypical location for exostosis (Borie *et al*. 2014). Although noteworthy, a direct link to sinus infection cannot be stated.

Figure 7.16: Left (A) and right (B) maxillary sinusitis on NP98.

7.3.3.6 Nasal Concha Bullosa

Nasal concha bullosa was observed on two adult males (1.4%) from lay period 4 at Portmahomack, aged 18-25 and 26-35 (Figure 7.17). One male (0.9%) from 13th century Norton, aged 46-59, also had evidence of this pathology. Studies on medieval populations have suggested no link between nasal concha bullosa and maxillary sinusitis (Mays *et al.* 2014). Only one male from Portmahomack had both maxillary sinusitis and nasal concha bullosa, which may support this suggestion, although the difficulty in assessing maxillary sinusitis on complete skulls hinders a complete comparison.

Figure 7.17: Nasal concha bullosa on PMK66.

7.3.4 Metabolic diseases

7.3.4.1 Rickets

One possible case of healed rickets was observed on a male (0.7%), aged 36-45 (period 4) from Portmahomack, which manifested as slight medial bowing of the right fibula midshaft. Rickets was observed on three sub-adults (7.5%) from Portmahomack; two aged 0-1 (periods 4, 5) and one aged 1.1-2.6 (period 4). Skeletal manifestations included anterior bowing of the femora (PMK2, PMK63) and tibiae (PMK6), associated porosity and flaring of the metaphyses of PMK2 and PMK6.

At Norton, healed rickets was observed on four males (3.5%); two aged 26-35 (14^{th} and 15^{th} century), one aged 36-45 (15^{th} century) and one aged 46-59 (unknown period). Pathological changes manifested as bowing of the left femur (mediolateral), tibiae and left fibula (lateral), femora (anteroposterior) and right tibia and fibula (medial) respectively. Probable rickets was also observed on one sub-adult (7.7%) from Norton, aged 0-1 (14^{th} century), manifesting as bone porosity on the cranium and mandible, although a differential diagnosis for this case could be scurvy. No evidence of osteomalacia was found on adults from Portmahomack or Norton.

7.3.4.2 Scurvy

From Portmahomack, probable scurvy was identified on two males (1.4%) from monastic period 2, aged 18-25 (PMK124) and 46-49 (PMK139). On PMK124, new bone deposits were present on multiple bones including the cranium, sphenoid, zygomatic, mastoid, nasal, palate, scapulae and right humerus. The evidence on PMK139 is less clear, although new bone deposits on the right orbit and zygomatic bones and on the mandible suggest possible scurvy. Evidence of probable scurvy was present on six sub-adults (15%) from Portmahomack, aged 0-1 from periods 4 (n=1) and 5 (n=5). Pathological changes included bone porosity and deposits of new bone, mainly on the skull (including the endocranial surface) and long bones.

No evidence of scurvy was found on the Norton adults, although a possible case was observed on one sub-adult, aged 1.1-2.5 from the 14^{th} century. Bone porosity and deposits of new bone were observed on the skull bones, namely the occipital, sphenoid, maxilla, temporal and pars lateralis and on both proximal humeri and proximal right femur.

7.3.4.3 Osteoporosis

Osteoporosis was observed on two females (1.4%) from Portmahomack, both aged 46-59 from periods 2 and 4. Skeletal changes to one female (PMK95) included parietal thinning (Figure 7.18), collapse of the 11th thoracic vertebra and trabecular bone loss to the right femur. Evidence for osteoporosis on PMK155 is less clear, although trabecular bone loss of the 6th thoracic vertebra and many bones being very light in weight suggest a probable case of osteoporosis. No evidence of osteoporosis for the Norton adults was observed.

Figure 7.18: Osteoporotic parietal thinning on PMK95.

7.3.4.4 Cribra Orbitalia

Cribra orbitalia (CO) was observed on three males (2.2%) from Portmahomack, two aged 46-59 (period 2) and one aged 60+ (period 1). In all three cases, porosity on the orbital roofs was healed and slight with no coalescent foramina. CO was also observed on five sub-adults (12.5%) from Portmahomack, including one perinate, one aged 1.1-2.5, one aged 2.6-6.5 and two aged 6.6-10.5, all from period 4. Porosity was very slight and healed at the time of death, with the exception of the perinate, where active slight to coalescing foramina was observed. This may suggest a lack of nutrition in the mother during pregnancy that subsequently affected the perinate.

CO was observed on eight males (7.0%) from the 12th to 15th centuries at Norton and from most age categories (except 60+). All cases had healed porosity, five being to a slight degree and three with moderate porosity, including coalescence of foramina in two cases (NP69, NP88). Evidence of CO was also observed on four sub-adults (30.8%) from Norton, aged 0-1, 1.1-2.5 and two aged 2.6-6.5, all from the 14th century. Again, all cases had healed porosity, with one being to a slight degree and three with moderate porosity, including coalescence of foramina in one case (NP31).

7.3.4.5 Porotic Hyperostosis

Porotic hyperostosis (PH) was observed on one sub-adult from Portmahomack, aged 6.6-10.5 (period 4), manifesting as slight porosity on the posterior aspect of both parietal bones, which was healed at the time of death. No evidence of PH was found on any adult skeletons from Portmahomack.

PH was observed on seven males from Norton (6.1%) from most age categories (except 60+) and from the 14th and 15th centuries. PH was also observed on one sub-adult from 14th century Norton. Most cases had slight porosity, which was healed at the time of death. One exception was an adult (NP88) aged 26-35, where the porosity appeared to be slightly active at the time of death.

7.3.4.6 Internal Frontal Hyperostosis

No evidence of internal frontal hyperostosis (IFH) was found on the Portmahomack adults, although many skulls were intact, hence examination of the endocranial (inner) surface was not possible in most cases. IFH was observed on seven adults (6.1%) from the 13th to 15th centuries at Norton, comprising two males aged 36-45 and 46-59 and five females, aged 18-25, 36-45 and two aged 46-59. IFH manifested as slight to thick nodular bone deposits on the endocranial surface of the frontal bone and in some cases, mostly on NP78 and NP127 (Figure 7.19), a thickened appearance of the surrounding frontal bone. Less marked skeletal manifestations of IFH appear as small thickened and ridged nodules on the endocranial frontal bone, often centred towards the crista galli (superior aspect of the ethmoid bone). A differential diagnosis on one female specimen (NP62) may be Paget's disease (see section 7.3.4.7).

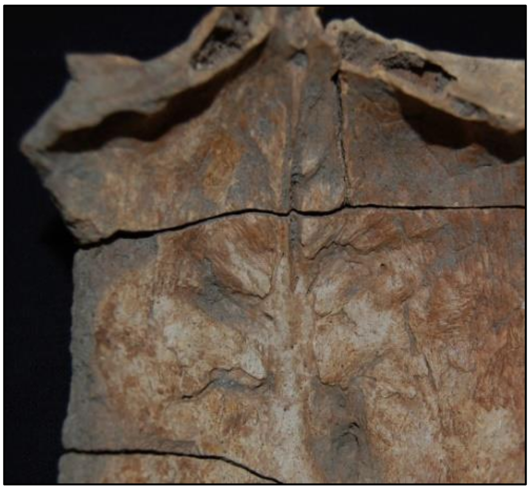


Figure 7.19: IFH new bone formation on NP127.

7.3.4.7 Paget's Disease of Bone

Paget's disease of bone (PDB) was previously identified on six males from Norton (Boylston 2008). In this study, PDB was identified on nine adults (7.8%) from the 13th to 15th centuries at Norton, a high concentration compared to cases from other British archaeological sites (see section 8.4.10). Seven males, one aged 36-45 (3.8%) and six aged 46-59 (20.0%) were affected. Possible cases of PDB are suggested here for two females, aged 46-59 (3.3%) and 60+ (25.0%), from evidence in the form of pagetic cranial thickening. However, this may be associated with other pathologies, such as IFH, which is a differential diagnosis for one of these females (NP62). Thickened and disorganised new bone growth, resulting in enlarged bones were observed on multiple bones of most males, with the most severely affected being NP22 (Figure 7.20), a possible wealthy lay benefactor to Norton (see Chapter 8).

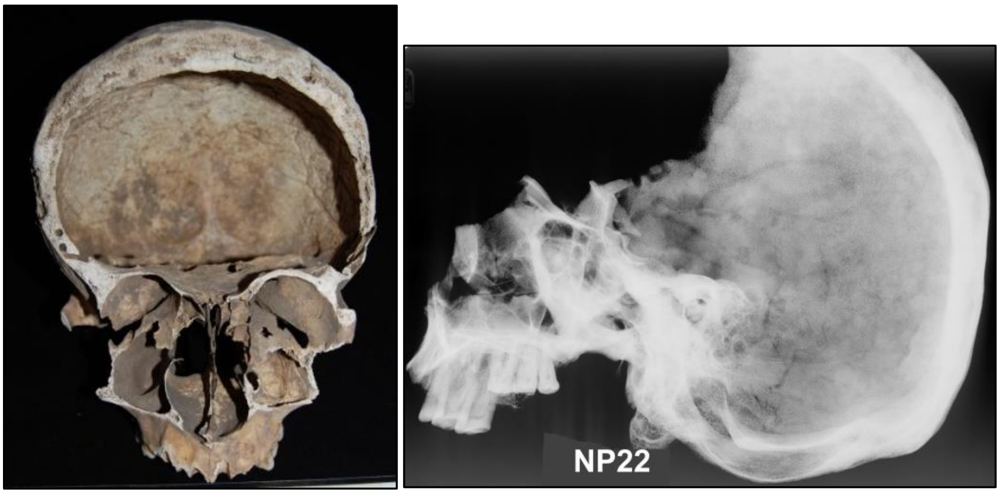


Figure 7.20: Cranial PDB thickening (left) and x-ray (right) of NP22.
X-ray image: © University of Bradford.

7.3.5 Developmental and Congenital anomalies

7.3.5.1 Spina Bifida Occulta

Spina bifida occulta was identified on one probable male, aged 36-45 (period 1) and one male aged 46-59 (period 2) from Portmahomack. In both cases a neural arch cleft from the 1st to 5th sacral vertebrae (S1-S5) is visible, both with a slight non-united neural arch at S2-S4. Spina bifida occulta was observed on nine adults from Norton (7.8%) from the 13th to 15th centuries; three aged 18-25 (1 male, 2 females), four aged 26-35 (3 males, 1 probable female) and two males aged 36-45 and 60+. In all cases the neural arch cleft was slight, affecting no more than two sacral vertebrae.

7.3.5.2 Developmental Anomalies of the Axial skeleton

Developmental anomalies of the axial skeleton were observed on 12 adult skeletons from Portmahomack (8.7%), the majority of which were males, apart from one probable female. All age categories were affected with individuals aged 36-45 and 46-59 and those from lay period 4 being most affected (Table 7.32). The majority of anomalies were border shifting of the vertebral segments, including sacralisation, thoracolumbar (T-L), occipital-cervical (O-C) and sacral-coccyx (SC) border shifting. Other anomalies included clefts and one bifid rib.

Table 7.32: Axial developmental anomalies on Portmahomack adults.

SK No.	Sex	Age	Period	Developmental axial anomalies
124	M	18-25	2	Occipitalised atlas (O-C)
141	M	36-45	2	L5 Sacralisation
164	M	46-59	2	L5 Sacralisation
97	?F	46-59	4	T12-L1 border shifting (T-L)
85	?M	18-25	4	L5 Sacralisation
41	M	18-25	4	L5 Cleft neural arch
103	M	26-35	4	Left bifid rib
30	M	36-45	4	C1 cleft foramina
31	M	36-45	4	S5-Co1 caudal shift (S-C)
192	M	36-45	4	L1 bifid facet
25	M	46-59	4	L6 Sacralisation
84	M	46-59	4	L5 Sacralisation
90	M	60+	4	Paracondylar process (O-C)

One sub-adult from Portmahomack, aged 1.1-2.5 from period 4, had congenital fusion of the 3rd and 4th thoracic vertebrae. Due to post-mortem damage, only the neural arches were present, although fusion here was smooth with no evidence of pathological involvement.

Axial developmental anomalies were observed on 11 adults from Norton (9.6%) from the 13th to 15th centuries, comprising seven males and four females from most age categories, apart from the 46-59 group. Axial anomalies (Table 7.33) mostly involved sacralisation and apertures of the sternum (Figure 7.21a) and rib. Congenital fusion of the 5th to 6th cervical vertebral bodies was observed on one adult male from the 13th century. Marginal osteophytes were also observed here, although the smooth fusion suggests a congenital cause. Developmental clefts on the vertebrae of two females from the 15th century were also observed. No developmental anomalies were observed on the Norton sub-adults.

Table 7.33: Developmental and congenital anomalies on Norton adults.

Sk. No	Sex	Age	Period	Developmental axial anomalies	Miscellaneous Developmental/ Congenital
115	F	36-45	?	Sternal aperture	
6	M	46-59	?		Craniosynostosis
57	M	46-59	13th C		Craniosynostosis
42	M	36-45	13th C	Congenital fusion (C5-C6)	
63	M?	26-35	13th C	L5 Sacralisation	
69	M	26-35	14th C	Sternal aperture	Absence L&R 3rd MC styloid process
75	M	36-45	14th C		Absence R.3rd MC styloid process
110	M	36-45	14th C	L6 Sacralisation	
112	F	18-25	15th C	C1 posterior arch cleft	
16	F	26-35	15th C	Rib aperture	
118	F	26-35	15th C	Cleft: LR L1 Facet	
30	M	18-25	15th C	L5 Sacralisation	
111	M	36-45	15th C		Absence R.3rd MC styloid process
33	M	60+	15th C	L5 Sacralisation	
70	M	60+	15th C	Xiphoid process aperture	

Shaded areas = no anomalies.

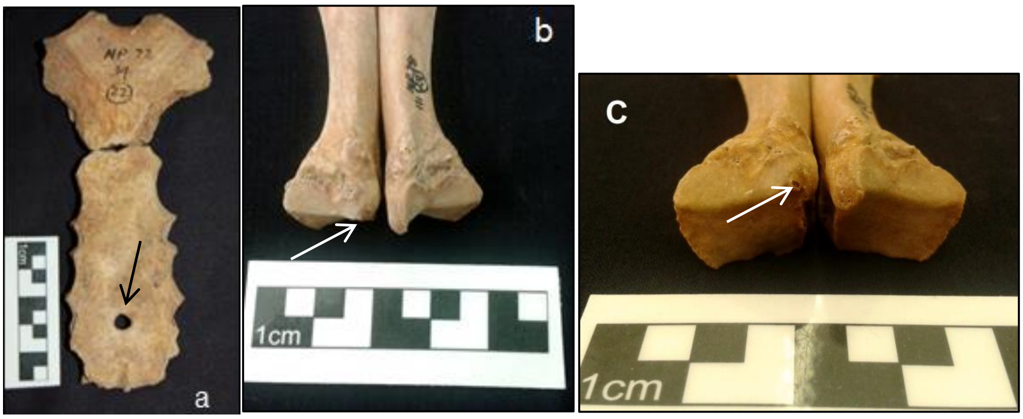


Figure 7.21: a) Sternal aperture on NP69, **b) and c)** absence of the right 3rd metacarpal styloid process on NP111.

7.3.5.3 Miscellaneous Congenital/Developmental Anomalies

Craniosynostosis was observed on one male (0.7%) from Portmahomack (lay period 4), aged 36-45. This was identified as plagiocephaly, which results in a lateral and oblique deformation of the skull (Barnes 2012a). Congenital/developmental anomalies were observed on five adults (4.3%) from Norton, in the form of craniosynostosis and absence of the 3rd metacarpal styloid process. Craniosynostosis was observed on two males, aged 46-59, one from the 13th century, and the other from an unknown period. Scaphocephaly, the premature closure of the sagittal suture, is the suggested craniosynostosis for both these cases. No evidence of craniosynostosis was observed on the Portmahomack or Norton sub-adults.

Absence of the 3rd metacarpal (MC) styloid process was identified on three males from Norton; one aged 26-35 (14th century) and two aged 36-45 (14th and 15th century), which was unilateral (Figure 7.21b) on two males and bilateral on one male. In all cases, the areas were smooth with no signs of porosity or new bone formation that would suggest avulsion fractures, which are evident on the 5th metatarsal tuberosity of a number of Portmahomack males. The styloid process can become a separate ossicle (Os styloideum), fuse to the capitate during development or be completely absent (Prescher 2001). The capitate bones were absent on two males and there was no sign of capitate fusion on NP111, suggesting either congenital absence of the styloid process or unrecovered Os styloideum ossicles.

7.3.6 Neoplastic disease

Neoplastic disease was observed on four adults from Portmahomack (2.9%) and seven adults from Norton (6.1%), in the form of either benign or malignant bone changes; the results of which are presented below.

7.3.6.1 Benign tumours

No benign neoplasms were observed on the Portmahomack adults or sub-adults. At Norton, benign tumours were observed on six adults (4 males, 2 females), aged from 36-45 to 60+ from the 13th to 15th centuries (CP: 5.2%). One male had a possible osteochondroma and associated cyst on the right proximal tibia. The remaining adults had button osteomas, mainly on the cranium, apart from one female from the 15th century, where small smooth osteomas were located on the dorsal aspect of the left 3rd proximal and interproximal hand phalanges.

7.3.6.2 Malignant tumours

Neoplastic disease was observed on four males from Portmahomack, one aged 26-35 (PMK93, period 4), two aged 46-59 (PMK38, PMK164, period 2) and one aged 60+ (PMK149, period 1). A mixture of destructive lesions and reactive new bone was found on multiple bones of PMK93 including the vertebrae (T12, L3), right humerus, scapulae, proximal femora, ribs, left pelvis and most noticeably on the frontal bone and mandible (Figure 7.22). Here, a diagnosis of metastic carcinoma is suggested. On PMK38 destructive lesions and reactive new bone on the pelvis, sacrum and right femoral head were observed, suggesting possible late-stage prostate cancer that had metastasised to bone. PMK149 and PMK164 are less definitive cases; a large lytic lesion inside the right orbit of PMK149 suggests a possible metastic carcinoma and a very large lytic lesion above the right acetabulum of PMK164 may be associated with a neoplastic disease, although soft tissue avulsion cannot be ruled out.

Figure 7.22: Neoplastic lytic lesions on the mandible (left) and frontal bone (right) of PMK93.

From Norton, one male aged 36-45 from the 14th century had multiple lytic lesions on the cranium, which had scalloped margins; suggesting multiple myeloma (Aufderheide and Rodríguez-Martin 1998). No neoplastic disease was observed on the Portmahomack and Norton sub-adults.

7.3.7 Circulatory Disorders

Circulatory disorders were observed on nine adults from Portmahomack (6.5%) and on three adults (2.6%) and one sub-adult (7.7%) from Norton. These were mainly in the form of osteochondroses, the results of which are presented below.

7.3.7.1 Osteochondroses

From Portmahomack, Scheuermann's disease was observed on the vertebrae of three adults, comprising two males, aged 36-45 and 45-59 and 1 probable male, aged 46-59, all from monastic period 2. The 11th thoracic vertebra was affected on two males and the 6th, 7th and 10th thoracic vertebrae of another male. Scheuermann's disease was observed on the 2nd lumbar vertebra of one sub-adult from Norton, aged 14.6-17.0 from the 15th century.

Osgood-Schlatter's disease was observed on the left tibia of one probable male from Portmahomack, aged 18-25 from period 4. The right tibia was not affected, although a unilateral occurrence is common in this condition (Ortner 2003).

Intervertebral osteochondrosis was observed on one probable female from Portmahomack, aged 46-59 from period 4. The 7th and 8th thoracic (T7-8) vertebrae were affected, with a slight wedge shape of the anterior vertebral body, which caused a slight kyphosis when all vertebrae were articulated. From Norton, this condition was also observed on three males from the 14th century, two aged 26-35 (affecting T6-7 and T9-10 respectively) and one aged 36-45, affecting the 5th lumbar vertebra.

7.3.7.2 Slipped femoral capital epiphysis

A possible case of slipped femoral capital epiphysis was observed on one adult male from Portmahomack (period 4), aged 36-45. The right femoral head has a noticeable mushroom-shape, and the neck is short, with new bone formation on the anterior aspect, giving an overall coxa vara angle between the femoral head and shaft (less than 120 degrees). This condition is associated with trauma, although because of its similarity to Legg-Calvé-Perthes disease, it is technically classed as a circulatory disorder (Ortner 2003).

7.3.8 Joint Diseases

In this section, results from a number of joint diseases are presented. As stated in the previous chapter, vertebral joint disease is often described as osteoarthritis or degenerative joint disease. However, as vertebral bodies and facets degenerate differently (Rogers and Waldron 1995), both have been assessed separately. As aforementioned, results are presented here as vertebral body joint disease (VBJD) and vertebral facet joint disease (VFJD), with summary results for overall vertebral joint disease (VJD) also provided. Results for extra-vertebral osteoarthritis and other joint diseases, such as Schmorl's nodes, are also presented here. Prevalence is presented here as either crude (CP%), age- (ASP%), sex- (SSP%) or period-specific (PSP%).

7.3.8.1 Vertebral Body Joint Disease (VBJD)

CP% for VBJD from Portmahomack is 50.0%, which affected 57 males and 12 females, giving a SSP% of 68.7% and 50.0% respectively (Table 7.34). Adult VBJD occurred mostly as mild changes (grade 1); apart from on the female cervical bodies, where moderate changes (grade 2) were the highest. In males, the greatest number of severe changes (grade 3) of VBJD occurred in the lumbar bodies and for females, in the cervical bodies. Overall, the lumbar bodies were most severely affected on males, and the cervical bodies on females. No statistical difference between male and female VBJD was observed.

Table 7.34: VBJD scores for Portmahomack adults.

			Cervical				Thoracic				Lumbar			
	No. adults scored/affected	**SSP %**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**
Males	83/57	68.7	51	27	21	5	66	37	22	7	43	33	25	12
Females	24/12	50.0	12	4	5	2	18	6	5	0	14	8	5	0
Totals	**107/69**		**63**	**31**	**26**	**7**	**84**	**43**	**27**	**7**	**57**	**41**	**30**	**12**

Shaded area: not applicable.

From Portmahomack, adults most affected by VBJD were from the 46-59 age category, with the thoracic bodies affecting mostly males (Figure 7.23) and the cervical bodies affecting mostly females (Figure 7.24). For the 36-45 and 60+ age categories, the lumbar bodies were affected the most in both sexes. No VBJD was observed on females aged 18-25 and 26-35.

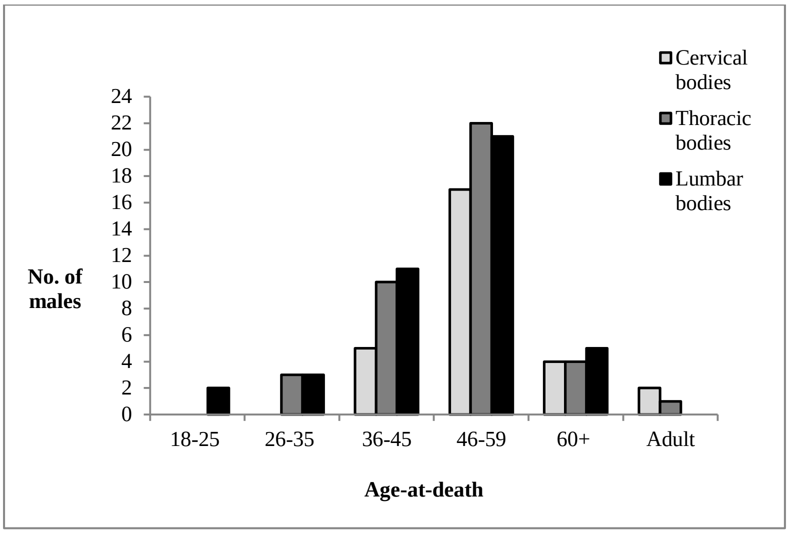


Figure 7.23: VBJD for Portmahomack males affected.

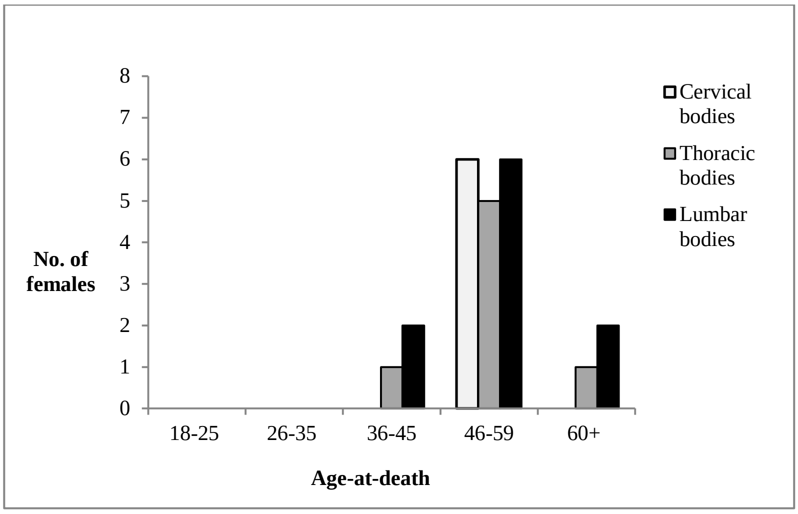


Figure 7.24: VBJD for Portmahomack females affected.

CP% of VBJD on adults from Norton was 67.0%, affecting 62 males and 15 females, giving a SSP% of 79.5% and 65.2 % respectively (Table 7.35). For both sexes, the most common occurrence of VBJD occurred as grade 1, apart from the male cervical bodies, where grade 2 had the highest occurrence. The greatest occurrence of grade 3 changes in VBJD was found in the thoracic bodies for males and in the cervical bodies for females. Overall, the thoracic bodies were the most affected in males and the cervical and thoracic bodies most affected in females. No statistically significant difference between male and female VBJD was observed.

Table 7.35: VBJD scores for Norton adults.

			Cervical				**Thoracic**				**Lumbar**			
	No. scored/ affected	**SSP %**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**
Males	78/62	79.5	58	25	31	11	54	48	36	20	45	29	22	13
Females	23/15	65.2	18	10	7	4	15	10	8	1	11	5	3	1
Totals	**101/77**		**76**	**35**	**38**	**15**	**69**	**58**	**44**	**21**	**56**	**34**	**25**	**14**

Shaded area: not applicable.

From Norton, the highest number of males affected by VBJD was aged 36-45, with the thoracic and lumbar bodies affected the most (Figure 7.25), which was also found to a lesser extent on those aged 46-59. Both the thoracic and lumbar bodies were affected equally in males aged 60+ and only one male aged 18-25 had evidence of VBJD.

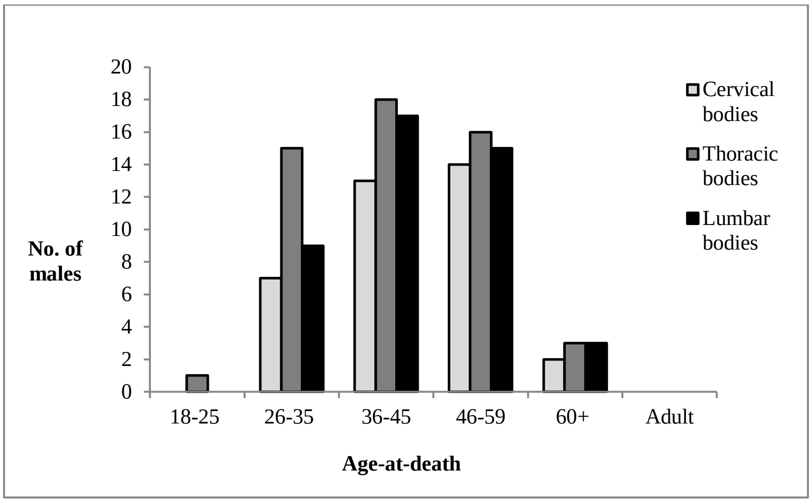


Figure 7.25: VBJD for Norton males affected**.**

From Norton, the highest number of female VBJD affected was within the 46-59 age category, with the cervical bodies mostly affected, followed by the thoracic and lumbar bodies (Figure 7.26). The thoracic bodies were mostly affected on females aged 26-35, although the thoracic and lumbar bodies were affected equally on females aged 36-45 and 60+, the latter of which also has an equal number of females affected by cervical body joint disease. The overall age distribution of adult VBJD may suggest degenerative changes as a causative factor, although prevalence within the younger age categories may suggest activity contributed to VBJD.

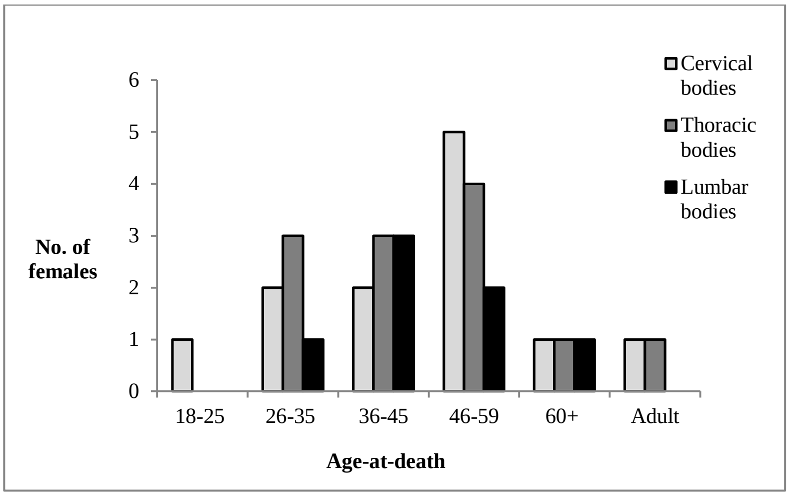


Figure 7.26: VBJD for Norton females affected.

7.3.8.2 Vertebral Facet Joint Disease (VFJD)

CP% of VFJD from Portmahomack was 44.2%, affecting 50 males and 11 females, giving a SSP% of 60.2% and 45.8% respectively (Table 7.36). The greatest occurrence for both sexes was found in grade 1 across all vertebral segments, although the thoracic facets were the most affected, followed by the lumbar and cervical facets. Severe changes (grade 3) had the least occurrence across all vertebral facets for males and only present in the lumbar facets for females. No statistical difference was observed between male and female VFJD.

Table 7.36: VFJD scores for Portmahomack adults.

			Cervical				**Thoracic**				**Lumbar**			
	No. adults scored/affected	**SSP %**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**
Males	83/50	60.2	57	17	13	5	70	31	20	6	67	19	11	6
Females	24/11	45.8	14	3	2	0	20	7	2	0	20	4	3	2
Totals	**107/61**		**71**	**20**	**15**	**5**	**90**	**38**	**22**	**6**	**87**	**23**	**14**	**8**

Shaded area: not applicable.

For both sexes at Portmahomack, those most affected by VFJD were from the 46-59 age category, with the thoracic facets affected the most within the male group (Figure 7.27) and the thoracic and lumbar facets affected equally in the female group (Figure 7.28). For males aged 36-45 and 60+, the lumbar facets were affected more than the cervical facets, although this is reversed for males aged 46-59. Facets were affected in all vertebral segments of 36-45 to 60+ in males, although only within the 46-59 female group. No VFJD was observed on females aged 18-25 and 26-35.

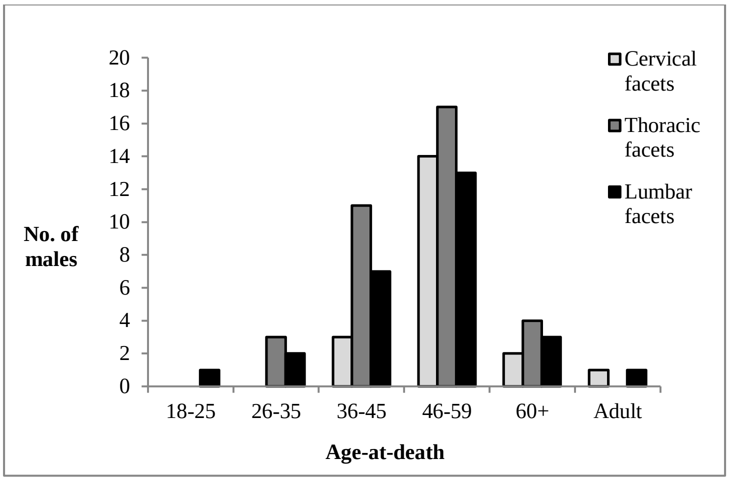


Figure 7.27: VFJD for Portmahomack males affected.

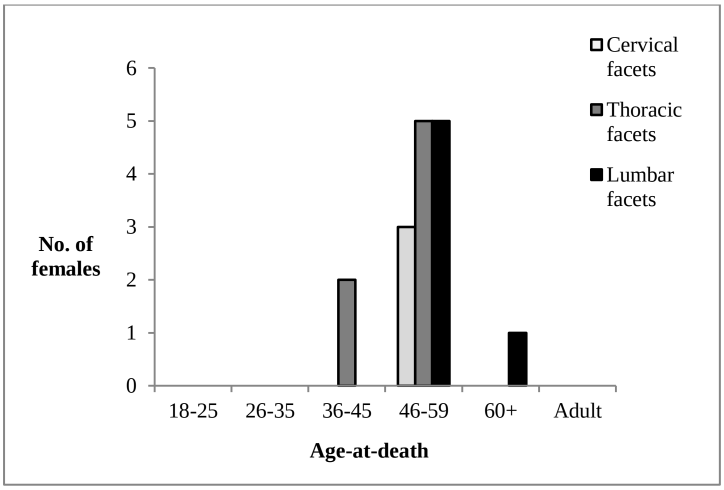


Figure 7.28: VFJD for Portmahomack females affected.

From Norton, CP% of VFJD was 47.0%, affecting 40 males and 14 females, giving a SSP% of 51.3% and 60.9% respectively (Table 7.37). For males, grades 1 and 2 changes occurred equally in the cervical and lumbar facets, with the majority of VFJD occurring as grade 1 in the thoracic facets. The cervical facets were most affected by grade 3 changes in males and for females in the thoracic facets. However, this is reversed for the total number of adults affected by VFJD, with males mostly affected by thoracic facets changes and females mostly affected by cervical facet changes. No statistical difference between male and female VFJD was observed from Norton.

Table 7.37: VFJD scores for Norton adults.

			Cervical				Thoracic				Lumbar			
	No. adults scored/affected	**SSP %**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**	**0**	**1**	**2**	**3**
Males	78/40	51.3	65	15	15	10	71	19	15	5	61	15	15	1
Females	23/14	60.9	21	4	5	1	17	4	3	2	17	3	1	0
Totals	**101/54**		**86**	**19**	**20**	**11**	**88**	**23**	**18**	**7**	**78**	**18**	**16**	**1**

Shaded area: not applicable.

For both sexes from Norton, those most affected by VFJD were from the 46-59 age category, with the cervical and lumbar facets affected the most within the male group (Figure 7.29) and the thoracic facets affected the most in the female group (Figure 7.30). Few males are affected from the 60+ age category compared to the other age groups.

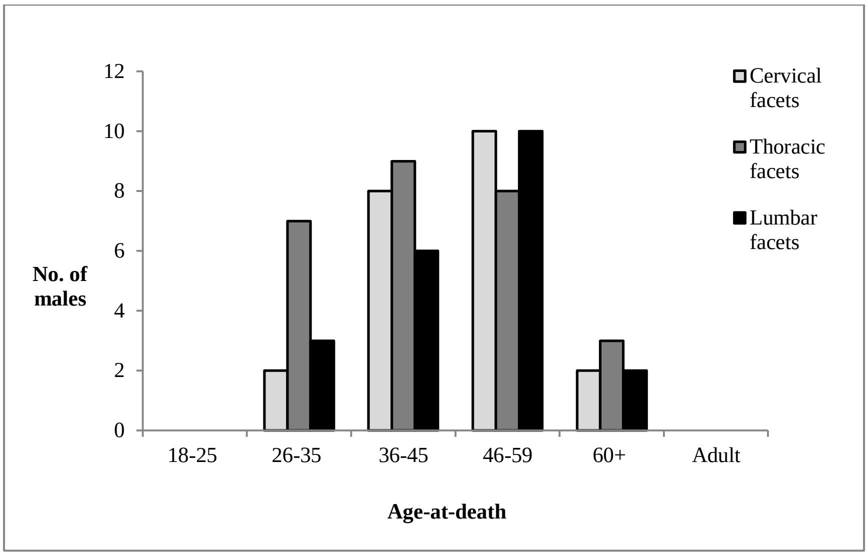


Figure 7.29: VFJD for Norton males affected.

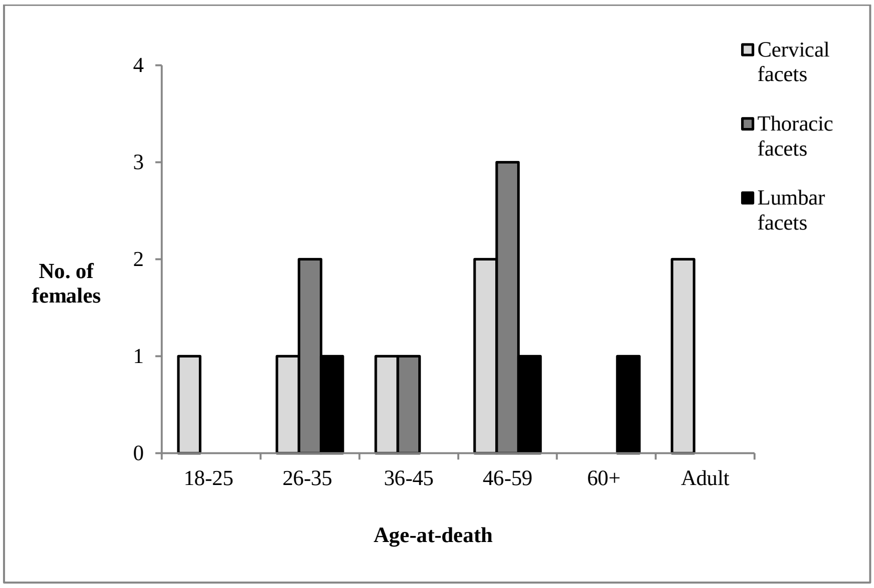


Figure 7.30: VFJD for Norton females affected.

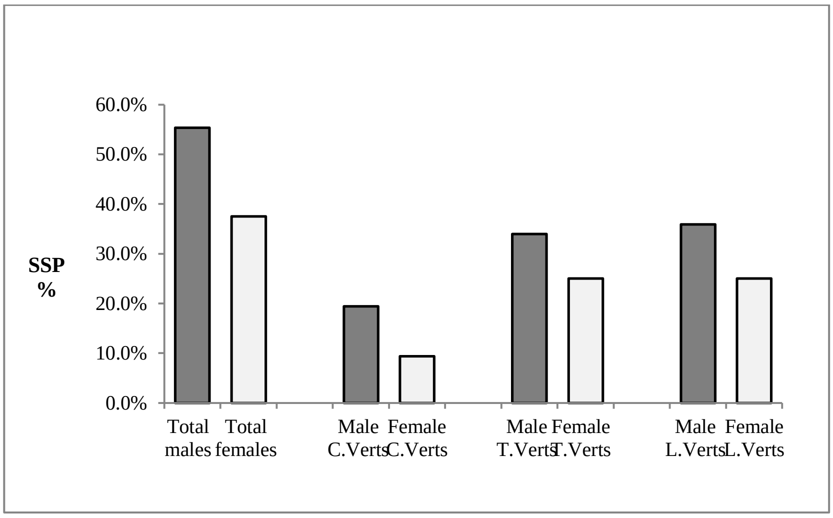


Figure 7.31: Portmahomack sex specific prevalence for VJD.

When SSP% is calculated for overall vertebral joint disease (VJD) on Portmahomack adults (Figure 7.31), the greatest prevalence is in the lumbar vertebrae for males (35.9%) and equally on the thoracic and lumbar vertebrae (25.0%) for females. Males are more affected on the cervical vertebrae (19.4%) than females (9.4%) (Figure 7.32). Adults most affected by VJD from Portmahomack were found in the 46-59 age group. Chi-square results for VJD was significant between adult age groups (χ^2 (4) = 31.67, $p < 0.001$). However, no significant differences were found when the VJD data was separated into male and female age groups. Moreover, no significant difference was found when the age group dataset was further split between VBJD and VFJD. This may suggest that although age degeneration may have been a contributory factor to VBJD and VFJD at Portmahomack, other factors, such as repetitive biomechanical loading, also contributed.

Figure 7.32: Joint disease on 3rd to 7th cervical vertebrae of PMK40.

Males from lay periods 1 and 4 at Portmahomack are less affected by VFJD than VBJD, as is the case for females from period 4 (Figure 7.33). However, this pattern is reversed for monastic period 2 males, where there is a slight increase in those affected by VFJD compared to VBJD. One of the four females from period 1 was affected only by VFJD and the only female from period 5 was affected by both VBJD and VFJD. No significant difference was found in the dataset between periods.

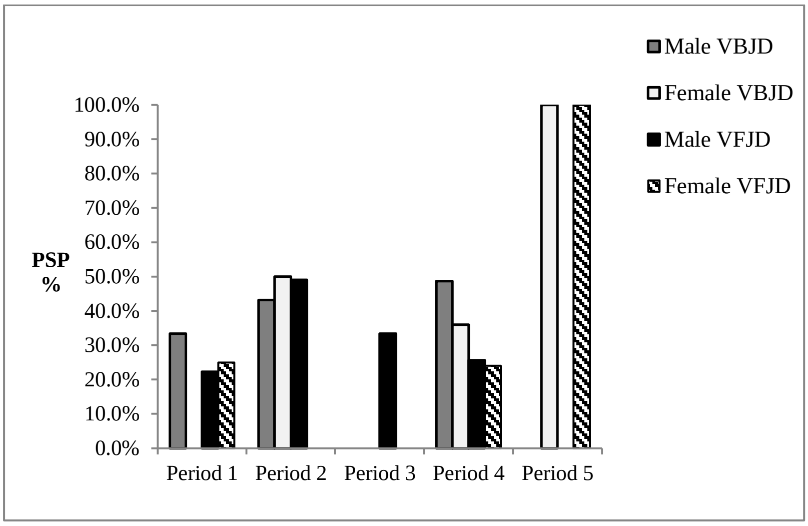


Figure 7.33: Portmahomack period specific prevalence for VBJD and VFJD.

SSP% for Norton adults (Figure 7.34) reveals the greatest prevalence of VJD for males was found in the thoracic vertebrae (62.4%) and equally in the cervical and thoracic vertebrae (44.4%) for females. There is a greater prevalence in the thoracic and lumbar vertebrae for males than females, with a greater SSP% in the cervical vertebrae for females. Males most affected by overall VJD from Norton were found in the 36-45 age group, whereas females most affected by overall VJD were aged 46-59. This may suggest some form of gender-division in activity, resulting in males being more affected by biomechanical stresses on the spine from an earlier age than females.

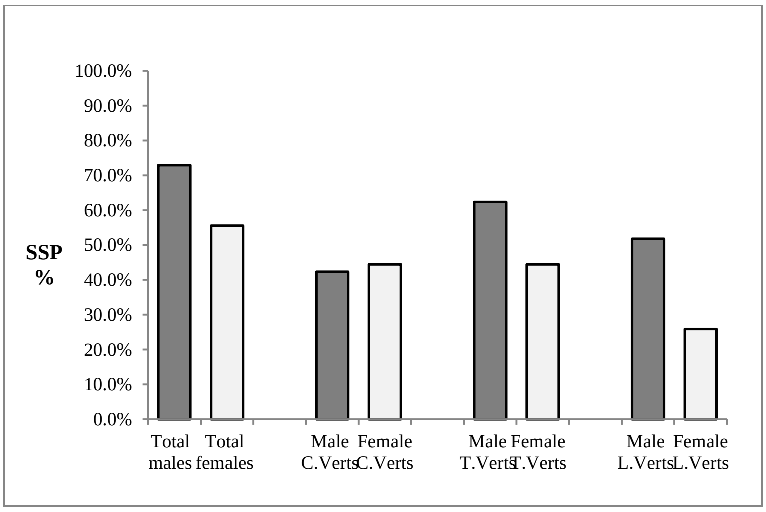


Figure 7.34: Norton sex specific prevalence for VJD.

Chi-square results for overall VJD at Norton was significant between adult age groups (χ^2 (4) = 28.79, p < 0.001). However, as at Portmahomack, no statistical differences were found when the VJD data was separated into male and female age groups or by VBJD and VFJD. Therefore, activity may have contributed to VBJD and VFJD, although age degeneration cannot be ruled out, especially for females from Norton.

PSP% for Norton adults revealed that in the 13^{th} to 15^{th} centuries, male prevalence of VBJD was greater than VFJD (Figure 7.35), although not to a significant level. This pattern was also found in the 13^{th} and 15^{th} century females, although this is reversed for females in the 14^{th} century and in the unknown (pre-dissolution) period, where the prevalence of VFJD is greater than VBJD. A significant relationship was found for adult VFJD between periods (χ^2 (5) = 23.44, $p < 0.001$), with those from the 14^{th} century most affected.

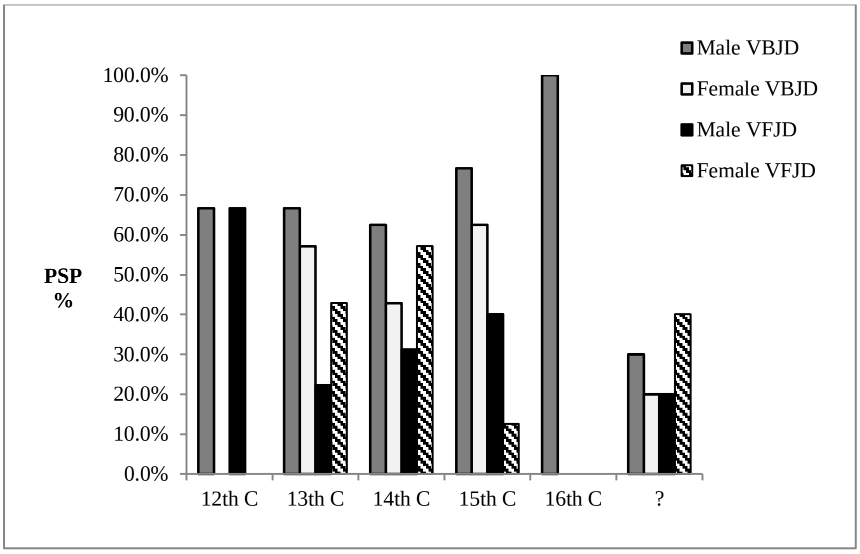


Figure 7.35: Norton period specific prevalence for VBJD and VFJD.

7.3.8.3 Extra-vertebral Osteoarthritis (EVOA)

Evidence of extra-vertebral osteoarthritis (EVOA) was observed on adults from Portmahomack (44.9%) and Norton (57.4%). Sex-specific prevalence (SSP%) for males and females respectively was 46.6% and 43.8% from Portmahomack and 61.2% and 40.7% from Norton (Table 7.38). Three adults of unknown sex from were also affected (100.0%). Summary data is presented in Appendices 4a-f.

Table 7.38: Crude (CP%) and sex-specific (SSP%) prevalence of EVOA for Portmahomack (PMK) and Norton (NP) adults.

	PMK adults affected	**PMK males affected**	**PMK females affected**	**NP adults affected**	**NP males affected**	**NP females affected**	**NP ?sex affected**
n=	62	48	14	66	52	11	3
SSP%		46.6%	43.8%		61.2%	40.7%	
CP%	44.9%			57.4%			100.0%

Shaded areas = not applicable.

Males from Portmahomack were affected mostly in the acromioclavicular, shoulder and hip joints (Figure 7.36). The least affected areas for males are the wrist, hand, ankle and foot, although within these areas, certain joints such as the carpus and metacarpophalangeal (MCPhal) articulations are more affected. The most affected areas for females are found in the acromioclavicular joints and in the proximal and distal humeri, although the corresponding shoulder (glenoid) and elbow (ulna) articulations are less affected and absent for the proximal radius (elbow). There is no evidence of female EVOA in the manubriosternum, wrist, ankle and tarsus and no evidence of males or females affected by EVOA of the skull joints.

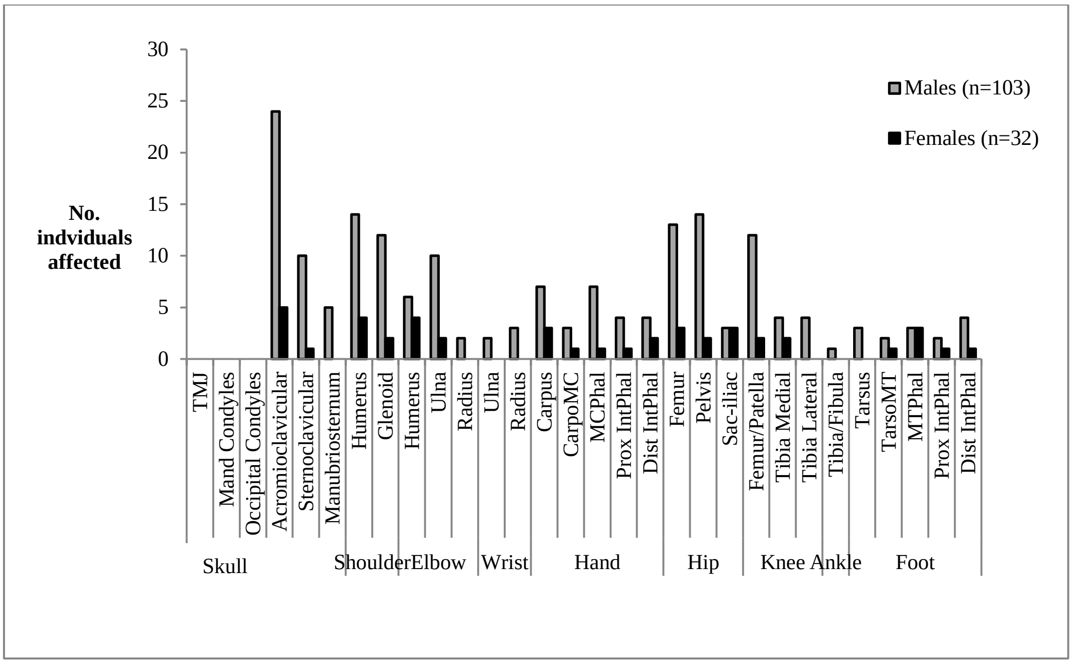


Figure 7.36: EVOA for Portmahomack adults affected.

From lay period 4 at Portmahomack, PSP% of individuals affected by EVOA reveal little difference between males (48.7%) and females (52.0%), and also when compared to males from period 2 (51.0%). Adults from periods 2 and 4 were affected more than those from period 1 (Figure 7.37 and Appendix 4b), with males (33.0%) from this period being affected more than females (25.0%). However, no statistical differences were found.

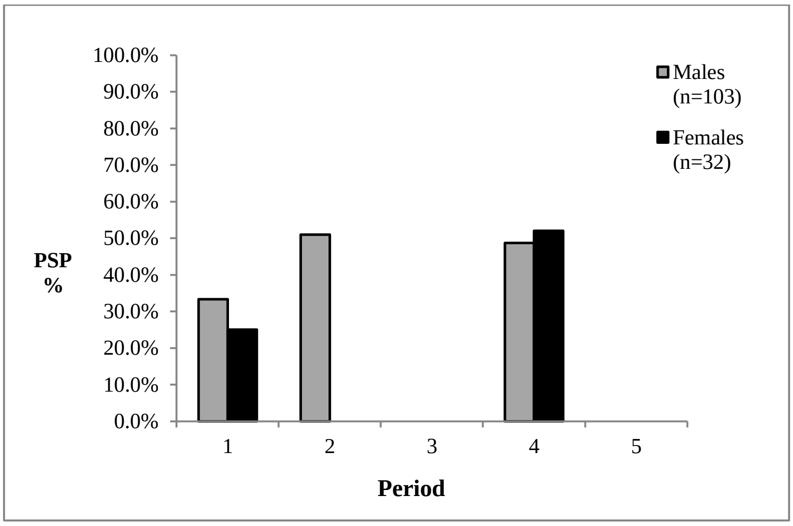


Figure 7.37: Period specific prevalence of EVOA for Portmahomack adults.

No evidence of EVOA was found in males aged 18-25 or females aged 26-35 from Portmahomack. When age-specific prevalence (ASP%) was calculated (Figure 7.38 and Appendix 4a), there is an increase in EVOA from males aged 26-35 to 60+ and in females aged 36-45 and 60+. A significant difference was found between male (χ^2 = (5) = 22.73, $p < 0.001$) and female (χ^2 = (5) = 12.42, $p = 0.029$) age groups, with both sexes aged 60+ most affected. These results may suggest that age was a contributory factor to EVOA, although a greater prevalence was found in females aged 18-25 (50.0%) compared to those aged 36-45 (25.0%). Factors other than natural age degeneration may therefore have contributed to EVOA on Portmahomack individuals.

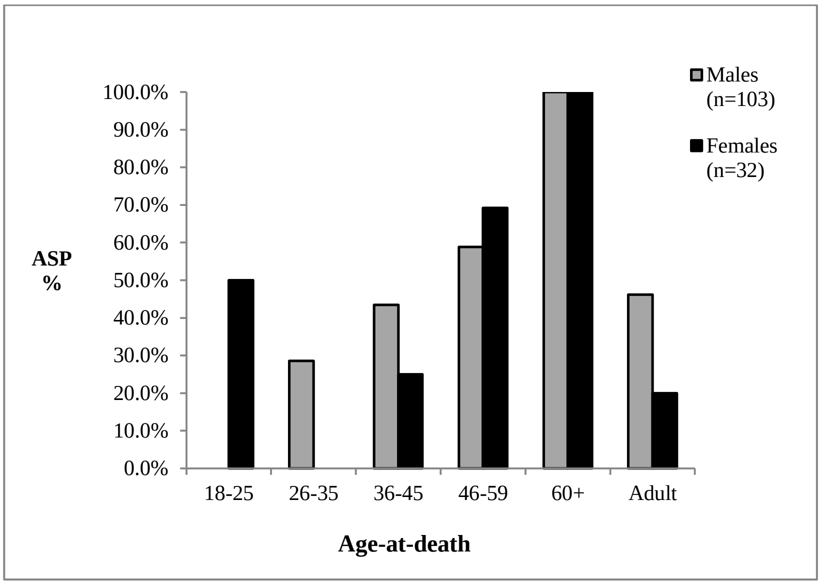


Figure 7.38: Age specific prevalence of EVOA for Portmahomack adults.

Males from Norton were affected by EVOA mostly in the acromioclavicular and sternoclavicular joints, with some increased occurrences in the shoulder (glenoid) and hip (pelvis) joints (Figure 7.39). Least occurrence of male EVOA occurred on the skull, ankle and foot joints. Females from Norton were most affected by EVOA in the sternoclavicular joint and on some articulations in the elbow (ulna) and knee (femur/patella) joints.

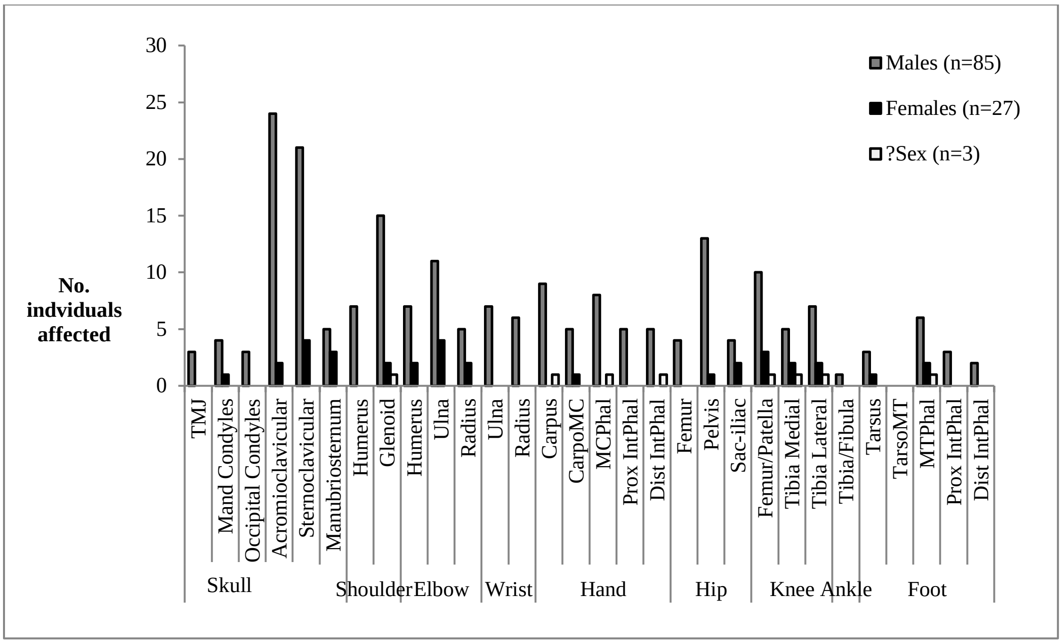


Figure 7.39: EVOA for Norton adults affected.

From Norton, male PSP% for EVOA was highest in the 15th and 16th century, and female prevalence was highest in the 13th and 14th century (Figure 7.40 and Appendix 4e). No evidence of female EVOA was found in the 12th or 16th centuries. Overall, no statistical difference was found between periods at Norton.

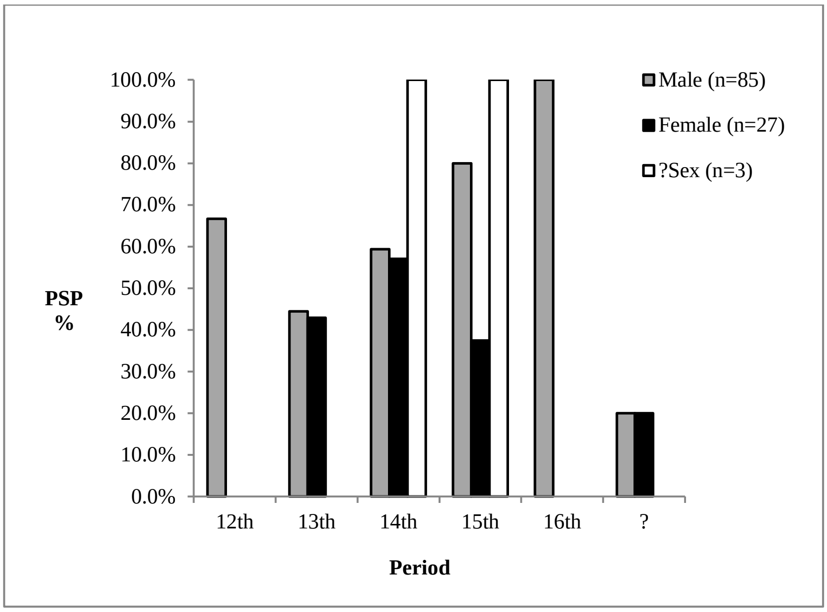


Figure 7.40: Period specific prevalence of EVOA for Norton adults.

Apart from 2 adults of unknown sex and age, the greatest ASP% of EVOA from Norton occurred in males and females aged 60+ (Figure 7.41 and Appendix 4d). There appears to be a steady increase of EVOA with age in females, although there is more of a fluctuation in male prevalence of EVOA, with those aged 36-45 more affected than the other age groups to a significant level (χ^2 = (5) = 21.94, $p < 0.001$). Overall, the increase in female EVOA with age may suggest that natural age degeneration was a contributory factor, with activity also contributing to EVOA, especially in males.

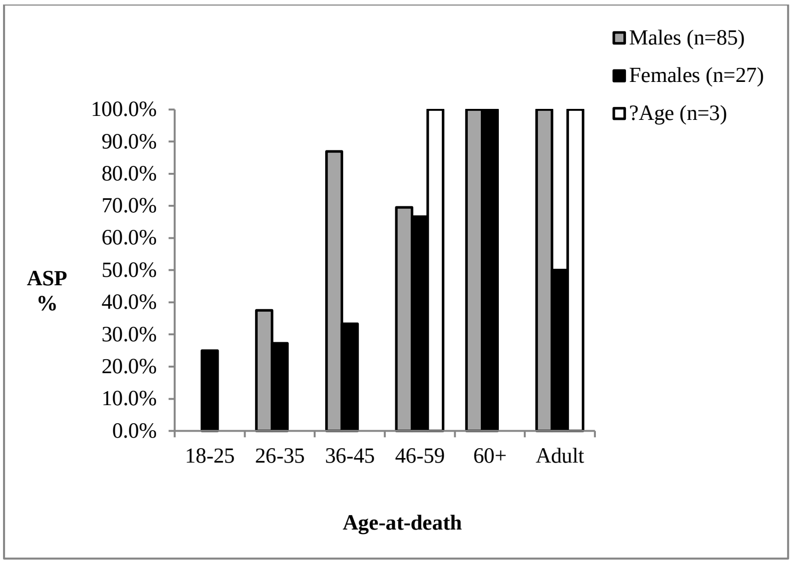


Figure 7.41: Age specific prevalence of EVOA for Norton adults.

7.3.8.4 Diffuse Idiopathic Skeletal Hyperostosis (DISH)

From Portmahomack, possible cases of DISH were observed on two adult males (1.4%) from period 4. On one male, aged 46-59, post-mortem damage to the thoracic vertebrae hindered full assessment. However, ossification of the right anterior longitudinal ligament on T12-L3 is present. A tentative diagnosis of DISH is suggested for a second male aged 36-45. All thoracic vertebrae are absent, although fusion of both sacro-iliac joints is evident as well as new bone growth on the distal left fibula. A differential diagnosis for this case is ankylosing spondylitis, although the involvement of new bone growth on limb bones is more characteristic of DISH (Resnick and Niwayama 1976; Roberts and Manchester 2005).

From Norton, DISH (Figure 7.42) was observed on five males (4.3%) from the 14th to 15th century, most aged 36-45, apart from one male aged 46-59. In all cases, there is evidence of anterior longitudinal ligament ossification on the right side of the thoracic vertebrae, although some have broken post-mortem. Apart from one male (NP68), where only thoracic vertebral fragments remain, more than five vertebrae are affected on each individual with the sacro-iliac joints also affected on two males (NP76, NP99).

Figure 7.42: DISH affecting 5th to 11th thoracic vertebrae of NP76.

7.3.8.5 Ankylosing Spondylitis

A possible case of ankylosing spondylitis was observed on one male from Portmahomack, aged 46-59 from monastic period 2. The intervertebral bodies, articulated facets and interspinous ligaments of the L3-4 are fused, with joint spaces obliterated on the left side. Absence of the pelvis hinders a more definitive diagnosis.

From Norton, a possible case of ankylosing spondylitis was observed on one male, aged 46-59 (period unknown). There is complete fusion of L2-3 with the joint space completely obliterated. T8-11 may also have been fused although post-mortem damage hinders full assessment. There is severe erosion on T8-11, on the visible bodies of L1-3 and on the sacro-iliac joints, suggesting ankylosing spondylitis, although psoriatic arthritis is offered as a differential diagnosis.

7.3.8.6 Miscellaneous Joint Diseases

From Norton, septic arthritis was observed on one female, aged 36-45 (period unknown), which manifested as disruption of the normal articular surface of the left proximal ulna, with healed pitted and spiculed new bone and slight erosive changes to the left proximal radius. This condition may be secondary to trauma, although there is no visible evidence of this.

Psoriatic arthritis was observed on one male from Norton, aged 60+ from the 15th century. Fusion of vertebral bodies and facets of the 2nd to 3rd cervical vertebrae and on the 4th to 5th thoracic vertebrae are present.

Gout was observed on one male from Norton, aged 36-45 from the 14th century, which manifested as erosive lesions on the right 1st metatarsal head, with a scooped lesion on the plantar surface. The presence of healed bone around the lesions suggests healing had occurred before death.

A seronegative spondyloarthropathy was observed on one male, aged 36-45 from 14th century Norton. This manifested as fusion between the inferior body of the 7th cervical vertebra and the superior body of the 1st thoracic vertebra. The morphology of new bone growth does not suggest fusion of a congenital nature, which would be more smooth and uniform in appearance. This diagnosis was also suggested in a previous osteological assessment (Boylston 2008).

Os acromiale is often linked to activity, caused by repetitive stress to the rotator cuff muscles during growth (e.g. Stirland 2000; Knüsel 2007). No evidence of os acromiale was found from Norton, although from Portmahomack, os acromiale was observed unilaterally on the right scapula of five adult males (SSP%: 4.9%) from periods 1 (n=1), 2 (n=3) and 4 (n=1) and across most age groups (apart from 46-59). One male affected from period 2 was aged 18-25. Considering the distal end of the acromion does not fuse until around 18-20 years (Scheuer and Black 2000), the difficulty here is differentiating between a naturally unfused acromion or os acromiale (Pagnani *et al.* 2006). A differential diagnosis of unfused acromial apophysis, as opposed to true os acromiale, should therefore be considered in this case.

7.3.8.7 Schmorl's Nodes

Presenting the number of vertebrae affected from the number of vertebrae scored, Schmorl's nodes were observed on 44 males (305/821) and 9 females (41/152) from Portmahomack (Appendix 5a), with a CP% of 38.4% (n=53). A SSP% of 42.7% for males and 28.1% for females was found, suggesting males were affected by Schmorl's nodes more than females. However, no significant difference was found between males and females, even when age- and period-specific data was considered. Using grades 1-3 for slight, moderate and severe nodes, of the total number of male vertebrae per segment affected (number of grade/vertebrae), slight and moderate nodes occurred the most in the thoracic vertebrae (98/452 and 94/452), with the fewest affected by grade 3 (29/452). The lumbar vertebrae in males were most affected by mild nodes (41/199) followed by moderate (28/199) and severe (15/199) nodes. For females, the severity occurred in the same pattern for mild, moderate and severe nodes respectively in the thoracic (21/81, 6/81 and 2/81) and lumbar (9/38, 2/38 and 1/38) vertebrae. No cervical vertebrae were affected in the Portmahomack adults. Males aged 46-59 were most affected, with those from monastic period 2-3 (n=27) being more affected than from lay periods 1 (n=3) and 4 (n=14). All females affected were from period 4, with those aged 46-59 being most affected.

Figure 7.43: Schmorl's nodes on 4th to 12th thoracic vertebrae of NP103.

From Norton, Schmorl's nodes affected 51 males (305/971) and 12 females (60/217), with an overall prevalence of 54.8% (n=63). For SSP%, 60.0% for males and 44.4% for females was calculated (Appendix 5b); suggesting males at Norton were affected by Schmorl's nodes more than females. As at Portmahomack, prevalence decreased with severity, with mild nodes occurring the most in the cervical, thoracic and lumbar vertebrae respectively for males (3/242, 94/515 and 45/214), followed by moderate (2/242, 81/515 and 26/214) and severe (1/242, 46/515 and 7/214) nodes (Figure 7.43). For females, the thoracic vertebrae were equally affected by mild and moderate nodes (19/114) and to a lesser extent for severe nodes (10/114). In the lumbar vertebrae, mild nodes occurred the most (10/35) with moderate and severe nodes occurring equally (1/35). No cervical vertebrae were affected for the Norton females. A low number of males (n=1) and females (n=2) aged 18-25 were affected, as were those from an undetermined age (n=2). Both males (n=21) and females (n=5) aged 26-35 and from the 13th to 15th centuries were most affected, with occurrences decreasing thereafter for males and females aged 36-45 (n=15, n=2), 46-59 (n=11, n=1) and 60+ (n=2, n=1). Although no statistical difference was found between sexes or age groups at Norton, a difference was found between periods (χ^2 (5) = 13.97, p = 0.016), with adults from the 14th century affected the most. Overall, the total number of Schmorl's nodes for Portmahomack and Norton adults (Figure 7.44) suggests an average prevalence in both males and females from both sites, although adults from Norton were affected at a younger age than those from Portmahomack. This may suggest individuals were engaging in strenuous forms of activity from an earlier age at Norton.

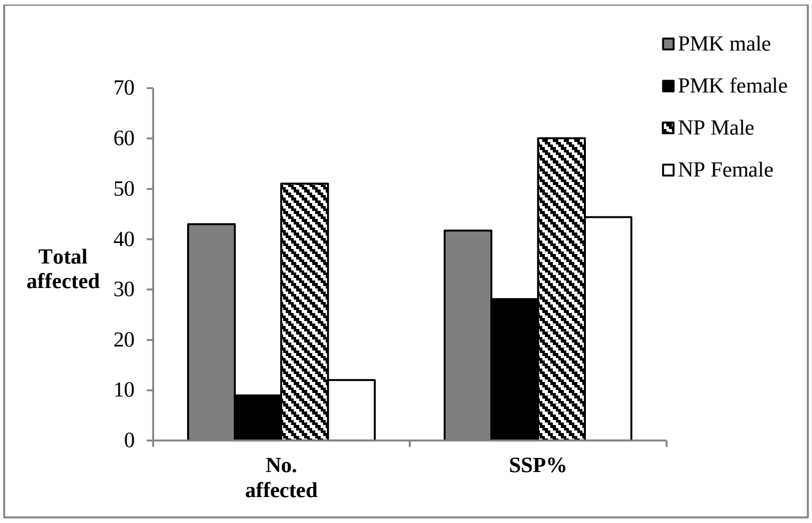


Figure 7.44: Schmorl's nodes on adults from Portmahomack and Norton.

7.3.9 Trauma

Trauma was observed on a number of individuals from both sites, with fractures being the most prevalent at both Portmahomack (21.0%) and Norton (10.4%) (Table 7.39). Evidence for a number of different fracture types (Figure 7.45) occurred on adults from both sites, suggesting a range of causes for this trauma (see chapter 8).

Table 7.39: Crude prevalence of trauma-related pathologies on Portmahomack (PMK) and Norton (NP) adults.

TRAUMA	PMK (N=138)					NP (N=115)				
	n	M	F	?	CP%	n	M	F	?	CP%
Fractures	**29**	26	3		21.0	**12**	11		1	10.4
Dislocation	**0**					**10**	7	3		8.7
Spondylolysis	**5**	5			3.6	**3**	3			2.6
Myositis ossificans traumatica	**1**	1			0.7	**1**	1			0.9
Vertebral compression	**5**	4	1		3.6	**1**	1			0.9
Blade injuries	**5**	5			3.6	**1**	1			0.9
Amputation	**0**					**1**	1			0.9
Osteochondritis dissecans	**2**	2			1.4	**0**				

Shaded areas = no trauma present.

Apart from osteochondritis dissecans, all pathologies discussed here were found on at least one individual at Norton. No evidence of dislocation or amputation was found at Portmahomack. Age-, sex- and period-specific prevalence data for trauma observed from both Portmahomack and Norton is presented in Appendices 6a-f.

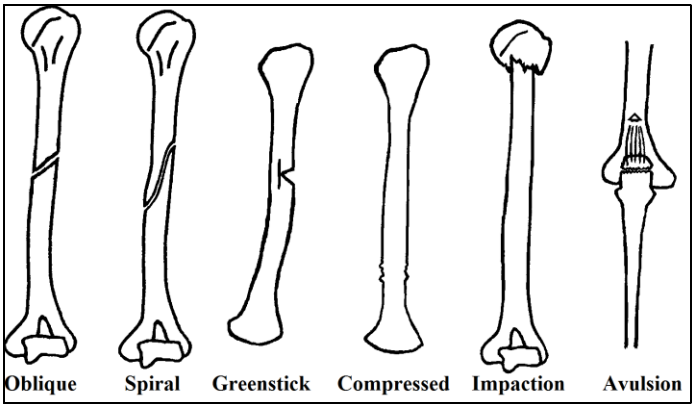


Figure 7.45: Fracture types (after Lovell 1997: 143).

7.3.9.1 Fractures and Trauma-related Pathologies

Evidence of adult trauma from both Portmahomack and Norton was dominated by fractures, although no evidence of fractures was observed on sub-adults from both sites. When SSP% was calculated for Portmahomack adults (Figure 7.46 and Appendix 6a), both males (25.2%) and females (9.4%) were affected by fractures, with transverse and avulsion fractures being the most common types (Table 7.40). Males were also affected by spondylolysis (4.9%), myositis ossificans traumatica (1.0%) and vertebral compression (3.9%). Apart from fractures, only one female (3.1%), aged 46-59 from period 5 was affected by other trauma, in the form of vertebral compression.

Table 7.40: Fractures observed on Portmahomack adults.

SK No.	Sex	Age	Period	Fracture type and bone affected
PMK187	?M	36-45	1	Avulsion: L&R 5th metatarsal tuberosity
PMK170	M	26-35	1	Transverse: Left clavicle
PMK149	M	60+	1	Transverse: 3rd-7th Right mid ribs
PMK39	?M	Adult	2	Oblique: Right fibula
PMK118	M	18-25	2	Avulsion: R.5th metatarsal tuberosity
PMK51	M	36-45	2	Avulsion: R.5th metatarsal tuberosity
PMK141	M	36-45	2	Oblique: Right fibula
PMK42	M	46-59	2	Transverse: Left rib neck
PMK122	M	46-59	2	Oblique: Left radius & Right fibula
PMK142	M	46-59	2	Avulsion: Right 5th metatarsal tuberosity
PMK151	M	46-59	2	Transverse: Left mid rib
PMK158	M	46-59	2	Transverse: Left mid ribs (5th-9th)
PMK164	M	46-59	2	Transverse: Right mid rib (x1); Left mid ribs (x2) & two rib fragments
PMK176	M	46-59	2	Complete: Left clavicle
PMK123	M	60+	2	Complete: Right 5th proximal phalanx
PMK125	M	60+	2	Oblique: Left tibia & fibula
PMK145	M	Adult	2	Non-united complete: Left clavicle
PMK114	F	18-25	4	Avulsion: Right patella
PMK5	F	46-59	4	Avulsion: R&L 5th metatarsal tuberosity
PMK105	F	46-59	4	Incomplete: Right fibula
PMK117	M	18-25	4	Avulsion: Right 3rd metacarpal styloid process
PMK134	M	18-25	4	?Fracture: Left 1st metacarpal
PMK80	M	36-45	4	Incomplete: 2 Left ribs; Complete: L.?10th rib
PMK113	M	36-45	4	Transverse: Left fibula & 3-7 Left ribs; Impacted: Right hamate
PMK64	M	46-59	4	?Fracture: Left fibula
PMK74	M	46-59	4	Avulsion: Left 3rd metacarpal styloid process
PMK84	M	46-59	4	Avulsion: Left patella
PMK109	M	46-59	4	Avulsion: L&R 3rd metacarpal styloid process
PMK1	?M	Adult	4	?Avulsion: Right fibula

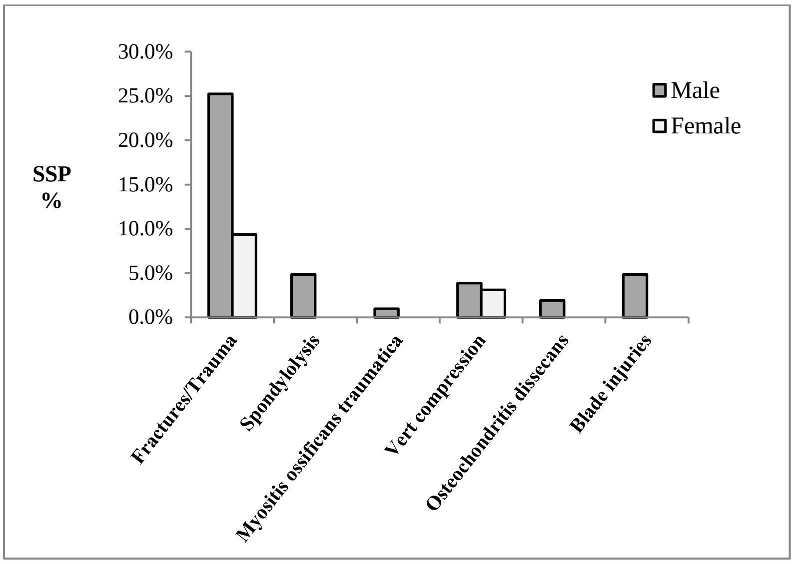


Figure 7.46: Sex specific prevalence of trauma for Portmahomack adults.

Although osteochondritis dissecans has been categorised as a circulatory disorder in some palaeopathology literature (e.g. Aufderheide and Rodríguez-Martin 1998), its aetiology is more often associated with trauma (e.g. Ortner 2003; Roberts and Manchester 2005), hence its inclusion here. At Portmahomack, osteochondritis dissecans was observed on two males (1.9%) from monastic period 2, aged 36-45 and 46-59, affecting both acetabula and the left distal femur respectively. No evidence of osteochondritis dissecans was found on the Norton individuals.

When ASP% was calculated for adult fractures at Portmahomack (Appendix 6b), the greatest prevalence was found in the 18-25 group (30.8%), closely followed by those aged 60+ (30.0%) and 46-59 (27.7%) and only one individual from the 26-35 age group (5.0%) was affected. The greatest number of adults affected overall were from the 46-59 age group (n=13).

PSP% of trauma on Portmahomack adults (Appendix 6c) revealed those most affected by fractures were males from monastic period 2 (25.0%). Those affected by fractures in period 1 were also male (23.1%), and those from period 4 comprised of three females and nine males (18.5%). Period 2 males were also affected by spondylolysis (7.1%), vertebral compression (5.4%), osteochondritis dissecans (3.6%) and blade wounds (3.6%). From lay period 4, one male, aged 36-45, was affected by myositis ossificans traumatica (1.5%) and three males, aged 18-25, 36-45 and 46-59 had evidence of blade injuries (4.6%) (Figure 7.47). The prevalence of fractures at Portmahomack may suggest activity-related trauma. However, two males affected by fractures, from period 2 (PMK158) and period 4 (PMK113), also had evidence of healed blade injuries. Although it cannot be stated with certainty that these fractures occurred at the same time as the blade wounds, a conflict-related cause is possible.

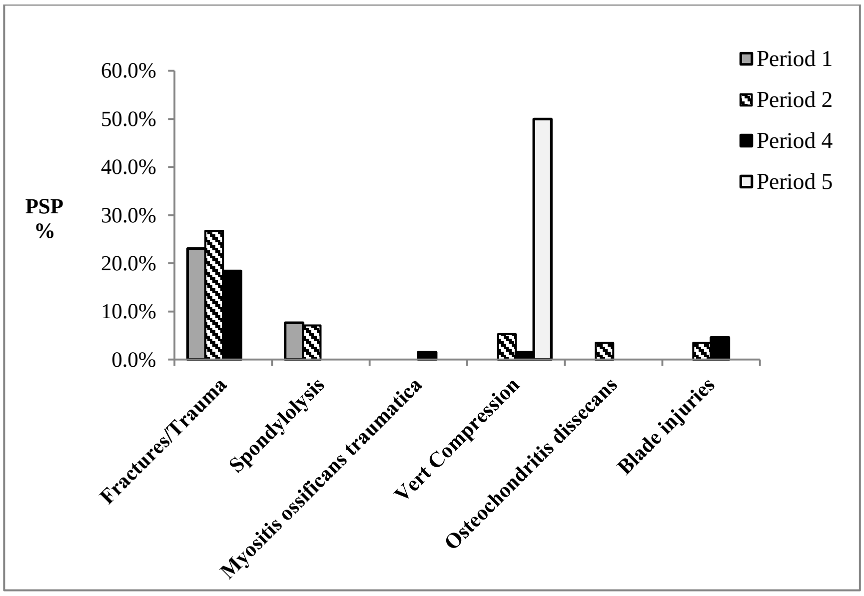


Figure 7.47: Period specific prevalence of trauma for Portmahomack adults.

SSP% calculated for Norton adults (Appendix 6d) revealed that males were affected by fractures (11.8%), dislocation (8.2%), spondylolysis (3.5%), myositis ossificans traumatica (1.2%), vertebral compression (1.2%) and amputation (1.2%). No evidence of fractures was observed on females from Norton, although dislocation was observed on three (11.1%) females (Figure 7.48). Both sexes were affected by dislocation mostly in the shoulder and clavicular area. A differential diagnosis for the individual (NP100) with an amputated 1st proximal hand phalanx may be symphalangism, a developmental failure of phalangeal bones (Barnes 2012a). However, the presence of reactive bone does suggest trauma.

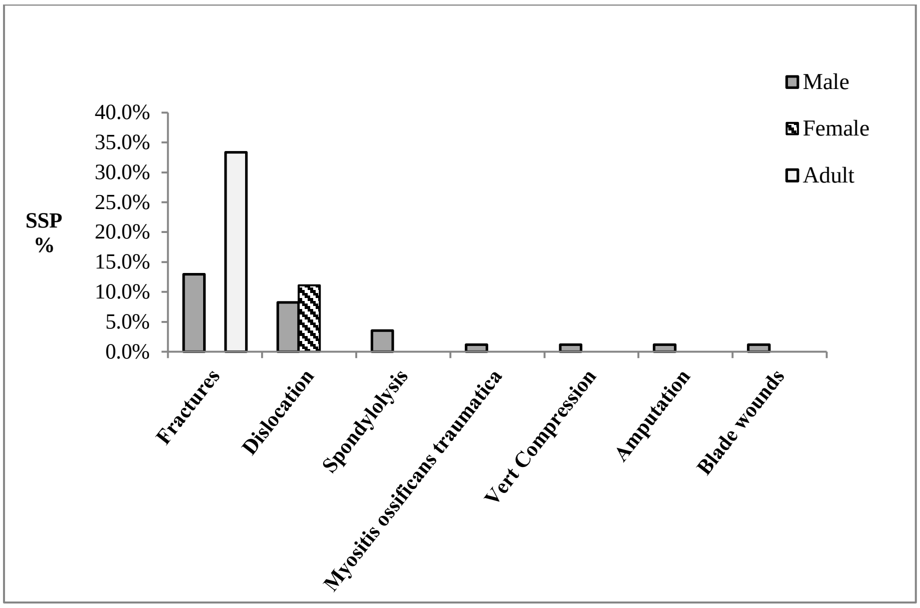


Figure 7.48: Sex specific prevalence of trauma for Norton adults.

ASP% for Norton adults (Appendix 6e) revealed that those aged 60+ (n=2) had the greatest prevalence in fractures (50.0%), with transverse and avulsion fractures being the most common types (Table 7.41). The greatest number of adults affected overall (n=4) were from the 46-59 age group (13.8%), which was also found at Portmahomack. One individual was affected from the 18-25 (14.3%) and one from the 26-35 (2.3%) age group. The greatest prevalence for dislocation overall was found on adults aged 46-59 (13.8%).

Table 7.41: Fractures observed on Norton adults.

Sk.No	Sex	Age	Period	Fracture type and bone affected
NP97	M	46-59	14th C	Transverse: Left fibula
NP105	M	46-59	14th C	Transverse: Rib shafts (x3) & Right fibula
NP106	M	60+	14th C	Avulsion: Left navicular; Transverse: Right fibula
NP30	M	18-25	15th C	Greenstick: Right femur
NP25	?M	26-35	15th C	Greenstick: Left ulna
NP19	M	36-45	15th C	Colles: Right radius
NP52	M	36-45	14th C	Oblique: Right 5th metacarpal
NP86	M	36-45	15th C	?Avulsion: Left pelvis (transverse ligament)
NP71	M	46-59	15th C	Impacted: Left 1st metacarpal; Oblique: Right 5th Metacarpal
NP101	M	46-59	15th C	Avulsion: Right humerus
NP70	M	60+	15th C	Oblique: Left wrist-thumb
NP79	?	Adult	15th C	Transverse: Right tibia & fibula

PSP% for trauma at Norton (Appendix 6f) revealed adults most affected by fractures were from the 15th century (21.1%). Adults from the 14th century were affected most by a range of traumatic pathologies (Figure 7.49), including fractures (10.3%), dislocation (12.8%), spondylolysis, myositis ossificans traumatica, and vertebral compression (2.6%). Traumatic pathologies most prevalent in the 13th century at Norton were spondylolysis (12.5%), with a PSP% for both dislocation and blade wounds in this period at 6.3%, the latter of which is presented below (section 7.3.9.2). No trauma was observed from the 12th or 16th century groups at Norton.

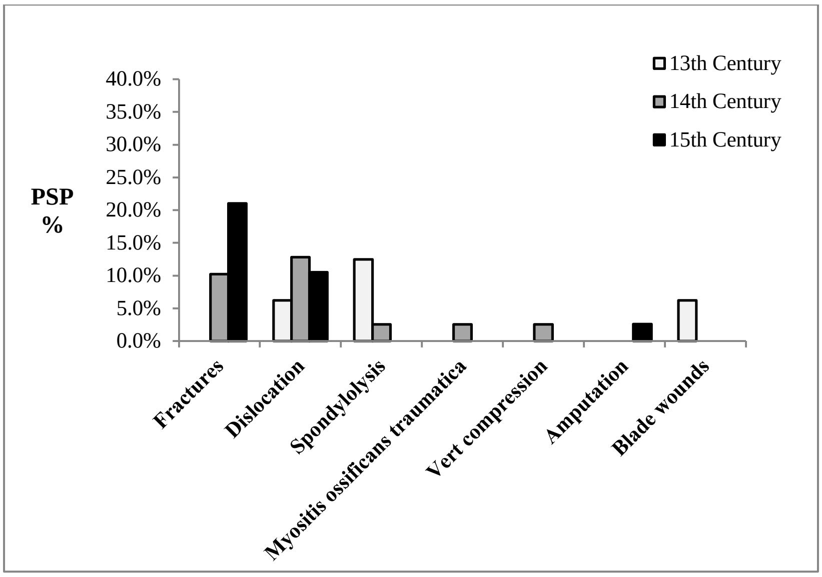
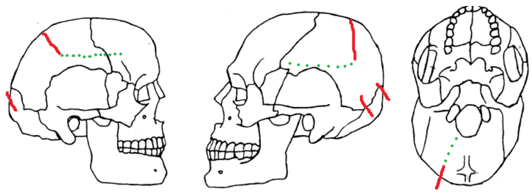
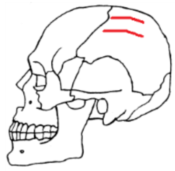
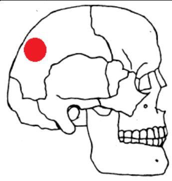
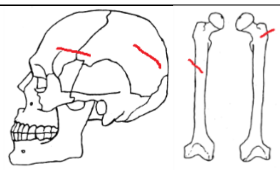
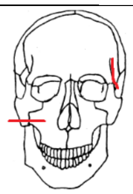


Figure 7.49: Period specific prevalence of trauma for Norton adults.

7.3.9.2 Sharp-force Trauma

Evidence of sharp-force trauma was observed on five males (4.9%) from Portmahomack (Table 7.42), comprising two from monastic period 2 (3.6%) and three from lay period 4 (4.6%). All age groups, apart from 60+, were affected (Appendix 6b). Evidence of sharp-force trauma presented here is suggested to be weapon-related, with unhealed cuts displayed on three males, suggesting these individuals met a violent death. A second opinion for a healed cut on one male (PMK113) was sought, due to the scooped circular morphology of the cut that did not penetrate the endocranial surface. Second opinions on this case resulted in different diagnoses, namely, a blade wound (J. Buckberry, *pers.comm.*) and a partial trepanation (S. Mays, *pers.comm.*).

Table 7.42: Location of blade injuries to Portmahomack adult males.

PMK152 (male, 26-35, period 2): Unhealed blade wounds crossing left parietal and occipital; left to right occipital (radiating fracture towards foramen magnum) and left to right parietal (radiating fractures towards frontal).	
PMK158 (male, 46-59, period 2): Two healed blade wounds to the anterior left parietal.	
PMK113 (male, 36-45, period 4): Healed circular sharp-force trauma to the posterior right parietal.	
PMK117 (male, 18-25, period 4): Unhealed blade wounds to left frontal and parietal and to lateral right proximal femur and posterior left proximal femur.	
PMK36 (male, 46-59, period 4): Unhealed blade wounds to right zygomatic and left frontotemporal.	

Sharp-force trauma was observed on one sub-adult (PMK65) from Portmahomack, aged 6.6-10.5 from period 4 (2.5%). The blade wound to the posterior aspect of the right frontal bone has a bevelled edge, with little sign of healing apart from slight reactive bone on the endocranial surface. Diagnosis of a peri-mortem blade injury is suggested for this individual, which was confirmed after a second opinion was sought (S.Mays, *pers comm*).

From Norton, there was evidence of a peri-mortem blade wound to one male, aged 46-59 from the 13th century (Figures 7.50 and 7.51). This individual is thought to have been a knight and wealthy lay benefactor to Norton and also had extensive Paget's disease (see section 7.3.4.7). The cut had severed the right transverse processes of the 1st to 8th thoracic vertebrae. Possible involvement of the 7th cervical and 9th thoracic vertebrae is also suggested, although post-mortem damage hindered full assessment.

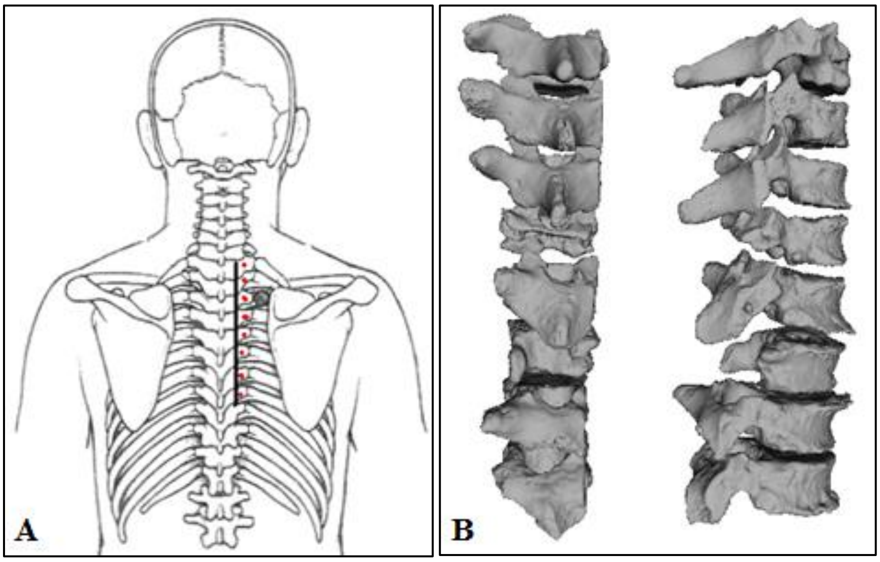


Figure 7.50: Location of blade wound (A) and 3D scan* showing posterior and right lateral view (B) of affected vertebrae on NP22.
*Mesh data for 3D scan supplied by www.OR3D.co.uk

Figure 7.51: Sharp-force on thoracic vertebrae of NP22.

Evidence of partial trepanations on three crania from Norton was originally identified by Robert Connolly at the University of Liverpool's Anatomy Department (R.

Connolly, *pers.comm.*) following excavations in the early 1970s. These specimens are disarticulated and cannot be assigned to an individual skeleton, although one was found with an adult male burial (NP52) from the 14th century.

7.4 Stable Isotope Results

Stable carbon and nitrogen isotope results are presented in Appendices 7a-c for Portmahomack and Appendices 7d-f for Norton. The analytical precision for both carbon and nitrogen is ± 0.1‰ (1σ), with $\delta^{13}C$ and $\delta^{15}N$ values reported relative to the international standards of Vienna-PDB and AIR respectively. Where relevant, isotope results for each sample group (n) are presented by the range of $\delta^{13}C$ and $\delta^{15}N$ values and the difference of each range ($\Delta^{13}C_{max-min}$ or $\Delta^{15}N_{max-min}$). Also presented are average (mean) $\delta^{13}C$ and $\delta^{15}N$ values and associated standard deviation (±). As well as presenting individual human and faunal $\delta^{13}C$ and $\delta^{15}N$ values in bi-plots; where relevant, average human isotope values will be presented alongside associated faunal data (see sections 7.4.2.1, 7.4.2.3 and 7.4.3.1) to interpret dietary reconstructions. Where statistically significant ($p < 0.05$), the results of paired *t*-test to compare means from human isotope data will be presented. Faunal isotope data was not statistically assessed due to low sample numbers per species. However, faunal isotope data presented in this study provides an important baseline to enable human dietary reconstructions.

7.4.1 Collagen Quality

The carbon to nitrogen (C:N) ratios for all human and animal Portmahomack bone samples analysed were between 2.9-3.6, therefore within the acceptable range for isotope analysis (DeNiro 1985). Of the 114 Norton human bone samples analysed, 30 failed, due to either C:N ratios outside the acceptable range or not producing enough collagen. The majority of Portmahomack and Norton sample weight percentages for carbon and nitrogen fell within the acceptable range of 30-50 wt.% for carbon and 10-20 wt.% for nitrogen (van Klinken 1999), although some samples from Portmahomack and Norton fell outside these ranges. Collagen yields for the Portmahomack and Norton human and faunal samples ranged from 0.2 to 26.0 wt.% and 0.2 to 23.4 wt.% respectively. The majority of samples are within the acceptable range of 0.5 wt.% (van Klinken 1999), although a small number fall below this range. However, as the C:N ratios for these samples are within the accepted range for good quality collagen, they are considered suitable to be included in this study.

7.4.2 Portmahomack Isotope Results

Results of $\delta^{13}C$ and $\delta^{15}N$ values of human and faunal bone collagen are presented here to provide dietary reconstructions of inhabitants from the 6th to 17th century at Portmahomack. As burials from period 3 are classed as closely associated with the monastic phase of period 2 (Curtis-Summers *et al.* 2014), isotope data from these periods shall be presented together, unless relating to period-specific individuals. Although the human sample numbers from period 5 are small (n=2), it is important to include them (see section 7.4.2.2) for continuity and completeness.

7.4.2.1 Isotope Data: Fauna

From Portmahomack, 71 faunal samples were included in this study to provide baseline isotopic data against which to interpret the human $\delta^{13}C$ and $\delta^{15}N$ values. Of the 71 faunal samples, 16 were analysed prior to this study (Curtis-Summers *et al.* 2014), which are marked bold in Appendix 7c. Isotope results for all Portmahomack fauna are presented below (Figure 7.52) and thereafter by species. No faunal samples from period 5 were available for analysis.

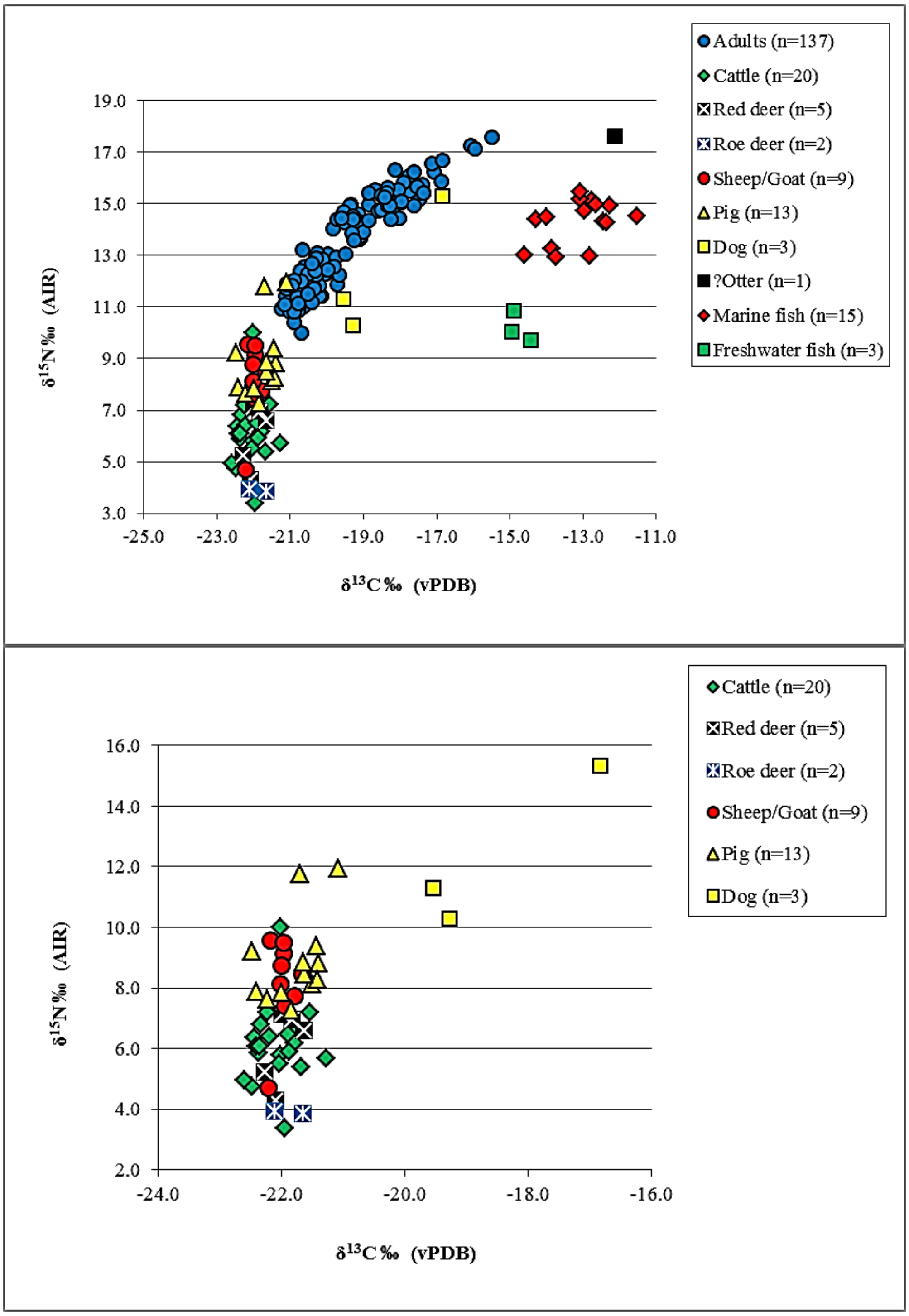


Figure 7.52: Portmahomack faunal and adult human $\delta^{13}C$ and $\delta^{15}N$ values (top), with expanded plot of terrestrial fauna (bottom).

7.4.2.1.1 Cattle (*Bos*)

Total cattle (n=20) $\delta^{13}C$ values ranged between -22.6‰ and -21.3‰ ($\Delta^{13}C_{max-min}$ 1.3‰), with an average of -22.1‰ ± 0.3‰. Total cattle $\delta^{15}N$ values ranged between 3.4‰ and 10.0‰ ($\Delta^{15}N_{max-min}$ 6.6‰), with an average of 6.1‰ ± 1.3‰. This is a wide range, although period-specific data produces closer ranges (Figure 7.53).

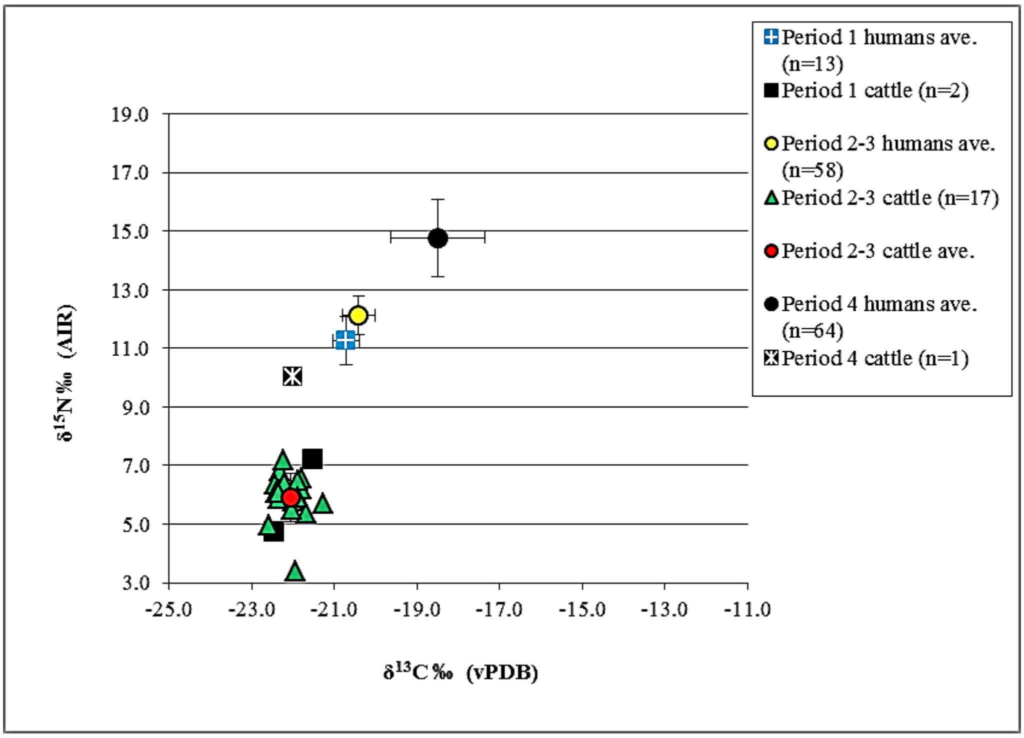


Figure 7.53: Portmahomack cattle and adult human $\delta^{13}C$ and $\delta^{15}N$ values.

From period 1, cattle (n=2) $\delta^{13}C$ values were -22.5‰ and -21.5‰ ($\Delta^{13}C_{max-min}$ 1.0‰), with an average of -22.0‰. The $\delta^{15}N$ values were 4.7‰ and 7.2‰ ($\Delta^{15}N_{max-min}$ 2.5‰), with an average of 6.0‰. Period 2-3 cattle (n=17) $\delta^{13}C$ values ranged between -22.6‰ and -21.3‰ ($\Delta^{13}C_{max-min}$ 1.3‰), with an average of -22.1‰ ± 0.3‰ and $\delta^{15}N$ values ranged between 3.4‰ and 7.2‰ ($\Delta^{15}N_{max-min}$ 3.8‰), with an average of 5.9‰ ± 0.8‰.

From period 4, only one cattle sample was available for analysis, with $\delta^{13}C$ and $\delta^{15}N$ values of -22.0‰ and 10.0‰ respectively. The $\delta^{15}N$ value here is the highest of all cattle analysed and a trophic level higher than the average $\delta^{15}N$ value for period 2-3 cattle ($\Delta^{15}N_{max-min}$ 4.1‰). It appears that cattle from all periods at Portmahomack were predominantly consuming C_3 plants, with no C_4 component to the diet. Increased $\delta^{15}N$ value for the period 4 cattle sample may suggest a shift in feeding strategies, with cattle grazing further afield and possibly consuming plants near the coastline or salt marshes, which have been found to be elevated in nitrogen (Britton *et al.* 2008).

7.4.2.1.2 Deer (*Cervidae*)

Red and roe deer from Portmahomack were analysed, most of which were from period 2-3, apart from one red deer from period 4 (Figure 7.54). For red deer from period 2-3 (n=4), the $\delta^{13}C$ values ranged between -22.3‰ and -21.6‰ ($\Delta^{13}C_{max-min}$ 0.7‰), with an average of -21.9‰ ± 0.2‰. The $\delta^{15}N$ values ranged between 5.2‰ and 7.1‰ ($\Delta^{15}N_{max-min}$ 1.9‰), with an average of 6.5‰ ± 0.7‰. The $\delta^{13}C$ and $\delta^{15}N$ values for period 4 red deer were -22.1‰ and 4.3‰ respectively.

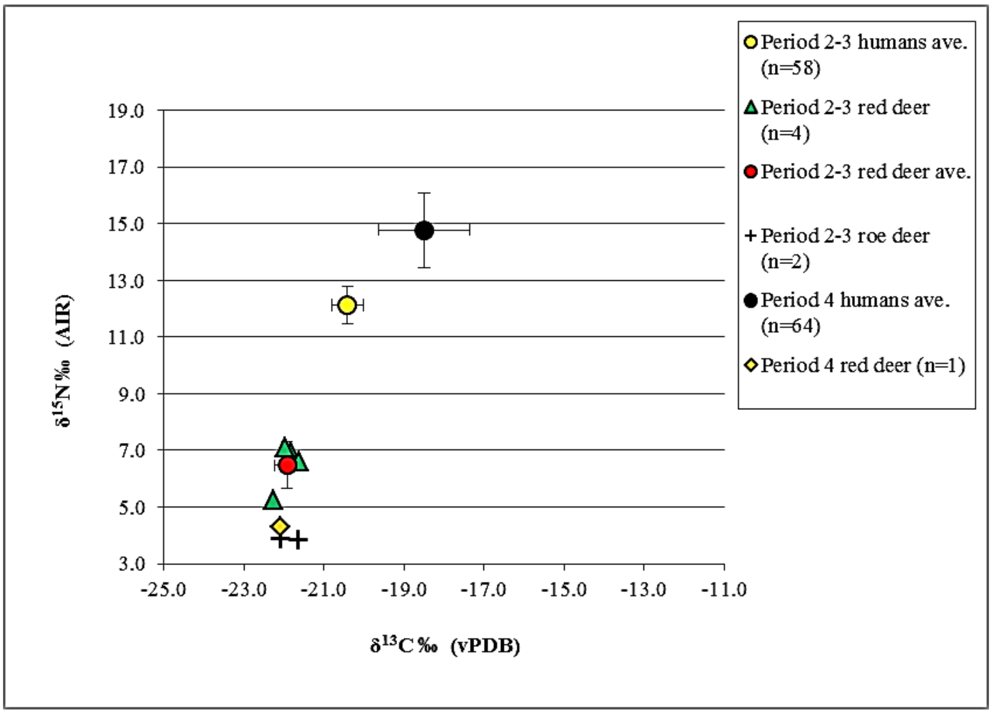


Figure 7.54: Portmahomack deer and adult human $\delta^{13}C$ and $\delta^{15}N$ values.

For roe deer from period 2-3 (n=2), $\delta^{13}C$ values were -22.1‰ and -21.6‰ ($\Delta^{13}C_{max-min}$ 0.5‰), with an average of -21.9‰ and $\delta^{15}N$ values were 3.8‰ and 3.9‰ ($\Delta^{15}N_{max-min}$ 1.9‰), averaging 3.9‰. Both red and roe deer have the same average $\delta^{13}C$ values, yet the $\delta^{15}N$ values for the roe deer is 2.6‰ less than the red deer, which may suggest different feeding activities between the two species, resulting in elevated $\delta^{15}N$ values in the red deer. The principal dietary component of deer samples from Portmahomack was native C_3 plants. The variation in $\delta^{15}N$ values between roe and red deer may suggest roe deer were mostly grazing on lowland vegetation, possibly even around the monastic grounds, whereas red deer may have had a mixed grazing pattern, consuming upland, lowland, woodland and possibly even coastal vegetation.

7.4.2.1.3 Sheep/Goat (*Ovis/Capra*)

Sheep and goat species could not be distinguished from the Portmahomack remains; hence the description 'sheep/goat' or 'S/G' (Seetah 2011) is used here. Total sheep/goat (n=9) $\delta^{13}C$ values ranged between -22.2‰ and -21.7‰ ($\Delta^{13}C_{max-min}$ 0.5‰), with an average of -22.0‰ ± 0.2‰ and total $\delta^{15}N$ values ranged between 4.7‰ and 9.6‰ ($\Delta^{15}N_{max-min}$ 4.9‰), averaging 8.2‰ ± 1.5‰ (Figure 7.55). These $\delta^{13}C$ ranges and difference were the same for period 2-3 sheep/goat, with an average of -21.9‰ ± 0.2‰. The $\delta^{15}N$ values for period 2-3 sheep/goat ranged between 7.4‰ and 9.6‰ ($\Delta^{15}N_{max-min}$ 2.2‰), with an average of 8.4‰ ± 0.7‰. No sheep/goat samples were analysed from period 1.

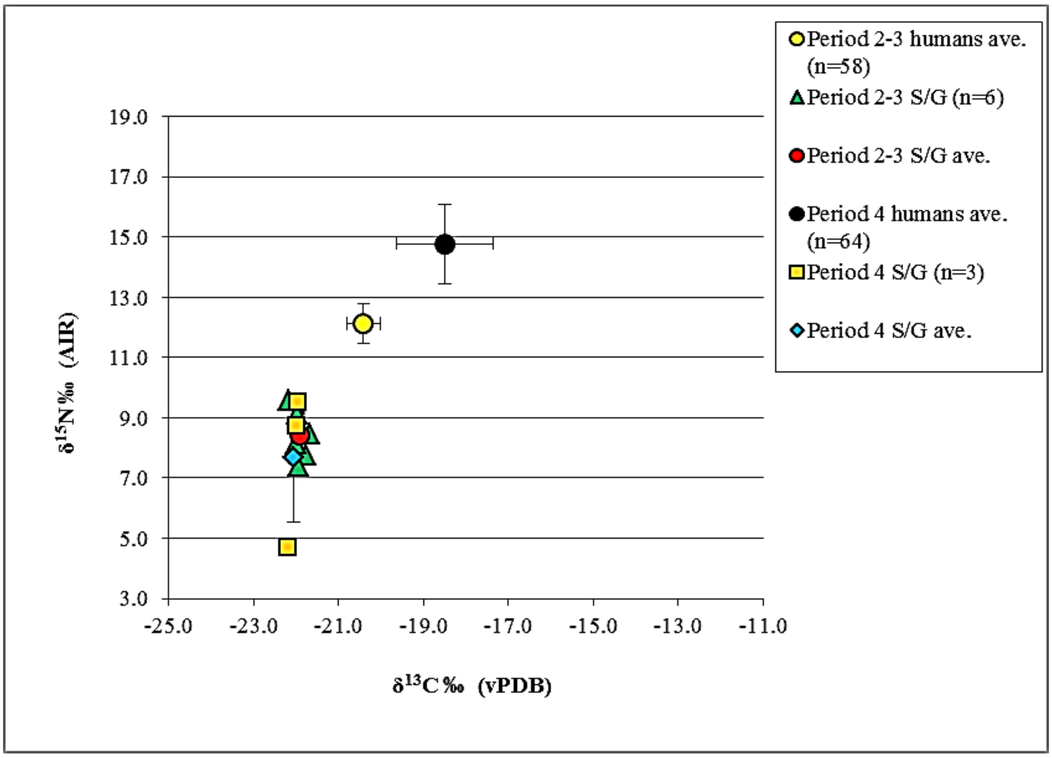


Figure 7.55: Portmahomack sheep/goat and adult human $\delta^{13}C$ and $\delta^{15}N$ values.

Period 4 sheep/goat (n=3) $\delta^{13}C$ values ranged between -22.2‰ and -22.0‰ ($\Delta^{13}C_{max-min}$ 0.2‰), with an average of -22.1‰ ± 0.1‰ and $\delta^{15}N$ values ranged between 4.7‰

and 9.5‰ ($\Delta^{15}N_{max-min}$ 4.8‰), with an average of 7.7‰ ± 2.1‰. This difference in $\delta^{15}N$ values is quite wide, although when the sheep/goat with the low $\delta^{15}N$ value (4.7‰) is removed, the difference is reduced ($\Delta^{15}N_{max-min}$ 0.7‰), with an average of 9.1‰ ± 0.5‰. Overall, there is very little variation in $\delta^{13}C$ values for sheep/goat from Portmahomack, suggesting a diet based on C_3 plant consumption, with no C_4 input. The sheep/goat sample with the lowest $\delta^{15}N$ value may have originated from a different geographical region and consuming different types of fodder, resulting in lower $\delta^{15}N$ values.

7.4.2.1.4 Pig (*Sus*)

Total pig (n=13) $\delta^{13}C$ values ranged between -22.5‰ and -21.1‰ ($\Delta^{13}C_{max-min}$ 1.4‰), with an average of -21.7‰ ± 0.4‰ and $\delta^{15}N$ values ranged between 7.3‰ and 12.0‰ ($\Delta^{15}N_{max-min}$ 4.7‰), with an average of 8.9‰ ± 1.5‰ (Figure 7.56).

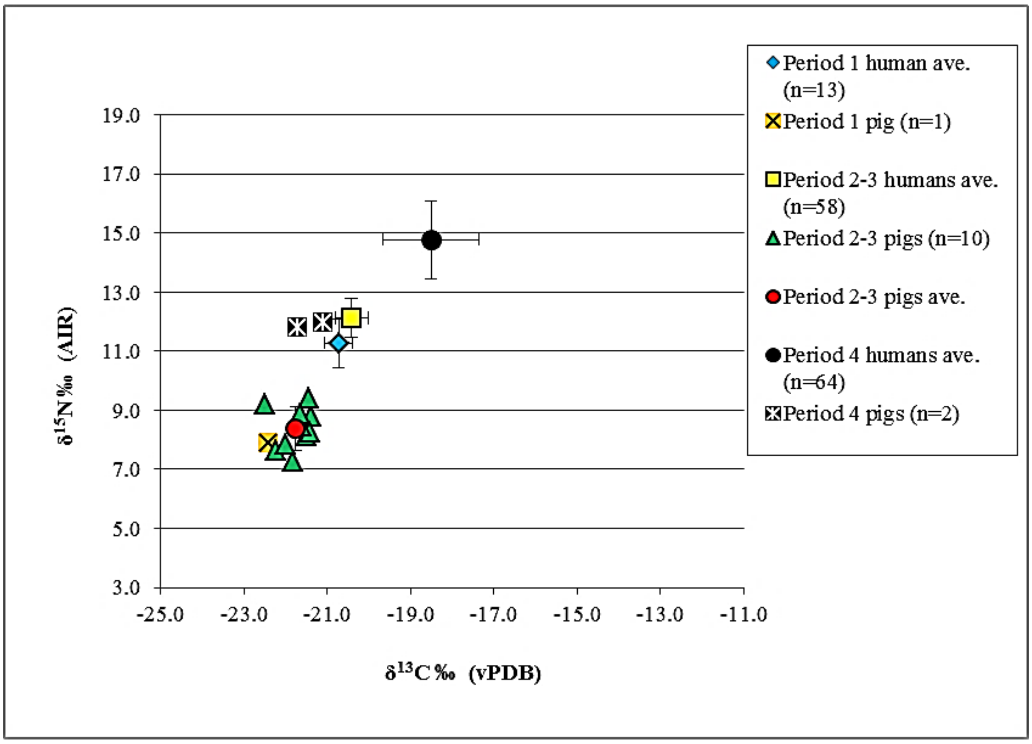


Figure 7.56: Portmahomack pig and adult human $\delta^{13}C$ and $\delta^{15}N$ values.

From period 1, only one pig sample was available for analysis, with $\delta^{13}C$ and $\delta^{15}N$ values of -22.4‰ and 7.9‰ respectively. Period 2-3 pig (n=10) $\delta^{13}C$ values ranged between -22.5‰ and -21.4‰ ($\Delta^{13}C_{max-min}$ 1.1‰), with an average of -21.8‰ ± 0.4‰ and $\delta^{15}N$ values ranged between 7.3‰ and 9.4‰ ($\Delta^{15}N_{max-min}$ 2.1‰), with an average of 8.4‰ ± 0.7‰. For pig samples from period 4 (n=2), $\delta^{13}C$ values were -21.7‰ and -21.1‰ ($\Delta^{13}C_{max-min}$ 0.6‰), with an average of -21.4‰ and $\delta^{15}N$ values were 11.8‰ and 12.0‰ ($\Delta^{15}N_{max-min}$ 0.2‰), averaging 11.9‰. This reveals a difference in average $\delta^{15}N$ values between pigs from period 4 and those from periods 1 ($\Delta^{15}N_{max-min}$ 4.0‰) and 2-3 ($\Delta^{15}N_{max-min}$ 3.5‰).

Overall, there is slight variation in pig $\delta^{13}C$ values, although not to the extent that would suggest anything other than C_3 plant consumption. The increase in period 4 pig $\delta^{15}N$ values reflects a trophic level shift in dietary animal protein, which may be due to an omnivorous diet that included consuming human food waste that differed to what was consumed by humans from earlier periods at Portmahomack.

7.4.2.1.5 Dog (*Canid*)

One dog bone sample from period 2 was analysed, with $\delta^{13}C$ and $\delta^{15}N$ values of -19.3‰ and 10.3‰ respectively. Two dog samples from period 4 had $\delta^{13}C$ values of -16.8‰ and -19.5‰ ($\Delta^{13}C_{max-min}$ 2.7‰), with an average of -18.2‰ and $\delta^{15}N$ values of 15.3‰ and 11.3‰ ($\Delta^{15}N_{max-min}$ 4.0‰), with an average of 13.3‰ (Figure 7.57). One dog sample from period 4 had $\delta^{13}C$ and $\delta^{15}N$ values that were closer to that of the period 2 dog sample. This may suggest that the dog sample with the highest $\delta^{13}C$ and $\delta^{15}N$ values was consuming a variety of different foods. Such foods probably came from human food waste, which may have included marine protein, hence the elevation in isotope values. Overall however, $\delta^{13}C$ values suggest the principal component of plant foods consumed were native C_3 plants, with an omnivorous variation in foods consumed.

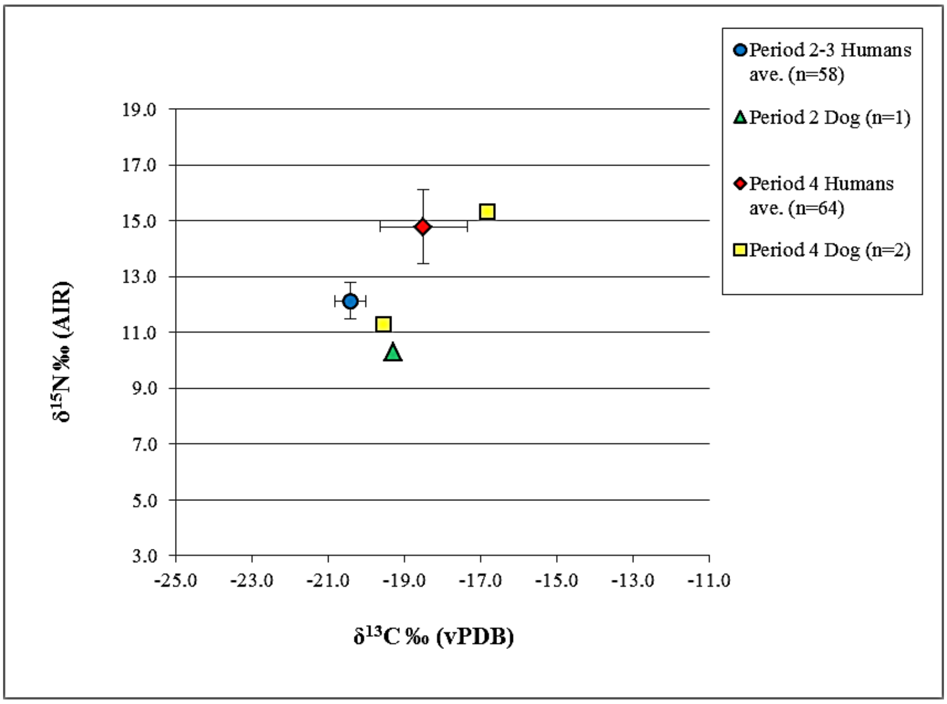
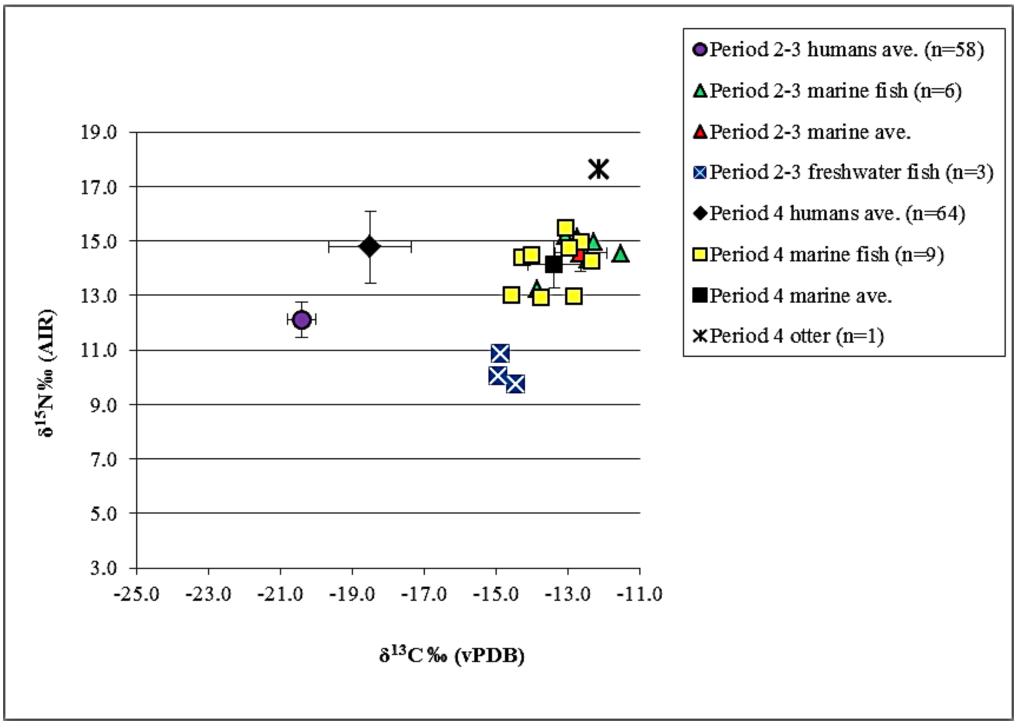


Figure 7.57: Portmahomack dog and adult human $\delta^{13}C$ and $\delta^{15}N$ values.

7.4.2.1.6 Marine Fish

A selection of marine fish from Portmahomack were analysed from periods 2-3 and 4, including haddock, cod, pollock, saithe; horse mackerel and conger eel (Figure 7.58). The total marine fish (n=15) $\delta^{13}C$ values ranged between -14.6‰ and -11.5‰ ($\Delta^{13}C_{max-min}$ 3.1‰), averaging -13.1‰ ± 0.8‰. Total marine fish $\delta^{15}N$ values ranged between 13.0‰ and 15.5‰ ($\Delta^{15}N_{max-min}$ 2.5‰), averaging 14.3‰ ± 0.9‰.



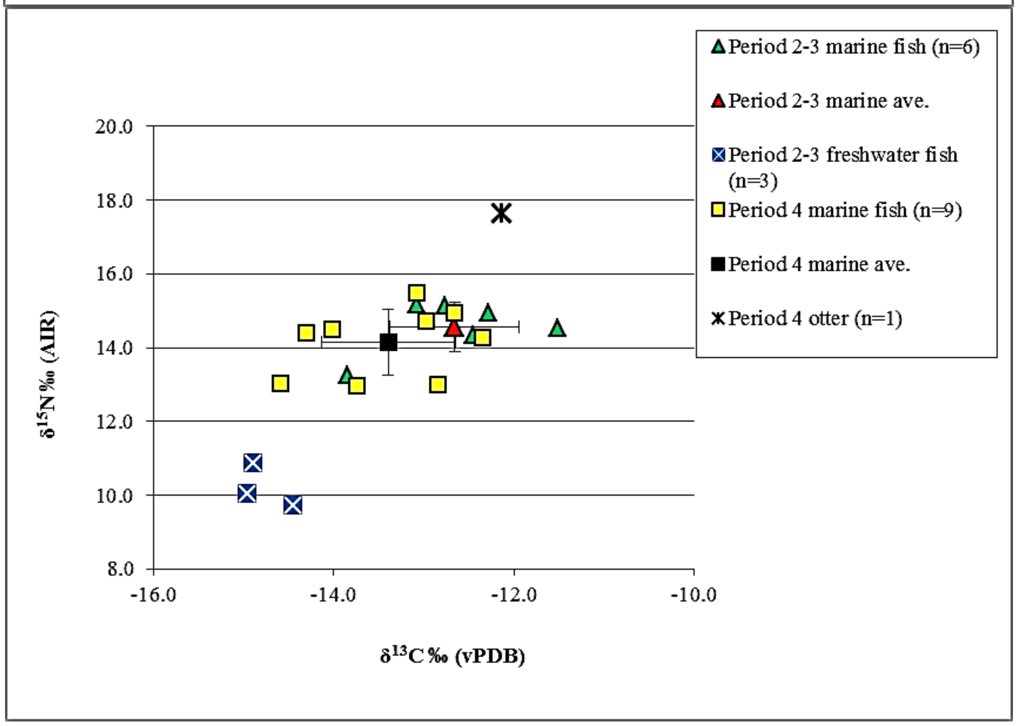


Figure 7.58: Portmahomack fish, otter and adult human δ^{13}C and δ^{15}N values (top), with expanded plot for aquatic species (bottom).

From period 2-3, the δ^{13}C values for cod (n=4), pollack (n=1) and horse mackerel (n=1) ranged between -13.8‰ and -11.5‰ ($\Delta^{13}C_{max-min}$ 2.3‰), averaging -12.7‰ ± 0.7‰ and δ^{15}N values ranged between 13.2‰ and 15.2‰ ($\Delta^{15}N_{max-min}$ 2.0‰), averaging 14.6‰ ± 0.7‰. Horse mackerel had the lowest δ^{13}C and δ^{15}N values; not surprising considering they are one of the fish consumed by carnivorous cod (dos Santos *et al*. 1993). However, the difference between average cod $\delta^{15}N$ values and that of the horse mackerel sample from period 2-3 ($\Delta^{15}N_{max-min}$ 1.5‰) is not enough to suggest a whole trophic level difference between these two species.

From period 4, the $\delta^{13}C$ values for cod (n=4), haddock (n=1), saithe (n=1), pollack (n=2) and conger eel (n=1) ranged between -14.6‰ and -12.4‰ ($\Delta^{13}C_{max-min}$ 2.2‰), averaging -13.4‰ ± 0.7‰ and $\delta^{15}N$ values ranged between 13.0‰ and 15.5‰ ($\Delta^{15}N_{max-min}$ 2.5‰), averaging 14.1‰ ± 0.9‰. There is variation in $\delta^{13}C$ and $\delta^{15}N$ values for marine fish from this period, although overall, a homogenous diet is suggested with no evidence of trophic level enrichment between marine fish. One marine mammal (otter) sample from period 4 was also analysed, with $\delta^{13}C$ and $\delta^{15}N$ values of -12.1‰ and 17.6‰ respectively. The otter $\delta^{15}N$ value reflects a trophic level increase compared to the marine fish data, which is expected between marine mammal and fish species.

7.4.2.1.7 Freshwater Fish

Three char fish bone samples from period 2-3 were analysed (plotted in Figure 7.58), with $\delta^{13}C$ values ranging between -15.0‰ and -14.4‰ ($\Delta^{13}C_{max-min}$ 0.6‰), averaging -14.8‰ ± 0.2‰. $\delta^{15}N$ values ranged between 9.7‰ and 10.9‰ ($\Delta^{15}N_{max-min}$ 1.2‰), averaging of 10.2 ± 0.5‰. There is wide variation in freshwater $\delta^{13}C$ and $\delta^{15}N$ values, for example, freshwater fish $\delta^{15}N$ values can be similar to those of terrestrial carnivores (Shoeninger and DeNiro 1984; Bocherens *et al.* 1991). Both marine and freshwater fish can also have wide-ranging $\delta^{13}C$ values depending on the source of carbon and type of food consumed, which was discussed in chapter 5. The $\delta^{13}C$

values of freshwater fish are similar to those of marine fish from Portmahomack, whereas $\delta^{15}N$ values are similar to some adult human values from period 2-3; a pattern which has been found in other studies (Shoeninger and DeNiro 1984).

7.4.2.2 Isotope Data: Adult Humans

Results from carbon and nitrogen isotope analysis on human bone collagen of 137 adult humans are presented here to provide dietary reconstructions of the early to late medieval inhabitants from Portmahomack. Of the 137 adults, 40 were analysed prior to this study (Curtis-Summers *et al.* 2014), which are marked bold in Appendix 7a.

Adult human $\delta^{13}C$ values from all periods at Portmahomack (n=137) ranged between -21.2‰ and -15.5‰ ($\Delta^{13}C_{max-min}$ 5.7‰), with an average of -19.5‰ ± 1.3‰. The $\delta^{15}N$ values ranged between 10.0‰ and 17.6‰ ($\Delta^{15}N_{max-min}$ 7.6‰), with an average of 13.3‰ ± 1.7‰. Two distinct clusters are visible, from periods 1-3 and from periods 4-5, although a small number of adults from period 4 have $\delta^{13}C$ and $\delta^{15}N$ values similar to those from periods 1-3 (Figure 7.59). However, the majority of period 4 adults show a distinction in diet compared to earlier periods, hence period-specific data is needed to produce more refined results.

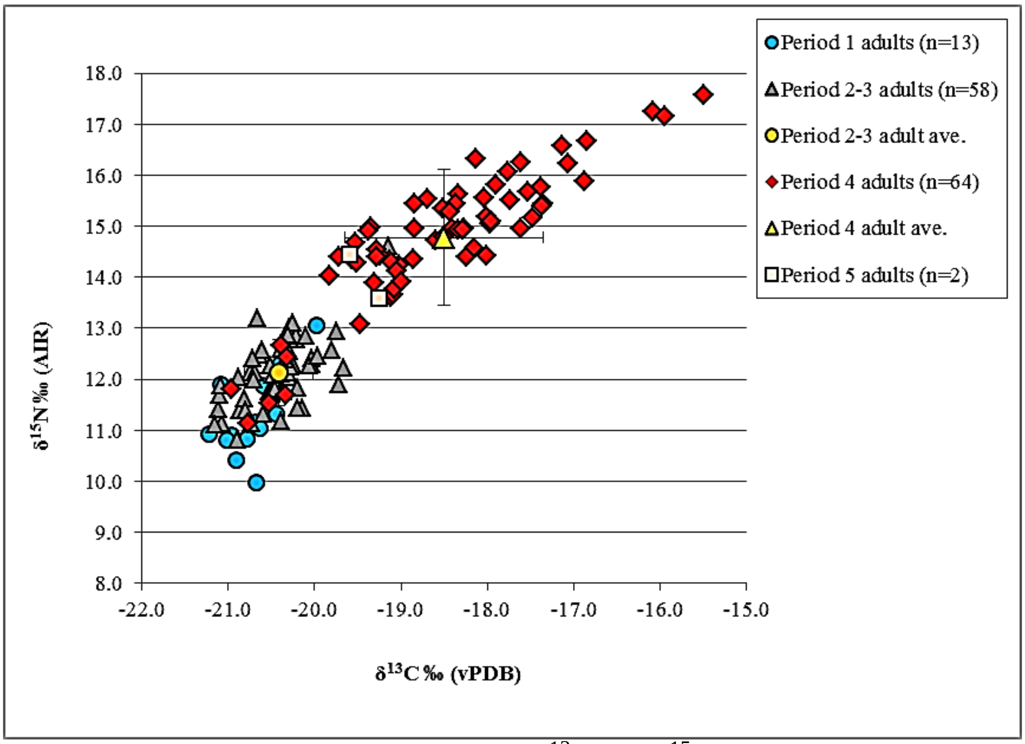
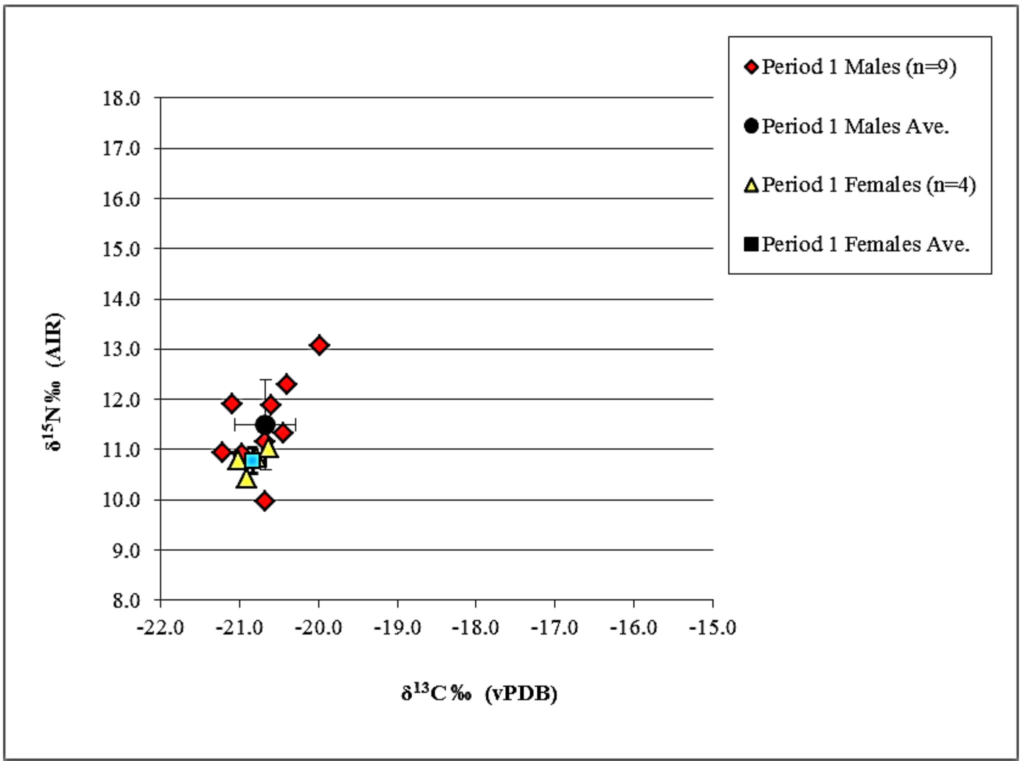


Figure 7.59: Portmahomack adult human $\delta^{13}C$ and $\delta^{15}N$ values from periods 1-5.

7.4.2.2.1 Adult diets: Lay Period 1 (c.550 – c.700)

Period 1 human (n=13) $\delta^{13}C$ values ranged between -21.1‰ and -20.0‰ ($\Delta^{13}C_{max-min}$ 1.1‰), with an average of -20.7‰ ± 0.3‰ and $\delta^{15}N$ values between 10.0‰ and 13.1‰ ($\Delta^{15}N_{max-min}$ 3.1‰), with an average of 11.3‰ ± 0.8‰ (Figure 7.60). Although average $\delta^{13}C$ and $\delta^{15}N$ values for males (-20.7‰ ± 0.4‰ and 11.5‰ ± 0.9‰) and females (-20.8‰ ± 0.2‰ and 10.8‰ ± 0.3‰) are similar, a number of male individuals from this period have significantly more enriched $\delta^{15}N$ values than females ($t(10) = 2.23$, $p = 0.053$). This suggests males consumed greater amounts of terrestrial animal protein than females from this period. Overall, human diet from period 1 consisted of C_3 cereals (e.g. barley) and terrestrial protein (e.g. beef, lamb, pork), but no apparent input from marine or freshwater fish.



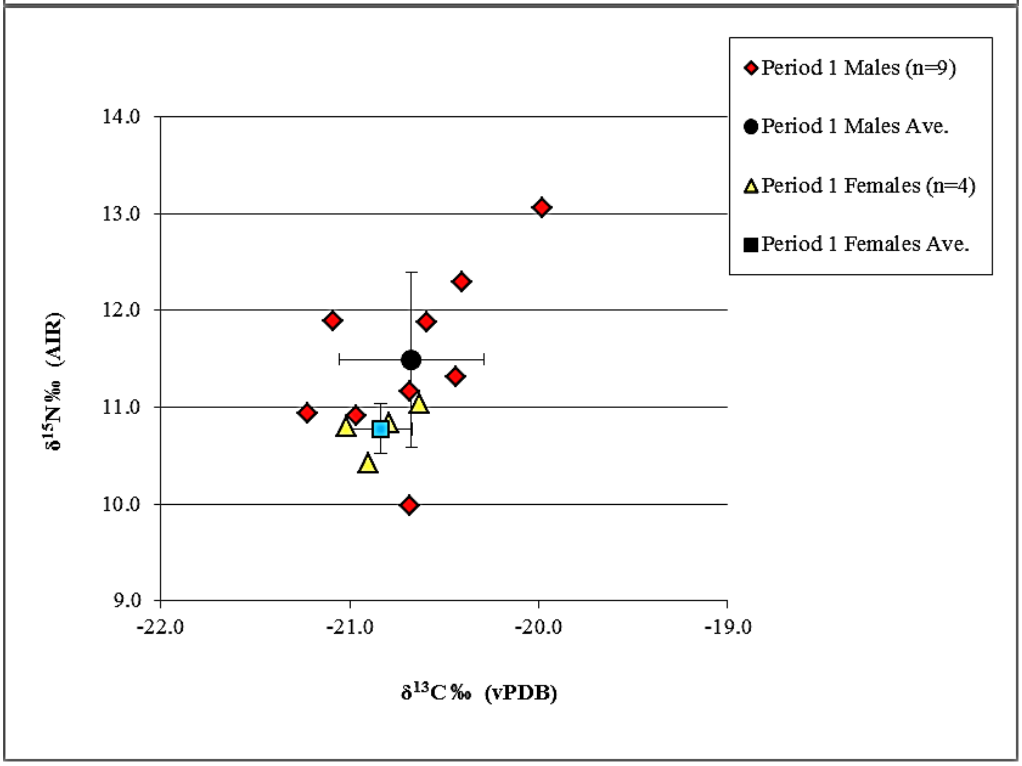


Figure 7.60: Portmahomack δ^{13}C and δ^{15}N values for period 1 adult humans (top), with expanded plot (bottom).

A significant difference was found between periods 1 and 2-3, with the latter being enriched overall in both δ^{13}C ($t(20) = 2.09$, $p = 0.008$) and δ^{15}N ($t(16) = 2.12$, $p =$

0.003). This may suggest that greater quantities of terrestrial protein were being consumed during period 2-3, which is supported by a richness of faunal bones from this period. Conversely, a lack of faunal bones was recovered from period 1, yet there was a presence of barley and wheat remains (Seetah 2011), which also suggests a predominantly C_3 cereal-based diet. A highly significant difference between periods 1 and 4 was also observed, which will be presented in section 7.4.2.2.3.

7.4.2.2.2 Adult diets: Monastic Period 2-3 (c.700 – c.1100)

Period 2-3 human (n=58) $\delta^{13}C$ values ranged between -21.1‰ and -19.1‰ ($\Delta^{13}C_{max-min}$ 2.0‰), with an average of -20.4‰ ± 0.4‰ and $\delta^{15}N$ values between 10.8‰ and 14.6‰ ($\Delta^{15}N_{max-min}$ 3.8‰), with an average of 12.1‰ ± 0.6‰. Most adult $\delta^{13}C$ and $\delta^{15}N$ values are within the same trophic level (e.g. within 3‰ for $\delta^{15}N$), apart from one outlier (Figure 7.61), an adult male aged 46-59. The $\delta^{13}C$ and $\delta^{15}N$ values for this individual are closer to those from period 4, suggesting some aquatic protein was included in this individual's diet. Although no fish bones were recovered from period 2-3, an increase in $\delta^{13}C$ compared to period 1 may suggest the consumption of fish by some individuals. Overall, the isotope data suggests adults from the monastic phase were consuming predominantly C_3 cereals (e.g. bread and pottage) and terrestrial protein (e.g. beef, lamb, pork and venison).

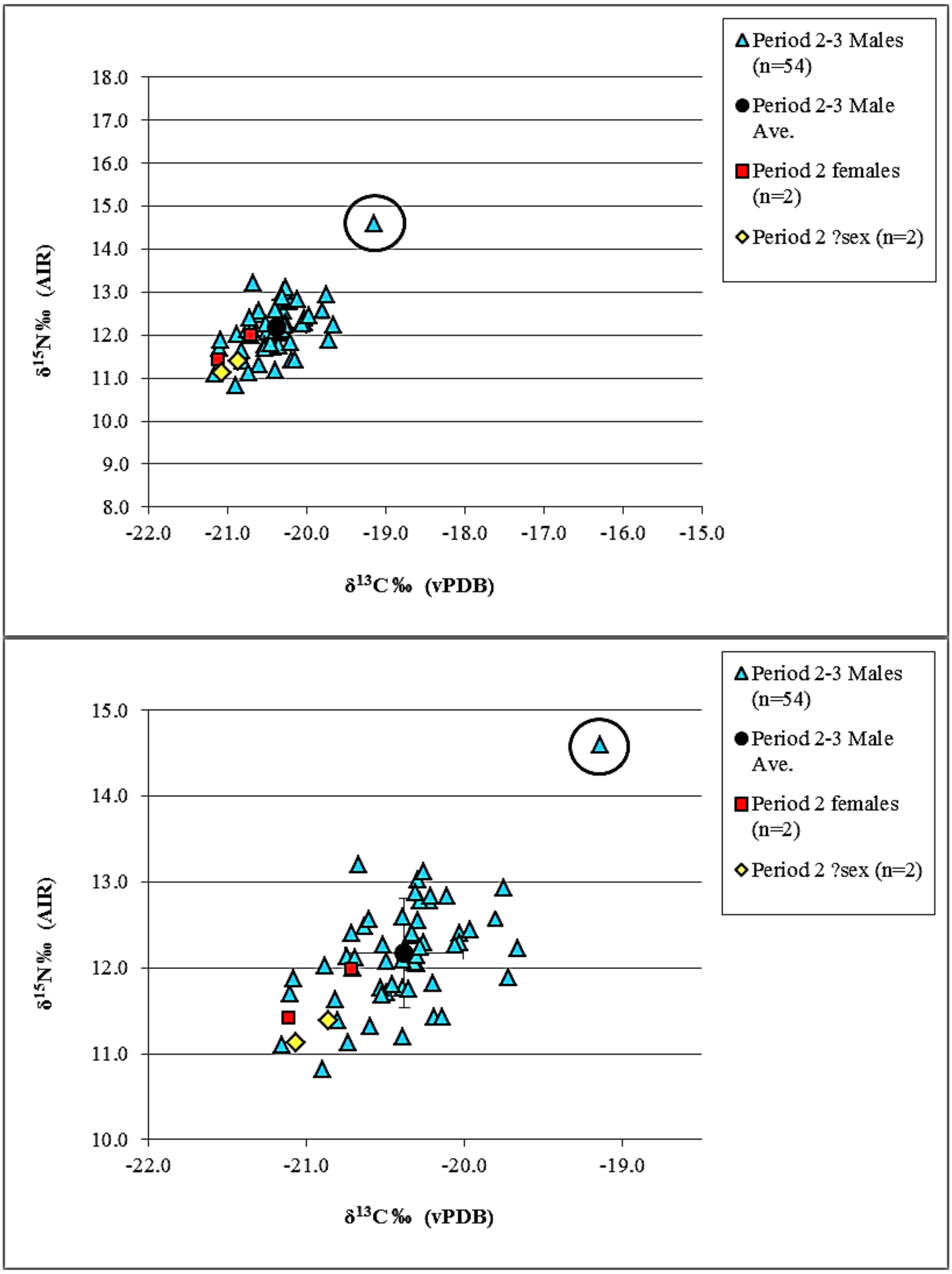


Figure 7.61: Portmahomack $\delta^{13}C$ and $\delta^{15}N$ values for period 2-3 adult humans (top), with expanded plot (bottom) and outlier circled.

When comparing isotope values between age groups, only males from period 2-3 (n=54) could be compared as female samples (n=2) were too low. There is little variation in $\delta^{13}C$ values between different male age groups from period 2-3 (Figure

7.62). The greatest difference ($\Delta^{13}C_{max\text{-}min}$ 0.2‰) occurred between the 26-35 group and between the 46-59 and 60+ groups, the latter two of which have the same average $\delta^{13}C$ values. There was larger variation in average $\delta^{15}N$ values with the greatest difference between the 18-25 and 60+ groups ($\Delta^{15}N_{max\text{-}min}$ 0.7‰), which was to a significant level ($t(6) = 2.45$, $p = 0.038$). This may suggest that males aged 60+ were consuming greater amounts of terrestrial protein compared to their younger counterparts. However, as aforementioned (section 5.2) bone turnover rates vary depending on age, with isotope values reflecting a diet from around the last 10 years of life (Libby *et al.* 1964; Stenhouse and Baxter 1979). Although there is a slight increase in $\delta^{15}N$ values as age increases, the variation is not enough to suggest trophic level shifts between any of the age groups. This may suggest a childhood dietary signal being reflected in $\delta^{15}N$ values for those aged 18-25, rather than different types of food being consumed. Overall, individuals from period 2-3 had a fairly homogenous diet, which may be expected from a monastic community where religious dietary regimes were followed.

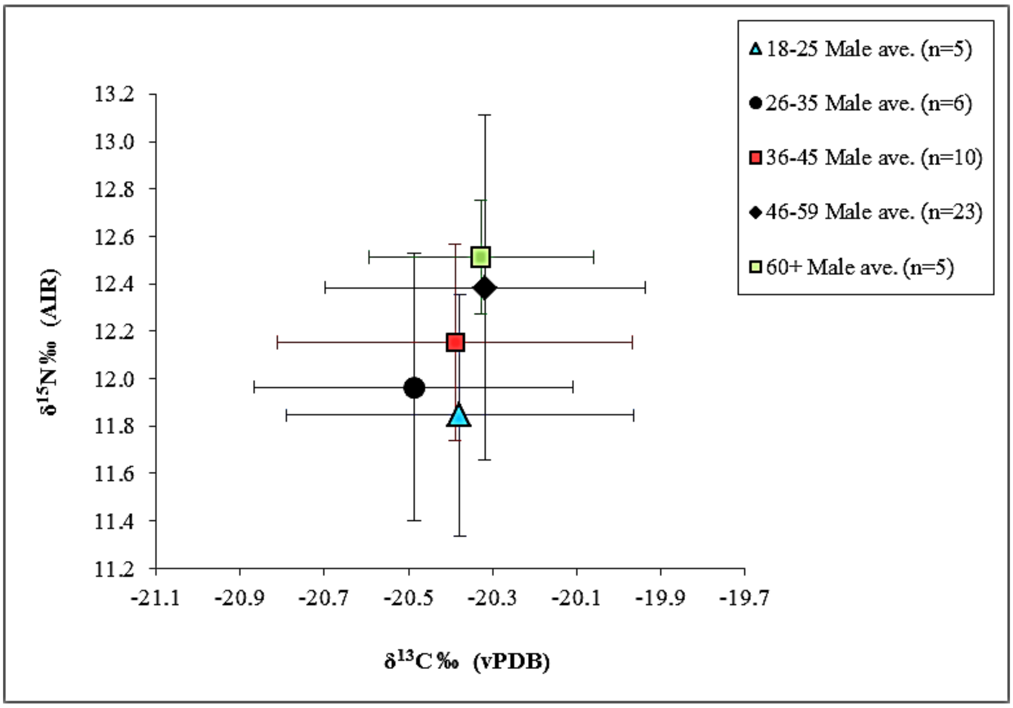


Figure 7.62: Portmahomack average $\delta^{13}C$ and $\delta^{15}N$ values for period 2-3 adult males.

A notable difference was found between periods 2-3 and 4, with the latter being highly enriched in both $\delta^{13}C$ ($t(79) = 1.99$, $p < 0.001$) and $\delta^{15}N$ ($t(94) = 1.99$, $p < 0.001$). This reflects a diachronic change in diet from the monastic phase to the later lay phase, with significant amounts of marine fish being consumed in the latter.

7.4.2.2.3 Adult diets: Lay Periods 4 and 5 (c.1100 – c.1700)

Period 4 human (n=64) $\delta^{13}C$ values ranged between -21.2‰ and -15.5‰ ($\Delta^{13}C_{max\text{-}min}$ 5.7‰), with an average of -18.5‰ ± 1.1‰. The $\delta^{15}N$ values were between 11.1‰ and 17.6‰ ($\Delta^{15}N_{max\text{-}min}$ 6.5‰), averaging 14.8‰ ± 1.3‰. This data reflects wide variation that reveals a whole trophic level increase and enriched $\delta^{13}C$ in some individuals. This suggests that some individuals were consuming greater amounts of aquatic protein compared to those with lower $\delta^{13}C$ and $\delta^{15}N$ values. Additionally, six adults from this period have noticeably lower $\delta^{13}C$ and $\delta^{15}N$ values that are closer to those from period 2-3 (Figure 7.63). These individuals may not have had a significant amount of aquatic protein in their diet and may have consumed predominantly terrestrial protein. Apart from these outliers, the majority of adults from period 4 consumed terrestrial C_3 and animal resources similar to those from periods 1 and 2-3 (e.g. bread, beef, lamb and pork), but with the inclusion of marine and freshwater fish in their diets, hence the shift in $\delta^{13}C$ and $\delta^{15}N$ values.

Period 5 adult (n=2) $\delta^{13}C$ values were between -19.2‰ and -19.6‰ ($\Delta^{13}C_{max-min}$ 0.4‰), with an average of -19.4‰ and $\delta^{15}N$ values between 13.6‰ and 14.4‰ ($\Delta^{15}N_{max-min}$ 0.8‰), with an average of 14.0‰. This data (plotted in Figure 7.63) is similar to those from the period 4 group that have low $\delta^{13}C$ and $\delta^{15}N$ values and those from the monastic phase, which may reflect some religious-influence in the types of foods consumed.

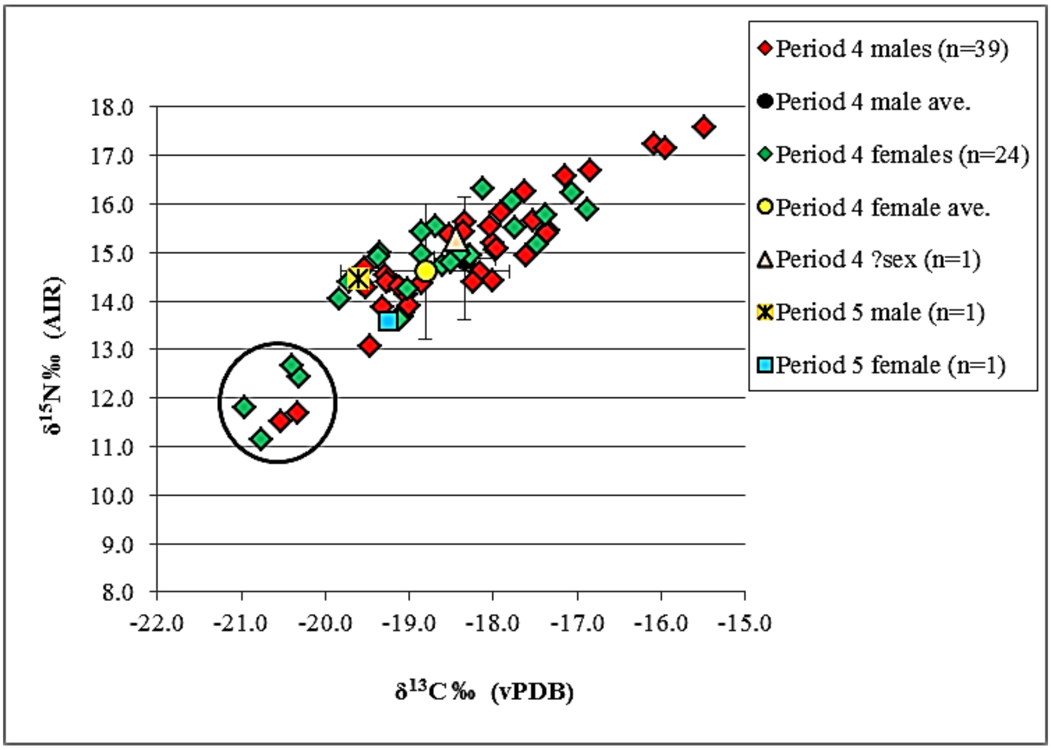


Figure 7.63: Portmahomack adult human $\delta^{13}C$ and $\delta^{15}N$ values from periods 4 and 5. Cluster (circled) similar to period 2-3 adult data.

When comparing isotope values between different age groups from period 4, some variation in average $\delta^{13}C$ and $\delta^{15}N$ values is evident. Males aged 18-25 have average isotope values that are lower in both $\delta^{13}C$ ($\Delta^{13}C_{max-min}$ 1.2‰) and $\delta^{15}N$ ($\Delta^{15}N_{max-min}$ 2.1‰) compared to those aged 26-35 (Figure 7.64). A significant difference in $\delta^{15}N$ values was found between males aged 18-25 and those aged 26-35, with the latter being more enriched ($t(8) = 2.31$, $p = 0.032$). This may suggest that some younger males were consuming smaller amounts of animal protein, especially for two individuals that have the lowest $\delta^{13}C$ and $\delta^{15}N$ values. Additionally, a significant difference was also found between males aged 26-35 and 46-59, in both $\delta^{13}C$ ($t(7) = 2.36$, $p = 0.049$) and $\delta^{15}N$ ($t(8) = 2.31$, $p = 0.020$), suggesting those aged 26-35 were consuming greater amounts of protein than older individuals (plotted in Figure 7.64 for comparison).

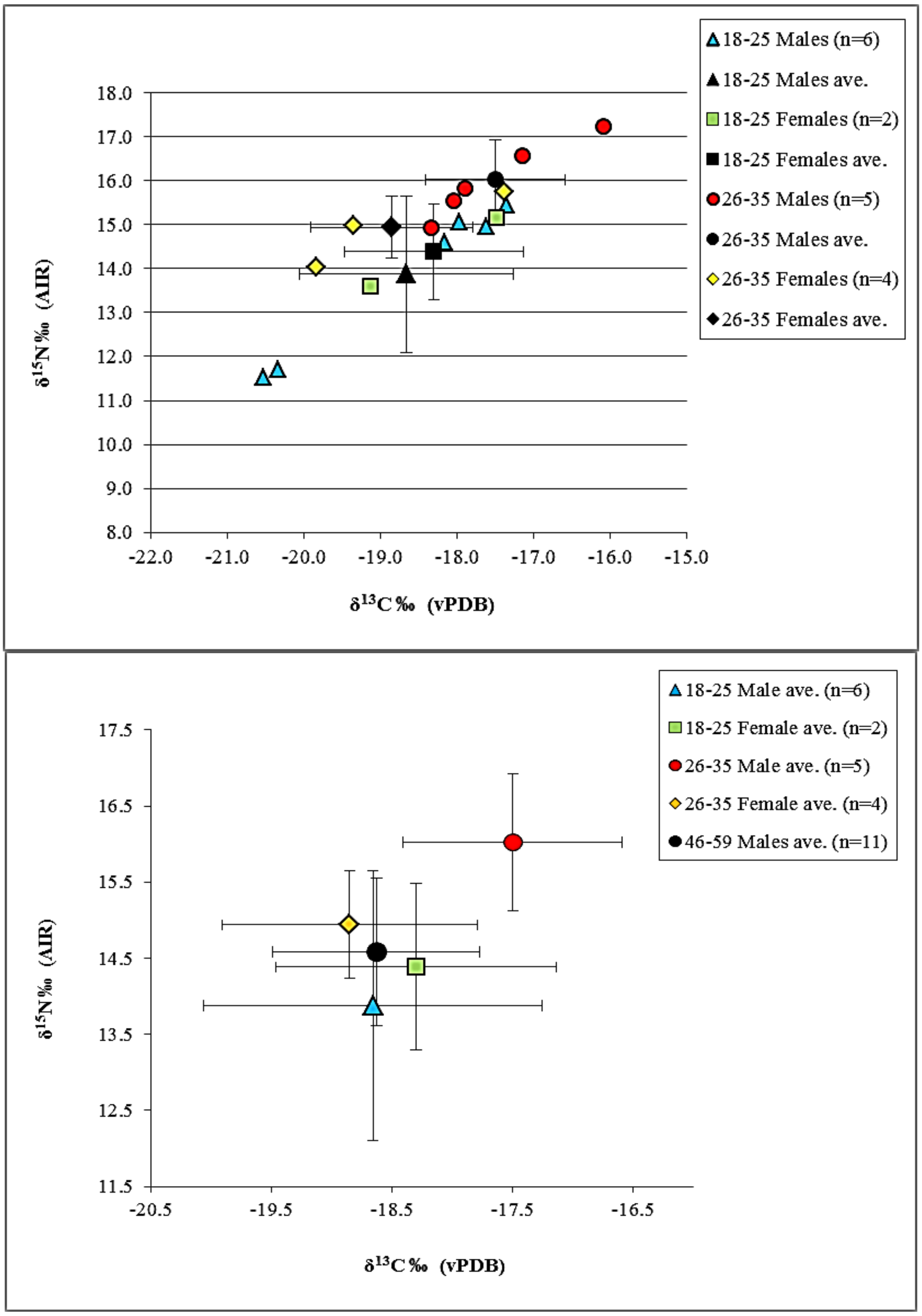


Figure 7.64: Portmahomack δ^{13}C and δ^{15}N values for period 4 younger adult age groups (top), with expanded plot for average isotope values (bottom).

From the older age categories (36-45 to 60+), females aged 60+ have the highest δ^{15}N values, although not to an extent that would suggest any significant dietary change. Overall, adults from this group have similar isotope values (Figure 7.65), suggesting the same types of foods were consumed, such as C_3 cereals and terrestrial and aquatic protein. Similar to period 2-3, $\delta^{15}N$ values increase slightly with age in the younger age groups (18-25 to 26-35) from period 4, although not in the older age groups (36-45 to 60+).

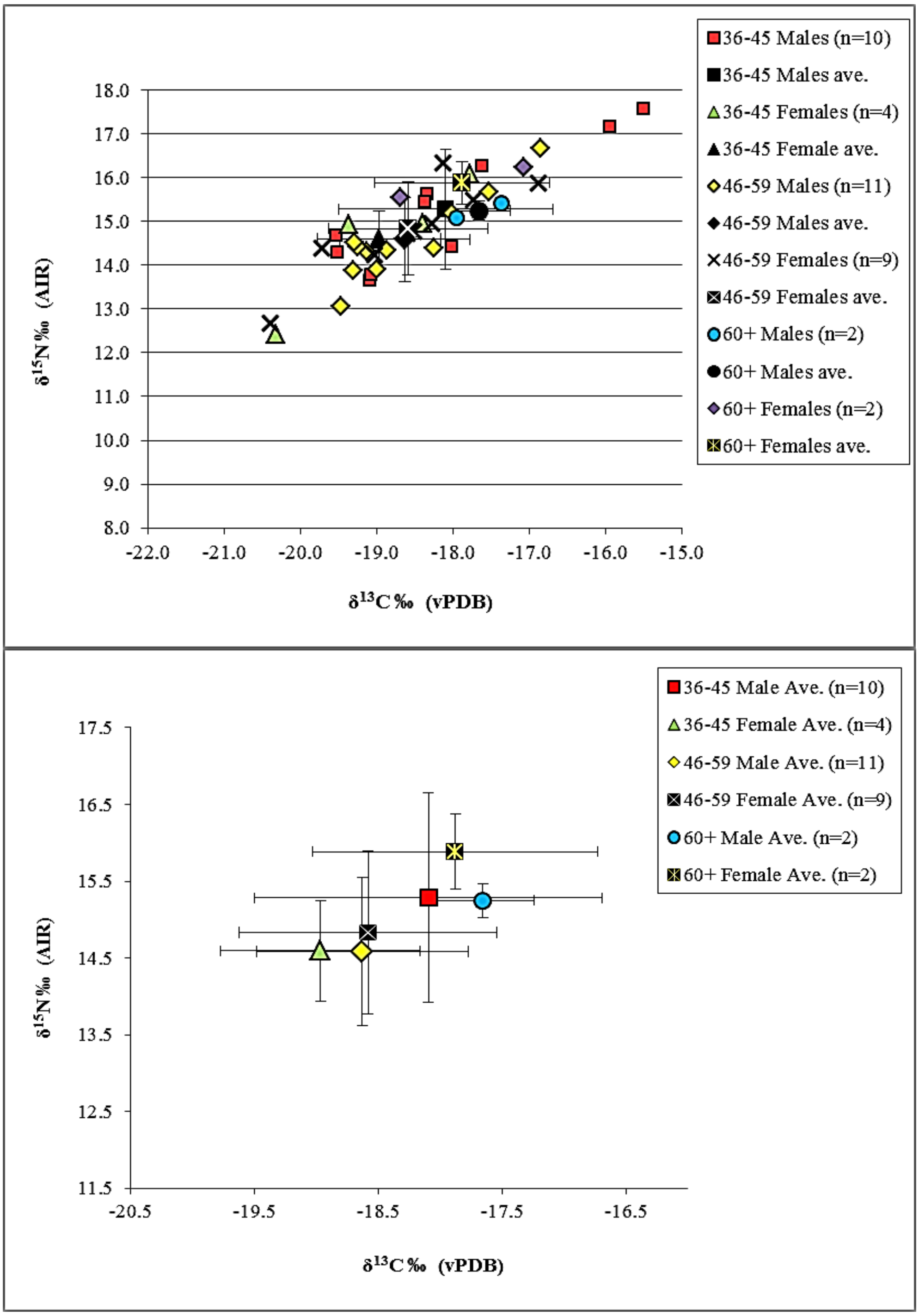


Figure 7.65: Portmahomack $\delta^{13}C$ and $\delta^{15}N$ values for period 4 older adult age groups (top), with expanded plot for average isotope values (bottom).

Similar to comparisons with period 2-3, a highly significant difference in isotope values between lay periods 1 and 4 was also observed, with the latter being greatly enriched in both $\delta^{13}C$ ($t(66) = 2.00$, $p < 0.001$) and $\delta^{15}N$ ($t(26) = 2.06$, $p < 0.001$). This reflects the extent of dietary change at Portmahomack, from predominantly terrestrial based diets in periods 1 and 2-3, to a significant level of aquatic fish consumption in periods 4 and 5.

7.4.2.3 Isotope Data: Sub-adult Humans

Eight sub-adult humans were analysed to provide a pilot study of childhood diet at Portmahomack. Older children (aged 10.6-14.5 and 14.6-17.0) were selected (Figure 7.66), to avoid isotope signals that would result in increased nitrogen levels during breastfeeding.

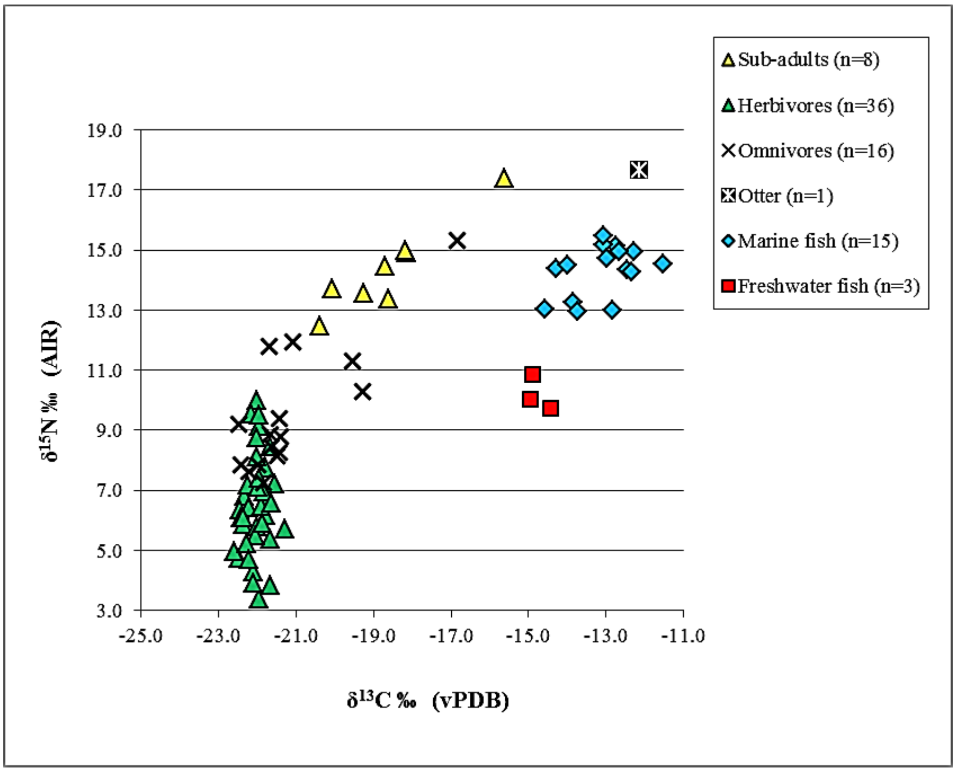


Figure 7.66: Portmahomack sub-adult human and faunal $\delta^{13}C$ and $\delta^{15}N$ values.

Only one sub-adult was present from monastic period 2 at Portmahomack, with $\delta^{13}C$ and $\delta^{15}N$ values of -20.4‰ and 12.5‰ respectively (Figure 7.67). The $\delta^{13}C$ values are identical to the adult male average $\delta^{13}C$ values from the monastic phase. A slight difference in $\delta^{15}N$ values ($\Delta^{15}N_{max-min}$ 0.4‰) was observed, compared to period 2-3 average male data (12.1‰), although not to a significant level. This suggests this child's diet was similar to that of the monks from Portmahomack.

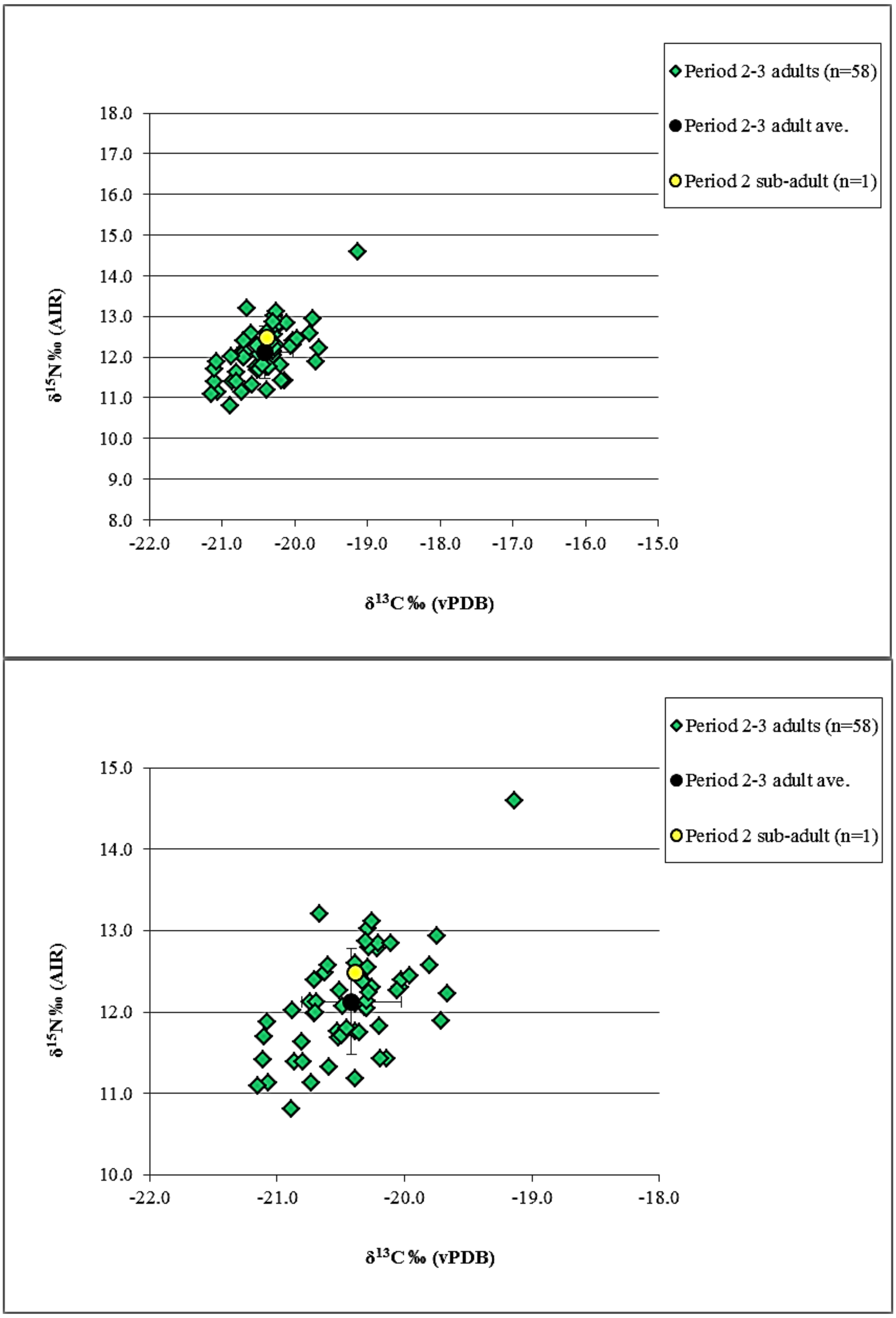


Figure 7.67: Portmahomack $\delta^{13}C$ and $\delta^{15}N$ values for period 2-3 adults and sub-adult (top), with expanded plot (below).

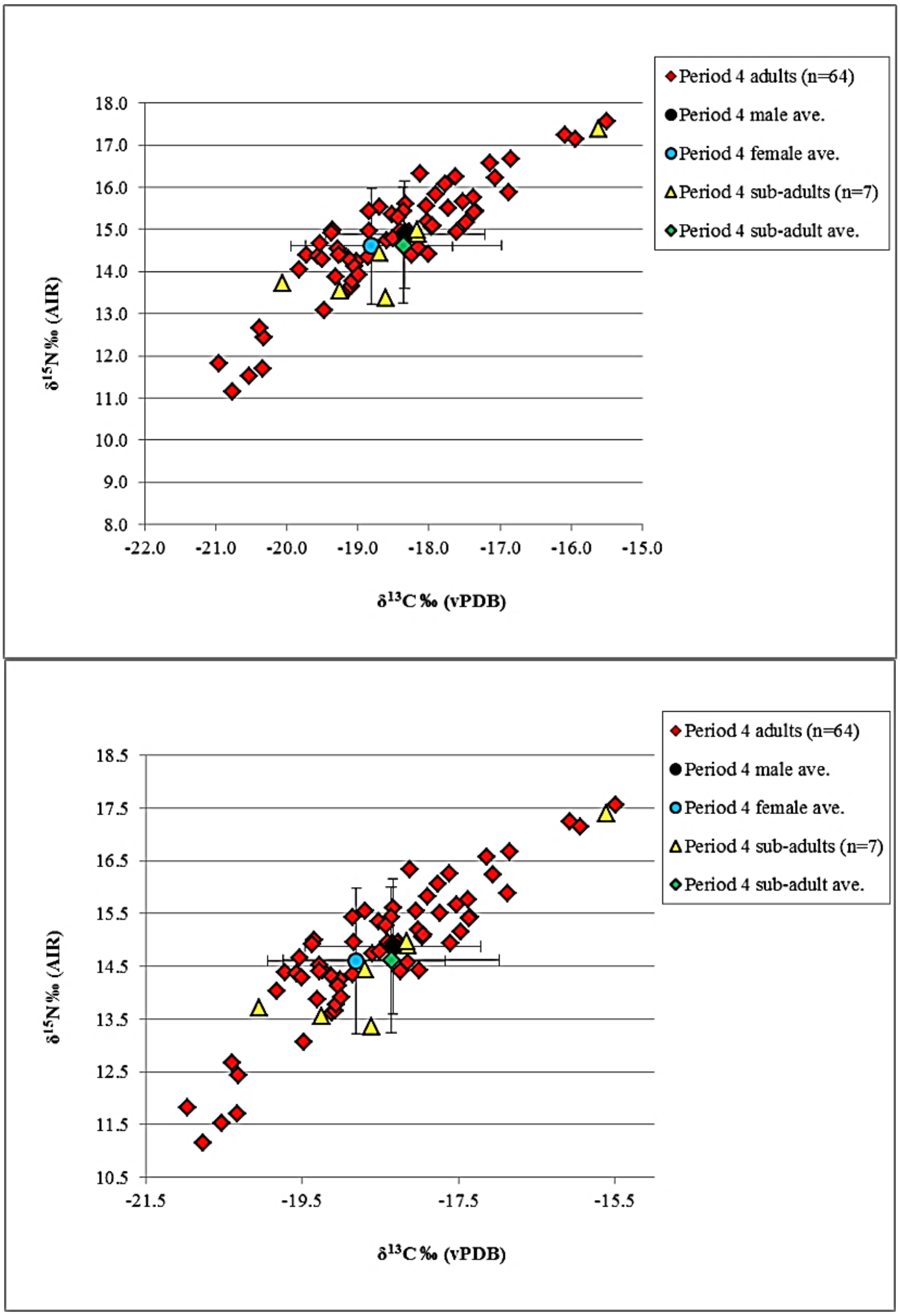


Figure 7.68: Portmahomack δ^{13}C and δ^{15}N values for period 4 adults and sub-adults (top), with expanded plot (bottom).

Sub-adult bone samples from lay period 4 (n=7) had δ^{13}C values ranging between -20.1‰ and -15.6‰ ($\Delta^{13}C_{max-min}$ 4.5‰), with an average of -18.4‰ ± 1.4‰. The δ^{15}N values ranged between 13.4‰ and 17.4‰ ($\Delta^{15}N_{max-min}$ 4.0‰), with an average of 14.6‰ ± 1.4‰. These are quite wide ranges, mostly due to one sub-adult being greatly enriched in both $\delta^{13}C$ and $\delta^{15}N$, by a whole trophic level compared to the other sub-adults (Figure 7.68). This individual may have had access to greater amounts of aquatic protein, especially considering that the isotope values are higher than the majority of adults from period 4. The remaining sub-adults have isotope values that are similar to average adult $\delta^{13}C$ and $\delta^{15}N$ values from this period, with only slight variations between sub-adult and male $\delta^{13}C$ ($\Delta^{13}C_{max-min}$ 0.1‰) and $\delta^{15}N$ ($\Delta^{15}N_{max-min}$ 0.3 ‰) averages. A slight difference between sub-adult and female $\delta^{13}C$ averages ($\Delta^{13}C_{max-min}$ 0.3‰) also occurred, although $\delta^{15}N$ averages were identical. Interestingly, all sub-adults from period 4 are more enriched in $\delta^{13}C$ and $\delta^{15}N$ than the group of adults (n=6) from the same period who have isotope values similar to those from monastic period 2-3, which is discussed further in chapter 8.

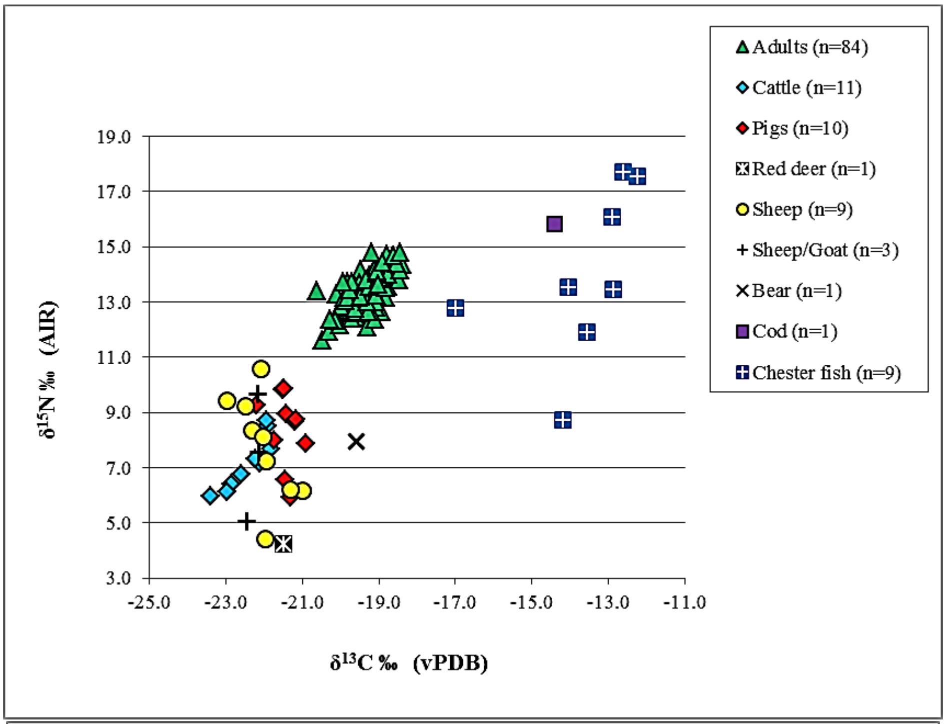
7.4.3 Norton Priory Isotope Results

Results of $\delta^{13}C$ and $\delta^{15}N$ values of human and faunal bone collagen are presented here to provide dietary reconstructions of inhabitants from the 12^{th} to 16^{th} century at Norton. The majority of human bone analysed is from the 14^{th} and 15^{th} centuries and although sample numbers from the 12^{th} (n=3), 13^{th} (n=9) and 16^{th} (n=1) centuries are small; they provide an important snapshot of human diet during these periods.

7.4.3.1 Isotope Data: Fauna

From Norton, 36 faunal bone samples were analysed (Figure 7.69) from the 14^{th} (n=6) and 15^{th} (n=2) century. A number of faunal bone samples (n=28) were not allocated to a specific period, but classed as ‘pre-dissolution’ (pre-16^{th} century).

Therefore, in the following sections, Norton faunal isotope results will be presented in three groups: 14th century, 15th century and pre-dissolution.



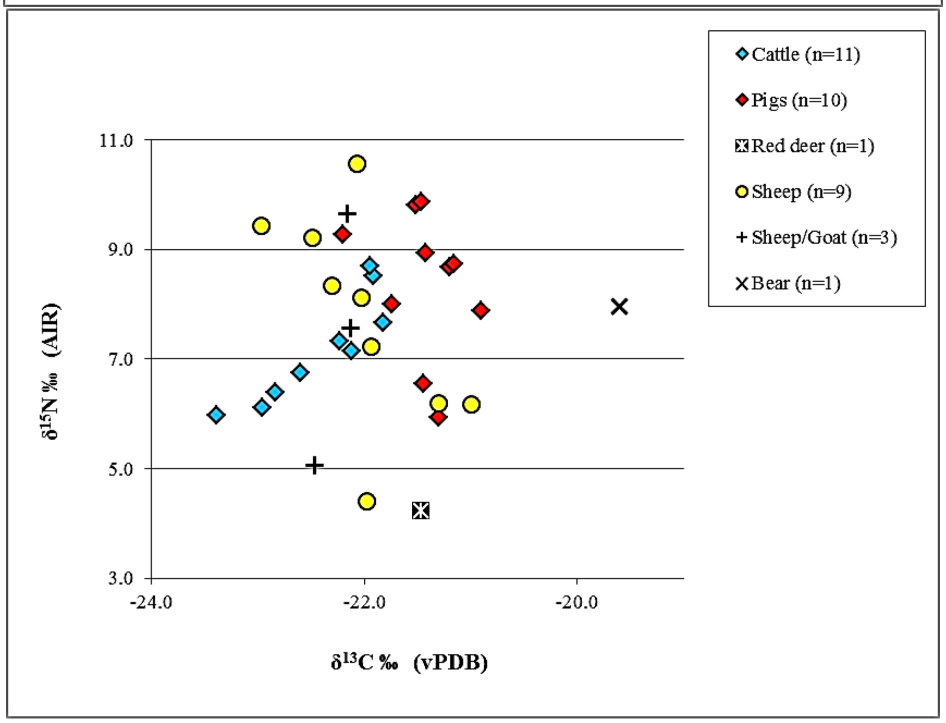


Figure 7.69: Norton faunal (including Chester fish) and adult human $\delta^{13}C$ and $\delta^{15}N$ values (top), with expanded plot of terrestrial fauna (bottom).

7.4.3.1.1 Cattle (*Bos*)

Cattle from the 14th (n=1) and 15th century (n=1) had $\delta^{13}C$ values of -22.1‰ and -22.2‰ respectively. Both samples had the same $\delta^{15}N$ values at 7.5‰. Pre-dissolution cattle samples (n=9) had $\delta^{13}C$ values ranging between -23.4‰ and -21.8‰ ($\Delta^{13}C_{max-min}$ 1.6‰), with an average of -22.4‰ ± 0.5‰ and $\delta^{15}N$ values between 6.0‰ and 8.7‰ ($\Delta^{15}N_{max-min}$ 2.7‰), with an average of 7.2‰ ± 0.9‰. These pre-dissolution results are the same as for those of total cattle (n=11) (Figure 7.70). Although there is some difference in cattle $\delta^{15}N$ values from the pre-dissolution group, this is not to the extent that would suggest atypical values. However, some variation in feeding strategies, that would elevate $\delta^{15}N$ values, cannot be ruled out. Overall, these results are typical of domesticated herbivores consuming a predominantly C_3 diet, with no evidence of C_4 plants.

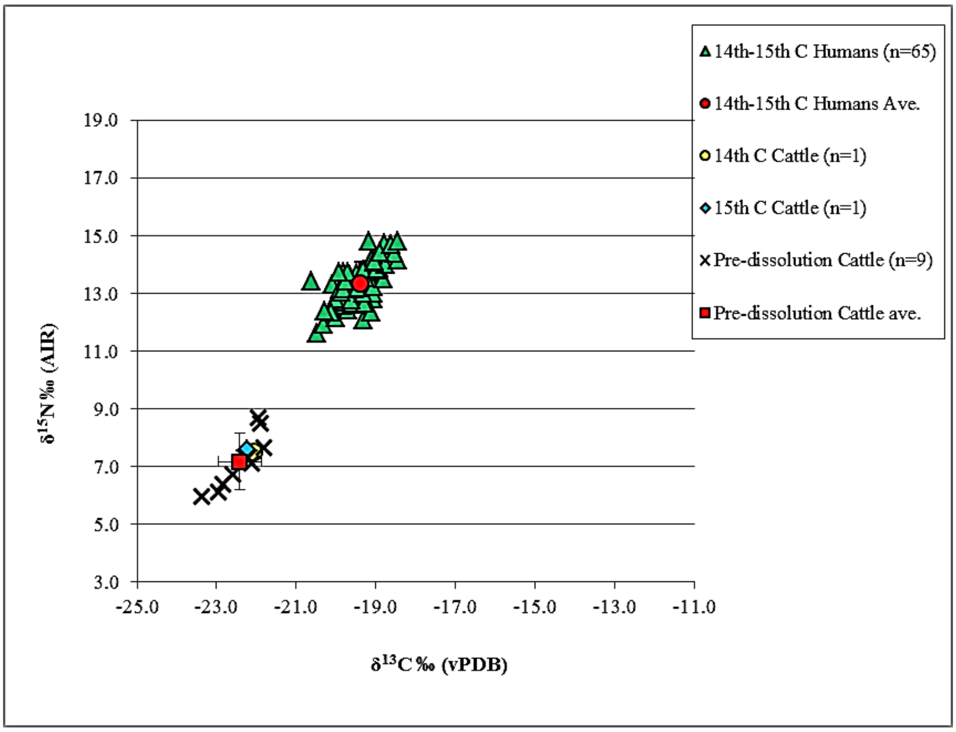


Figure 7.70: Norton cattle and adult human $\delta^{13}C$ and $\delta^{15}N$ values from 14th-15th century and pre-dissolution groups.

7.4.3.1.2 Deer (*Cervidae*)

One red deer bone sample from Norton was analysed, which had $\delta^{13}C$ and $\delta^{15}N$ values of -21.5‰ and 4.2‰ respectively. This sample is illustrated within the sheep/goat isotope plot in Figure 7.71. The $\delta^{15}N$ value for this red deer sample is lower than those from Portmahomack, the average values of which are increased by +1.8‰ in comparison. This however reflects normal variability of herbivore diet; the main component from C_3 plants, which is consistent with other studies (e.g. Jay and Richards 2007).

7.4.3.1.3 Sheep/Goat (*Ovis/Capra*)

Sheep and sheep/goat species from Norton (n=12) were identified (S.Stallibrass, *pers.comm.*) and dated to the 14th and 15th centuries and pre-dissolution levels (Figure 7.71). Sheep samples from the 14th century (n=3) had $\delta^{13}C$ values ranging between -22.3‰ and -21.0‰ ($\Delta^{13}C_{max-min}$ 1.3‰), with an average of -21.8‰ ± 0.7‰ and $\delta^{15}N$ values between 6.2‰ and 8.3‰ ($\Delta^{15}N_{max-min}$ 2.1‰), averaging 7.5‰ ± 1.2‰. Sheep $\delta^{13}C$ and $\delta^{15}N$ values from the 15th century (n=1) were -23.0‰ and 9.4‰ respectively.

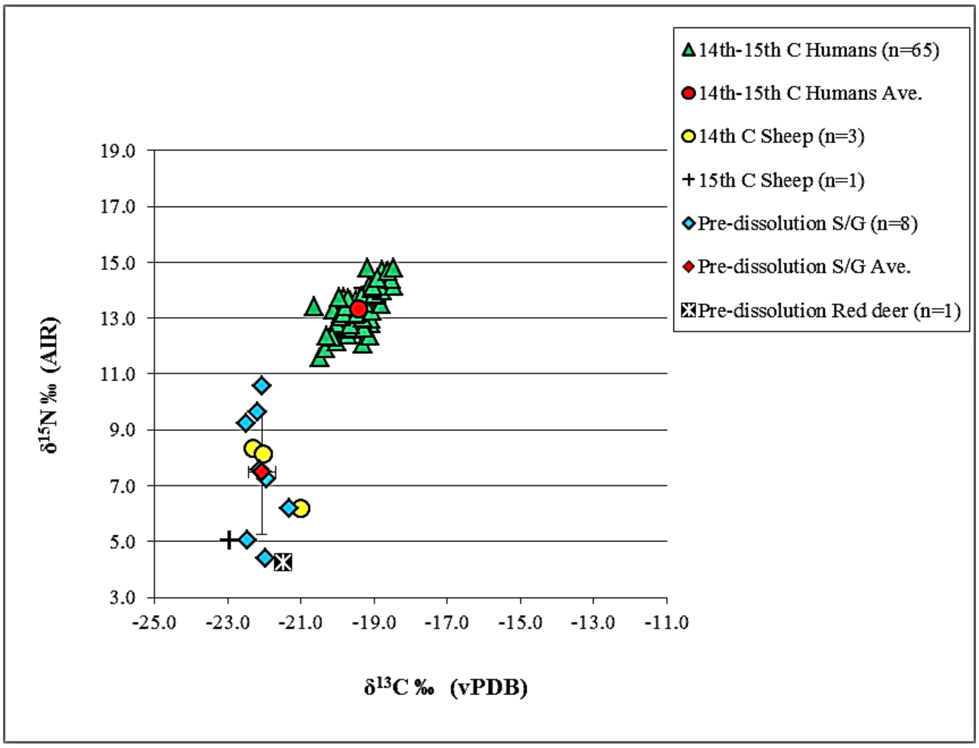


Figure 7.71: Norton Sheep/goat, deer and adult human δ^{13}C and δ^{15}N values from 14th-15th century and pre-dissolution groups.

From the pre-dissolution group, sheep and sheep/goat samples (n=8) had δ^{13}C values ranging between -22.5‰ and -21.3‰ ($\Delta^{13}C_{max-min}$ 1.2‰), with an average of -22.1‰ ± 0.4‰. The δ^{15}N values were between 4.4‰ and 10.6‰ ($\Delta^{15}N_{max-min}$ 6.2‰), averaging 7.5‰ ± 2.2‰. Sheep/goat and red deer isotope values from Norton reflect a diet of predominantly C_3 plants, although there is variation between periods, which will be discussed in chapter 8.

7.4.3.1.4 Pig (*Sus*)

Total pig (n=10) δ^{13}C values ranged between -22.2‰ and -20.9‰ ($\Delta^{13}C_{max-min}$ 1.3‰), with an average of -21.4‰ ± 0.4‰ and δ^{15}N values ranged between 5.9‰ and 9.9‰ ($\Delta^{15}N_{max-min}$ 4.0‰), with an average of 8.4‰ ± 1.3‰ (Figure 7.72).

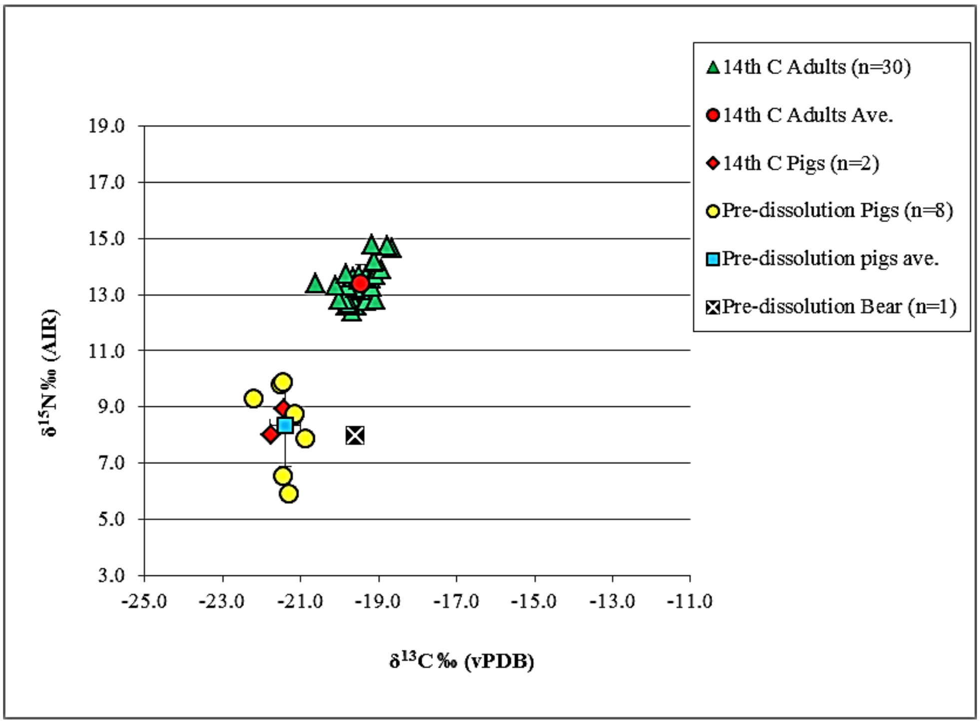


Figure 7.72: Norton pig, bear and adult human δ^{13}C and δ^{15}N values from 14th century and pre-dissolution groups.

Pig samples from the 14th century (n=2) had δ^{13}C values ranging between -21.7‰ and -21.4‰ ($\Delta^{13}C_{max-min}$ 0.3‰), with an average of -21.6‰ and δ^{15}N values between 8.0‰ and 8.9‰ ($\Delta^{15}N_{max-min}$ 0.9‰), with an average of 8.5‰. These results suggest the diet of pigs from 14th century Norton consisted of C_3 foods and possibly scraps from human refuse, although not to the extent that would elevate their isotope values to that of humans.

Pig samples from the pre-dissolution group (n=8) had δ^{13}C values ranging between -22.2‰ and -20.9‰ ($\Delta^{13}C_{max-min}$ 1.3‰), with an average of -21.4‰ ± 0.4‰. δ^{15}N values were between 5.9‰ and 9.9‰ ($\Delta^{15}N_{max-min}$ 4.0‰), with an average of 8.3‰ ± 1.9‰. The varied δ^{15}N values may suggest various omnivorous feeding activities that involved consuming different types of human food waste, resulting in a trophic level shift, as evident in the aforementioned difference between δ^{15}N values.

7.4.3.1.5 Bear (*Ursus*)

Analysis of one possible bear (K. Seetah, *pers.comm.*) sample, allocated to the pre-dissolution group, resulted in $\delta^{13}C$ and $\delta^{15}N$ values of -19.6‰ and 8.0‰ respectively. These results (Figure 7.72) suggest an omnivorous diet similar to that of pigs from Norton of C_3 plant foods and probably some aquatic protein, which is suggested by the bear $\delta^{13}C$ value being similar to those of humans at Norton.

7.4.3.1.6 Marine Fish

Because only one fish (cod) bone was available from Norton, access to 9 medieval fish bone samples (cod: n=8 and conger eel: n=1) was granted (M. Morris, *pers.comm.*) from nearby Chester Cathedral, which is approximately 33 kilometres from Norton. The Norton cod isotope values are within the same range as the Chester samples (Figure 7.73), hence the inclusion of the Chester fish data will provide useful comparisons to enable interpretations of marine fish consumption at medieval Norton.

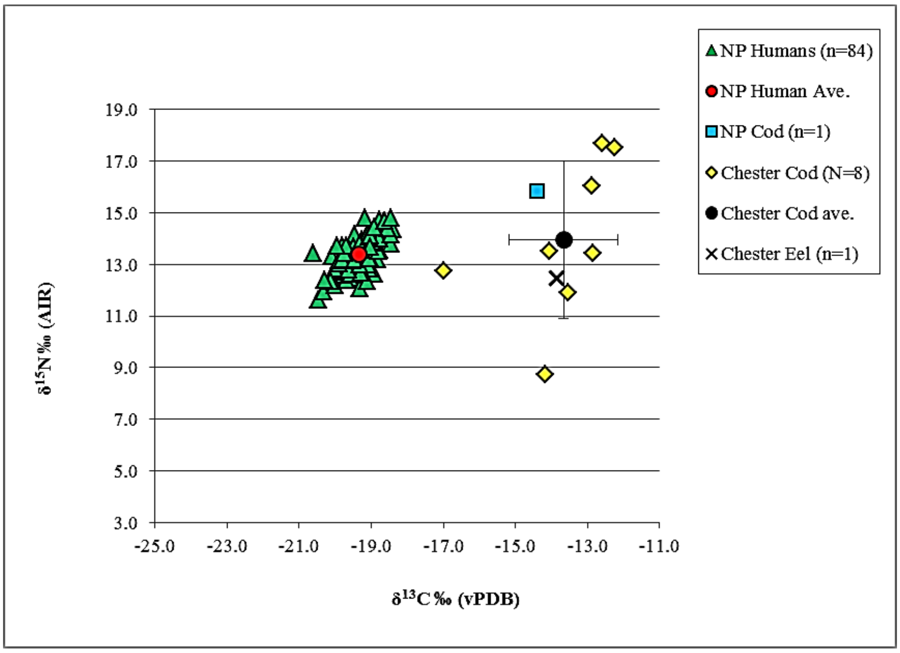


Figure 7.73: Norton (NP) human, cod and Chester marine fish $\delta^{13}C$ and $\delta^{15}N$ values.

The Norton cod sample from the pre-dissolution group (n=1) had $\delta^{13}C$ and $\delta^{15}N$ values of -14.4‰ and 15.8‰ respectively. From Chester Cathedral, the marine fish samples had $\delta^{13}C$ values ranging between -17.0‰ and -12.2‰ ($\Delta^{13}C_{max-min}$ 4.8‰), with an average of -13.7‰ ± 1.5‰. The $\delta^{15}N$ values ranged between 8.7‰ and 17.7‰ ($\Delta^{15}N_{max-min}$ 9.0‰), with an average of 14.0‰ ±3.0‰. These are wide variations for both $\delta^{13}C$ and $\delta^{15}N$, which may suggest some of these fish originated from different marine ecosystems and were imported to Chester. However, all isotope data is consistent with those from the British Holocene (Müldner and Richards 2005, Richards *et al.* 2006; Jay and Richards 2007).

7.4.3.2 Isotope Data: Adult Humans

Bone collagen from 84 adult humans was analysed to reconstruct the diets of mid-late medieval inhabitants from Norton. Human $\delta^{13}C$ values from all periods at Norton (n=84) ranged between -20.6‰ and -18.4‰ ($\Delta^{13}C_{max-min}$ 2.2‰), with an average of -19.3‰ ± 0.5‰ and $\delta^{15}N$ values between 11.6‰ and 14.8‰ ($\Delta^{15}N_{max-min}$ 3.2‰), with an average of 13.4‰ ± 0.7‰ (Figure 7.74).

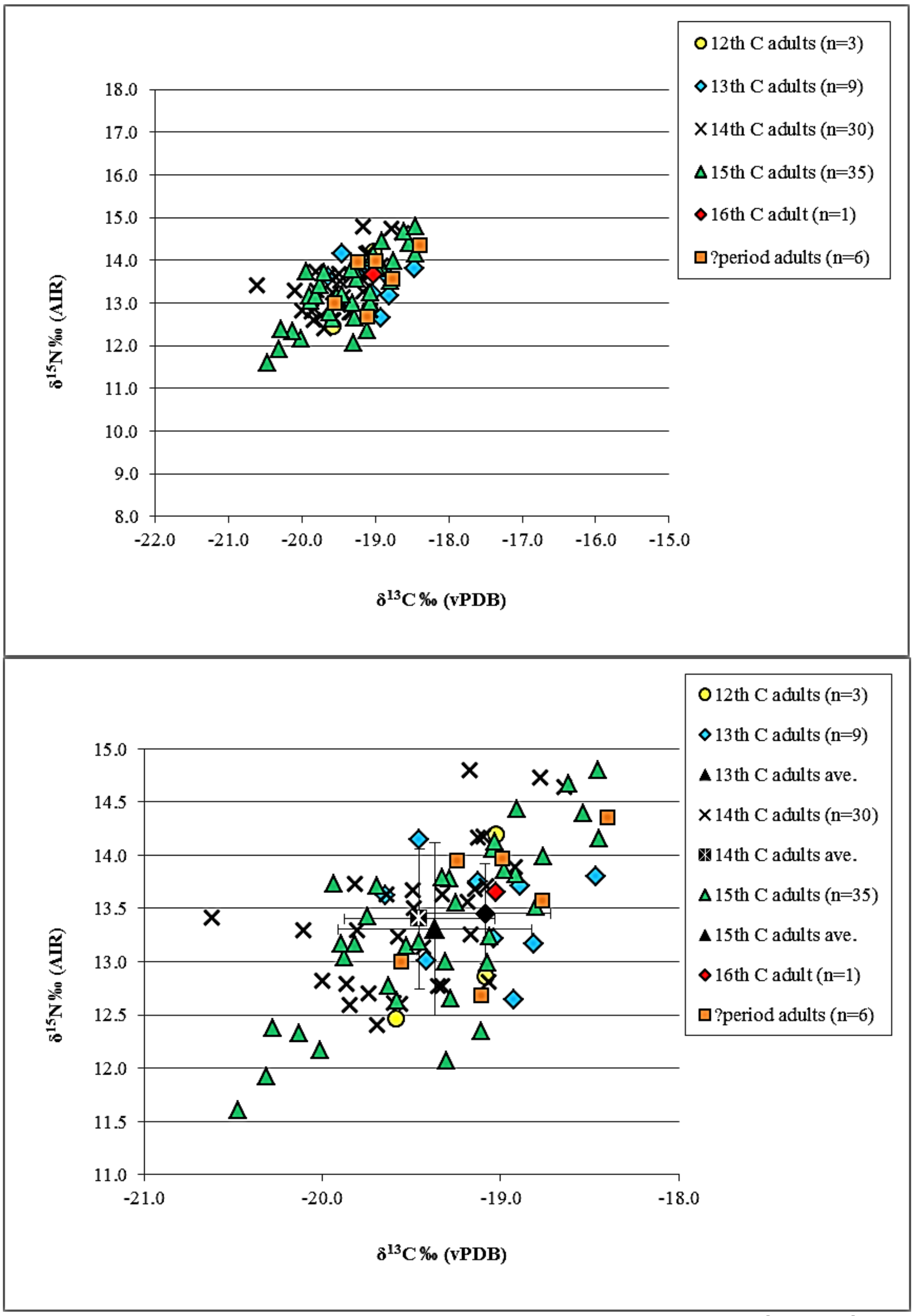


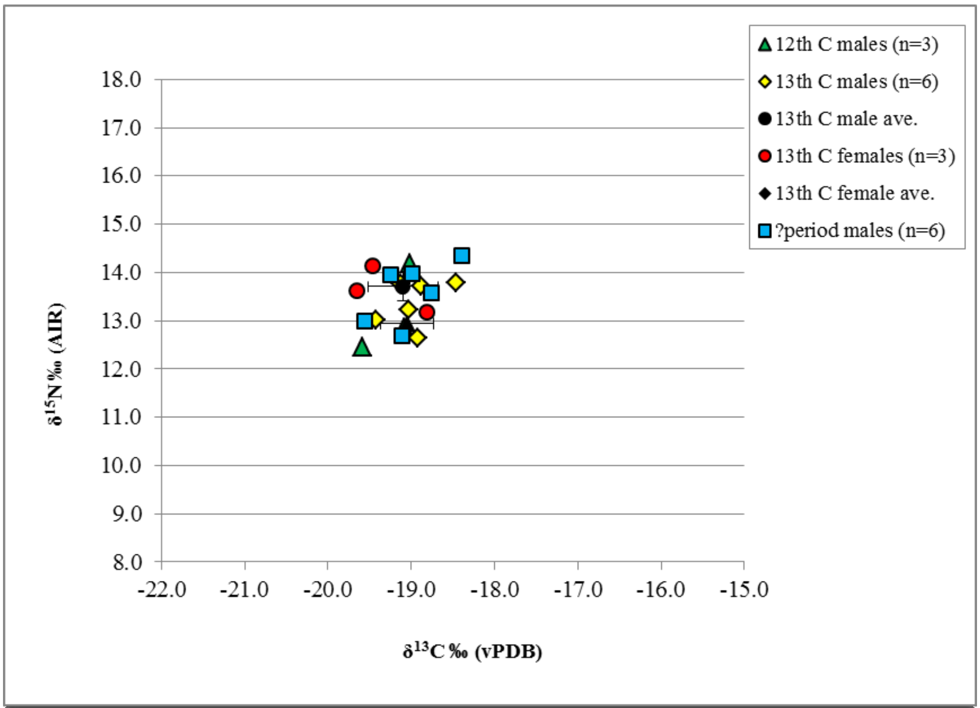
Figure 7.74: Norton human δ^{13}C and δ^{15}N values from 12th to 16th centuries (top), with expanded plot and average values (bottom).

Six adult male bone samples, that could not be allocated to a specific period, had δ^{13}C values ranging between -19.6‰ and -18.4‰ ($\Delta^{13}C_{max-min}$ 1.2‰), with an average of -19.0‰ ± 0.4‰. The δ^{15}N values ranged between 12.7‰ and 14.4‰ ($\Delta^{15}N_{max-min}$ 1.7‰), with an average of 13.6‰ ± 0.6‰. The results for this group are presented in this study for consistency, although they cannot be used to compare against period-specific groups.

7.4.3.2.1 Adult diets: 12^th^ and 13^th^ century

Due to low sample numbers from the 12th century adult humans (n=3), the isotope results are plotted together with adults from the 13th century and from the unknown period group (Figure 7.75). From the 12th century, human $\delta^{13}C$ values ranged between -19.6‰ and -19.0‰ ($\Delta^{13}C_{max\text{-}min}$ 0.6‰), with an average of -19.2‰ ± 0.3‰. $\delta^{15}N$ values were between 12.5‰ and 14.2‰ ($\Delta^{15}N_{max\text{-}min}$ 1.7‰), with an average of 13.2‰ ± 0.9‰. No female samples were present from the 12th century group. These results suggest a diet consisting of C_3 plants, along with terrestrial and marine protein.

From the 13th century, adult (n=9) bone collagen $\delta^{13}C$ values ranged between -19.6‰ and -18.5‰ ($\Delta^{13}C_{max\text{-}min}$ 1.1‰), with an average of -19.1‰ ± 0.4‰ and $\delta^{15}N$ values between 12.6‰ and 14.1‰ ($\Delta^{15}N_{max\text{-}min}$ 1.5‰), averaging 13.5‰ ± 0.5‰. Male isotope values from this period have slightly more variation than female values, although there is no trophic level shift, suggesting a homogeneous diet occurred in both sexes. Moreover, no statistically significant differences were found between males and females from this period. A significant difference was found in $\delta^{13}C$ values between the 13th and 14th century isotope data ($t(15) = 2.13$, $p = 0.023$), with adults from the 13th century more enriched in $\delta^{13}C$. This may suggest either greater quantities of marine foods were consumed in the 13th century or that adults in the 14th century were consuming more freshwater fish, hence the difference in isotope values.



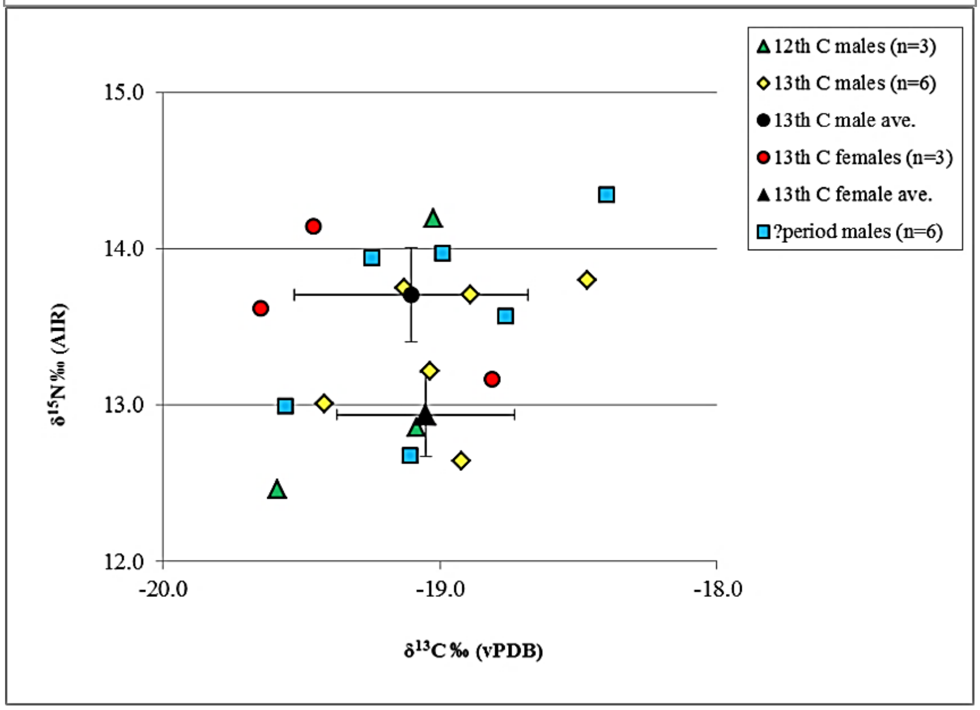


Figure 7.75: Norton $\delta^{13}C$ and $\delta^{15}N$ values for adult humans from the 12th to 13th century and unknown period (top), with expanded plot (bottom).

Only two age categories (26-35 and 46-59) from the 13th century were available to provide average isotope values. However, sample numbers here are low (Figure 7.76), hence statistical comparisons would not yield meaningful results. Overall, the greatest variation in average $\delta^{13}C$ and $\delta^{15}N$ values was found between the 26-35 male group and 46-59 female group, with a difference of $\Delta^{13}C_{max-min}$ 0.7‰ and $\Delta^{15}N_{max-min}$ 0.6‰ respectively. However, this variation is minimal and does not suggest a shift in trophic levels of +3‰ to +5‰, for example. All age groups from 13th century Norton appear to have had a homogeneous diet of C_3 cereals (e.g. bread and pottage) and terrestrial and aquatic protein (e.g. beef, pork and marine fish).

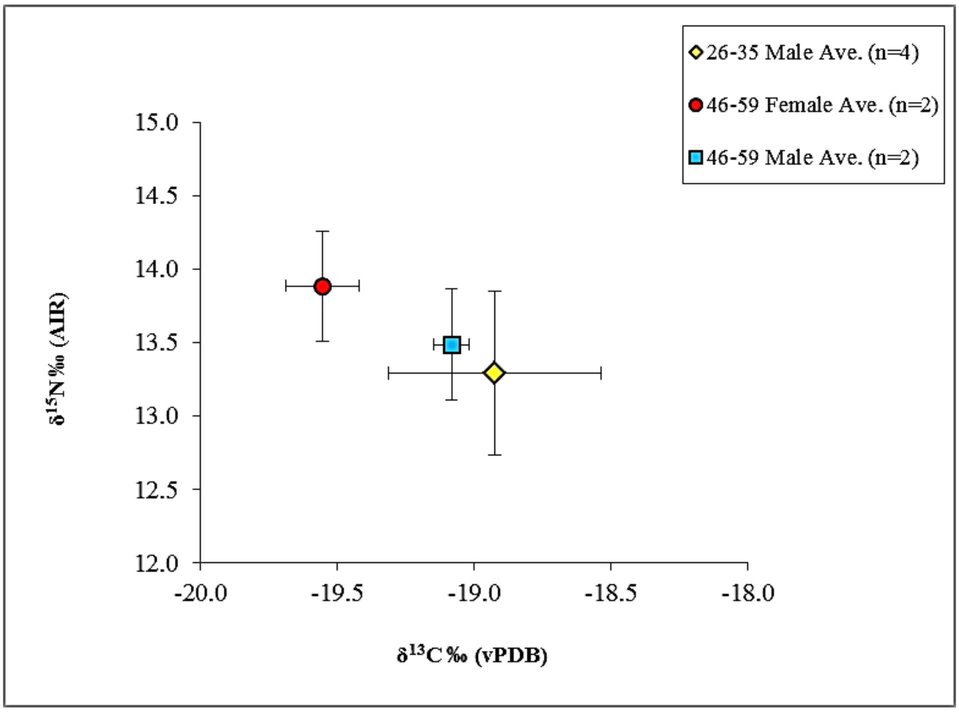


Figure 7.76: Norton average $\delta^{13}C$ and $\delta^{15}N$ values for 13th century adult age categories.

7.4.3.2.2 Adult diets: 14th century

Adults from 14th century Norton (n=30) had $\delta^{13}C$ values that ranged between -20.6‰ and -18.6‰ ($\Delta^{13}C_{max-min}$ 2.0‰), with an average of -19.5‰ ± 0.4‰. The $\delta^{15}N$ values ranged between 12.4‰ and 14.8‰ ($\Delta^{15}N_{max-min}$ 2.4‰), averaging 13.4‰ ± 0.7‰ (Figure 7.77). As with the previous period data, male isotope values have more variation than female values, although this is minimal at $\Delta^{13}C_{max-min}$ 0.2‰ and

$\Delta^{15}N_{max\text{-}min}$ 0.9‰. Moreover, no significant difference between 14th century male and female isotope data was observed.

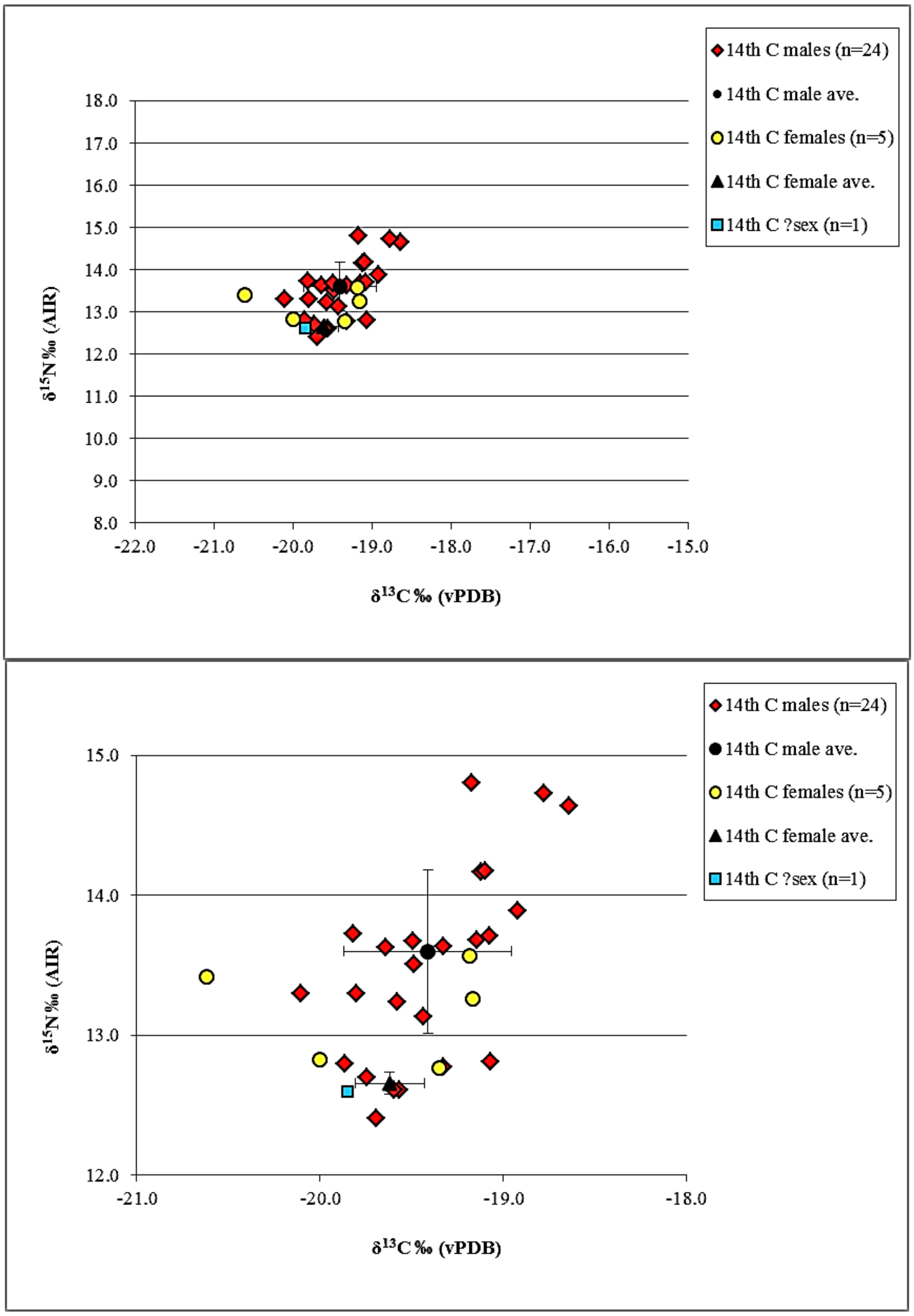


Figure 7.77: Norton $\delta^{13}C$ and $\delta^{15}N$ values for 14th century adult humans (top), with expanded plot (bottom).

Only certain male age categories from the 14th century at Norton could be compared for average $\delta^{13}C$ and $\delta^{15}N$ values, as female age groups were too low for age-specific comparisons. Male age categories of 18-25 (n=0) and 60+ (n=1) could not be included here due to absent or low samples. Average $\delta^{13}C$ values for all age categories were the same at 19.4‰. Average $\delta^{15}N$ values had minimal variation with the greatest difference between the 26-35 male group and the 46-59 group at $\Delta^{15}N_{max-min}$ 0.3‰ (Figure 7.78). No significant difference was found between age groups from this period. These results suggest similar foodstuffs were being consumed by males during the 14th century at Norton, including those of supposed ecclesiastical or high status. Overall, the isotope data from this period suggests that adult diets were fairly homogeneous, predominantly consisting of C_3 cereals, terrestrial and marine protein. However, greater amounts of freshwater fish may have been consumed in this period, as is suggested by $\delta^{13}C$ values being less enriched than in the 13th century.

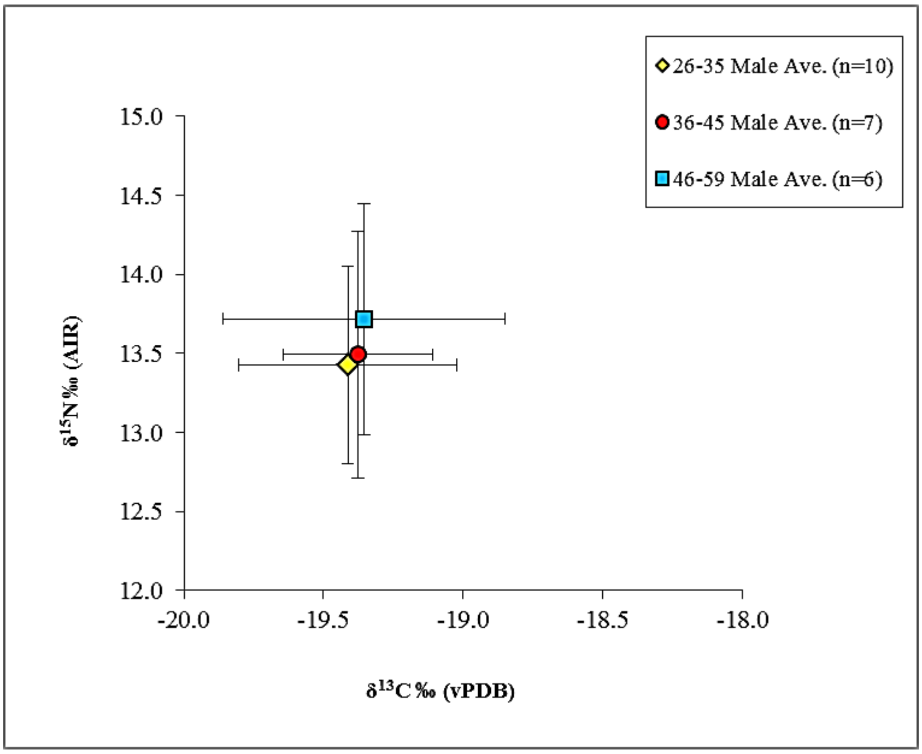


Figure 7.78: Norton average $\delta^{13}C$ and $\delta^{15}N$ values for 14th century male age categories.

7.4.3.2.3 Adult diets: 15th century

For 15th century adults (n=35) from Norton, $\delta^{13}C$ values ranged between -20.5‰ and -18.4‰ ($\Delta^{13}C_{max-min}$ 2.1‰), with an average of -19.4‰ ± 0.5‰ and $\delta^{15}N$ values between 11.6‰ and 14.8‰ ($\Delta^{15}N_{max-min}$ 3.2‰), with an average of 13.3‰ ± 0.8‰. One adult bone sample was allocated to the 16th century with $\delta^{13}C$ and $\delta^{15}N$ values of -19.0‰ and 13.7‰ respectively, which is similar to the average $\delta^{13}C$ values ($\Delta^{13}C_{max-min}$ 0.2‰), and identical to average $\delta^{15}N$ values of males from the 15th century (Figure 7.79). There is some variation in $\delta^{13}C$ ($\Delta^{13}C_{max-min}$ 0.5‰) and $\delta^{15}N$ ($\Delta^{15}N_{max-min}$ 1.3‰) average values between 15th century males and females. A significant difference was found between the sexes from this period in both $\delta^{13}C$ ($t(12) = 2.18$, $p = 0.024$) and $\delta^{15}N$ ($t(12) = 2.18$, $p = 0.014$), suggesting a significant number of males were consuming greater amounts of terrestrial and marine protein than females. This may suggest a number of male ecclesiastics, or those of high status, had greater access to fish.

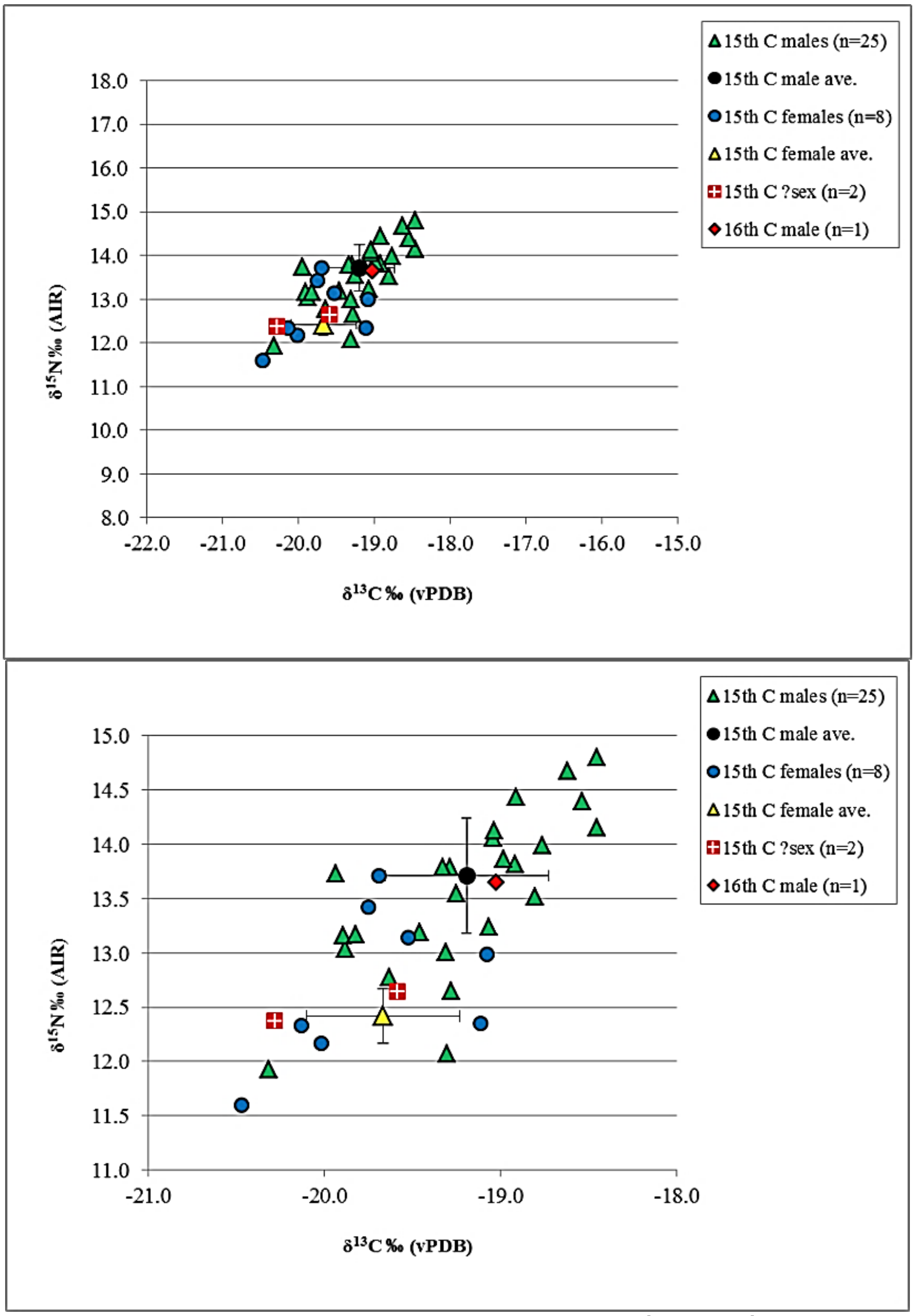


Figure 7.79: Norton δ^{13}C and δ^{15}N values for 15th and 16th century adult humans (top), with expanded plot (bottom).

Sample numbers for age categories of 18-25 (n=2) and 60+ (n=3) from 15th century Norton were too low to include in age-specific comparisons. The greatest variation in average $\delta^{13}C$ values was found between the 26-35 female group and the 36-45 and 46-59 male groups (Figure 7.80), with a difference of $\Delta^{13}C_{max-min}$ 0.5‰. Average $\delta^{15}N$ values had minimal variation with the greatest difference between the 26-35 female group and the 36-45 male group at $\Delta^{15}N_{max-min}$ 0.6‰. Overall, no significant differences were found between age groups from this period. These results suggest similar foodstuffs were being consumed during the 15th century, such as C_3 cereals, terrestrial and aquatic protein.

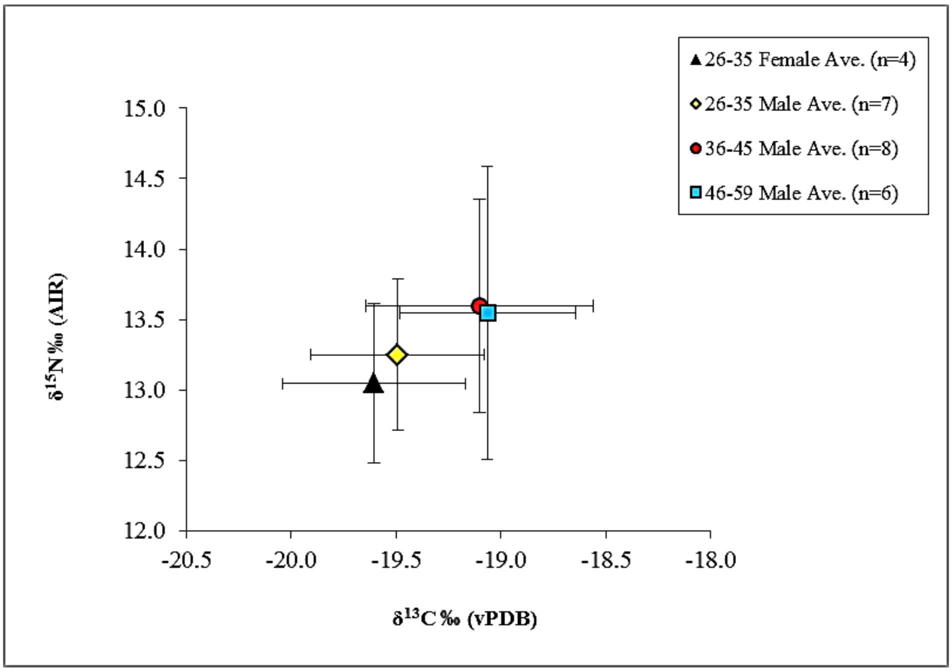


Figure 7.80: Norton $\delta^{13}C$ and $\delta^{15}N$ averages for 15th century adult age categories.

7.4.3.3 Isotope data: Pathology Case Study

Pathological bone from adult males (n=5) with Paget's disease of bone (PDB) were analysed to provide a case study for the effects of pathological bone on isotope values, compared to normal bone data from the same individual (Figure 7.81). Most males affected by PDB were aged 46-59, apart from one male aged 36-45, and from the 13th, 14th and 15th century. All pathological samples were taken from trabecular bones (rib, scapula and pelvis); hence any isotope variation should not derive from normal bone turnover rates.

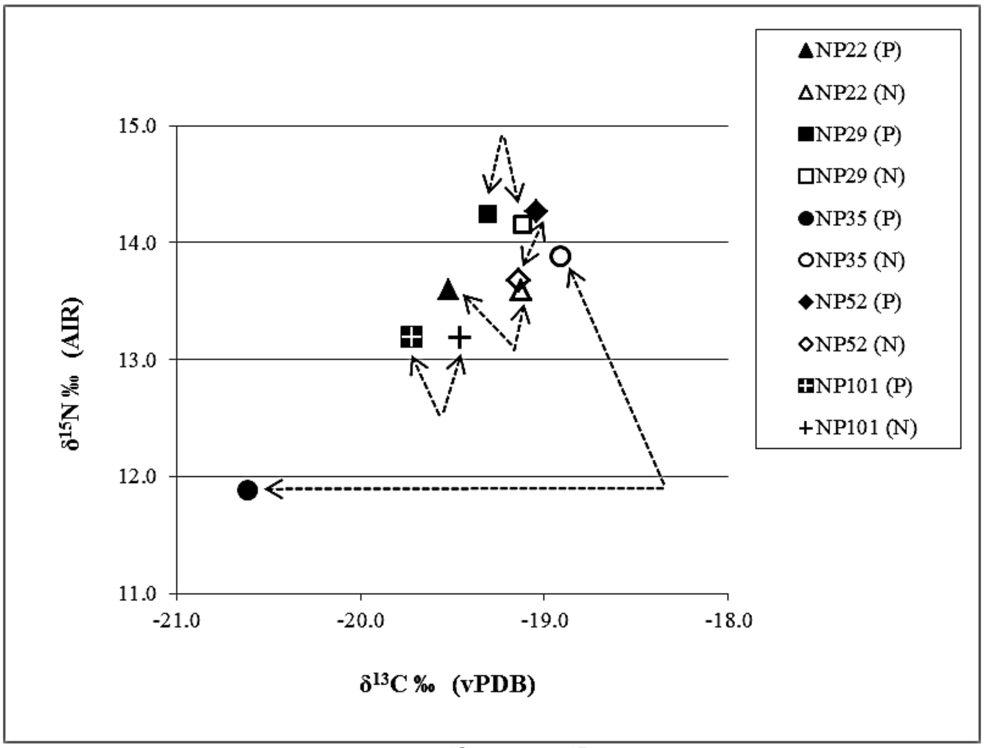


Figure 7.81: Norton male $\delta^{13}C$ and $\delta^{15}N$ values for normal (N) and Pagetic (P) bone, with associations arrowed.

From the pathological bone samples, $\delta^{13}C$ values ranged between -20.6‰ and -19.0‰ ($\Delta^{13}C_{max-min}$ 1.6‰), with an average of -19.6‰ ± 0.6‰. The $\delta^{15}N$ values were between 11.9‰ and 14.3‰ ($\Delta^{15}N_{max-min}$ 2.4‰), with an average of 13.4‰ ± 1.0‰. Variation for normal bone $\delta^{13}C$ and $\delta^{15}N$ values was 0.2‰ and 0.4‰ respectively. Three pathological samples exceeded normal $\delta^{13}C$ variation and compared to their respective normal bone values, the differences were ± 0.4‰ (NP22), ± 1.7‰ (NP35) and ± 0.3‰ (NP101). Two individuals (NP35 and NP52) exceeded $\delta^{15}N$, with ± 2.0‰ and ± 0.6‰ differences respectively, compared to normal bone analysed. The greatest variation for both $\delta^{13}C$ and $\delta^{15}N$ values was found from an adult male aged 46-59 from the 14th century (NP35). From this individual, the difference between normal and pathological bone for $\delta^{13}C$ (± 1.7‰) and $\delta^{15}N$ (± 2.0‰) values is striking. Isotope values from the normal bone samples analysed were within the same trophic level, suggesting these individuals had very similar diets. This study therefore suggests that carbon and nitrogen isotope variation occurred in pagetic bone collagen due to abnormal bone turnover.

7.5 Chapter Conclusion

This chapter has presented results from osteological assessments to determine age, sex and stature, osteometric and non-metric analyses, as well as evidence of dental and bone pathologies. Results from this study found some intriguing evidence that contributes to a greater understanding of medieval lifeways. Although no evidence was found to suggest biological affinity between adults from Portmahomack, cranial non-metric traits and dental anomalies from Norton suggests a familial link, especially between wealthy lay benefactors. Evidence of infectious and respiratory diseases was present on a number of individuals from Portmahomack and Norton, which may reflect exposure to certain living or working conditions. Moreover, the presence of infectious diseases, such as leprosy and tuberculosis, reflects the susceptibility of certain individuals to human infection; especially at Norton, which appears to have been a larger and more diverse society than at Portmahomack.

Evidence of various joint diseases on a number of adults from Portmahomack and Norton reflects activity-related stresses on the body, as well as natural age degeneration. A number of individuals, mostly from Portmahomack, were susceptible to malignant neoplasms. Although the aetiology of these neoplasms cannot be determined, their presence is noteworthy, especially considering such conditions are rarely reported in the archaeological record. Another condition that is rarely reported is Paget’s disease, which is present on a number of adults from Norton. Again, the aetiology of this disease is unknown, although isotope data presented here on pagetic and normal bone may contribute to current debates on this disease. The presence of skeletal trauma on individuals from both sites reflects not only probable accidental injuries, but violence towards the monastic community at Portmahomack, and on a supposed high-status individual at Norton. More surprisingly, evidence of a blade wound to a child from Portmahomack suggests that violence towards children was very extreme in some cases, although such evidence is rare in the archaeological record.

Nutritional stress or illness is reflected in conditions, such as DEH, rickets and scurvy, although stable isotope analysis on sub-adult skeletons would be needed to link childhood diet to skeletal indicators of stress. Evidence of dental pathologies from both sites may suggest gendered-divisions in food intake. For example, calculus is more prevalent in males, and caries is more prevalent in females. The isotope data also support this in some cases, from period 1 at Portmahomack and from the 15th century at Norton, for example. The evidence from these periods suggest males were consuming more animal protein than females, which may reflect labour- or status-divisions that influenced the types of food consumed between males and females.

The isotope data presented in this chapter reveals an apparent diachronic change in diet at Portmahomack, with individuals in the later lay phase consuming aquatic protein, which is not seen in the earlier periods. The typical monastic diet, which included fish on fast days, is therefore not reflected in the diets of the early Christian community at Portmahomack. Isotope data from a selection of sub-adult samples from Portmahomack revealed they were consuming similar types of foods to adults, although some appear to have had access to more animal protein than other sub-adults and adults from the same period. This may reflect a status-division in diet that included children at Portmahomack. At Norton, a more homogenous diet is suggested, including the consumption of aquatic protein, although variations between periods and sexes were observed. Overall, a diet consisting of C_3 plants, terrestrial protein, and in some cases marine and freshwater fish, is evident. Results presented here will be discussed further in the next chapter to understand aspects of medieval lifeways at Portmahomack and Norton.

Chapter 8

DISCUSSION

8.1 Introduction

This chapter provides discussions, formed from results in the previous chapter that places the evidence of medieval lifeways at Portmahomack and Norton Priory into the wider context of those from medieval Britain. Firstly, a general overview of health and society in medieval Britain is revisited that was more broadly discussed in chapter 4. Thereafter, this chapter addresses four key themes, of ‘indicators of bio-cultural or familial affinity’, ‘the living environment’, ‘trauma and conflict’ and ‘diet and nutrition-related stresses’ (some examples in Table 8.1). This approach broadly correlates with a previous study by Roberts (2009), who focused on the living environment, economy and diet, and access to health care. However, this study provides an added dimension of being fully integrated with historical and archaeological evidence and uses stable isotope analysis for reconstructing diets directly. By adopting a multidisciplinary bioarchaeological approach, a powerful research tool is provided that enables the reconstruction of medieval Christian lifeways. The above-mentioned four key themes were chosen because they enable the answering of the research questions set out in chapter 1, which were:

1) To what extent can bioarchaeology be used to infer bio-cultural or familial affinity?

2) To what extent did the way of life of Christian communities have an impact on their skeletal remains?

3) What evidence is there for trauma and conflict in Christian communities?

4) To what extent did diet differ between communities that followed different Christian practices…and are there any dietary stresses that can be specifically tied to Christian practices?

Overall, this chapter intends to consider how medieval lifeways had an impact on the body and to what extent certain influences, religious or social, for example, can be interpreted from bioarchaeology. As discussed in chapter 2 and 3, a number of different religious orders were formed during the medieval period in Britain, with more than one followed over time at Portmahomack. It is therefore worth reiterating here that individuals during period 1 (*c*.550 – *c*.700) at Portmahomack were classed as layfolk with a possible early Christian focus. Individuals from period 2-3 (*c*.700 – *c*.1100) represented a monastic community, possibly of Insular (Irish) origin, whereas by period 4 (*c*.1100 – *c*.1600), a lay community emerged that followed the Roman Catholic faith, with a subsequent Augustinian focus, and finally to Presbyterian in period 5 (*c*.1600 – *c*.1700). During the 12th to 16th centuries at Norton, secular canons and layfolk followed the Augustinian faith, hence no apparent shift in religious focus throughout the Priory’s existence. Different Christian communities are identified here, hence where possible; they are described as lay, monastic (e.g. monks at Portmahomack) or ecclesiastical (e.g. canons, priors or abbots at Norton).

Table 8.1: Sex-specific prevalence of health indicators associated with medieval lifeways at Portmahomack (PMK) and Norton (NP).

Lifeways categories ↓	PMK Male SSP% (n)	PMK Female SSP% (n)	Health indicators results ← →	NP Male SSP% (n)	NP Female SSP% (n)	Possible contributory factors ↓
The living environment	10.7 (11)	9.4 (3)	**Periosteal new bone**	44.7 (38)	40.7 (11)	Poor living conditions Dense population conditions Chronic widespread infections
	1.0 (1)	3.1 (1)	**Rib periosteal new bone**	1.2 (1)	3.7 (1)	Exposure to poor air/smoke Dense population conditions Chronic respiratory infections
	4.9 (5)		**Maxillary sinusitis**	1.2 (1)	7.4 (2)	Exposure to poor air/smoke Dense population conditions Chronic nasal/sinus infections
	55.3 (57)	37.5 (12)	**Vertebral body joint disease**	72.9 (62)	55.6 (15)	Degenerative process Repetitive/hard labour
	48.5 (50)	34.4 (11)	**Vertebral facet joint disease**	47.1 (40)	51.9 (14)	Degenerative process Repetitive/hard labour
	46.6 (48)	43.8 (14)	**Extra-vertebral osteoarthritis**	61.2 (52)	40.7 (11)	Accidental Injury Obesity/Joint strain
Trauma and conflict	25.2 (26)	9.4 (3)	**Fractures**	12.9 (11)		Violence or Conflict Accidental injury
	4.9 (5)		**Sharp-force trauma**	1.2 (1)		Violence or Conflict External violence
Diet and nutrition	53.4 (55)	28.1 (9)	**Calculus**	71.8 (66)	70.4 (19)	High protein intake
	21.4 (22)	21.9 (7)	**Caries**	30.6 (26)	37.0 (10)	High carbohydrate intake
	1.9 (2)		**DISH**	5.9 (5)		High intake of rich foods
	1.0 (1)		**Rickets**	4.7 (4)		Nutritional stress/ Vitamin D deficiency
	1.9 (2)		**Scurvy**			Nutritional stress/ Vitamin C deficiency
	2.9 (3)		**Cribra orbitalia**	9.4 (8)		Nutritional stress/ dietary deficiency
			Porotic hyperostosis	8.2 (7)		Nutritional stress/ dietary deficiency

PMK = Portmahomack, **NP** = Norton Priory. **Shaded areas** = no pathologies observed.

8.2 Health and Society in Medieval Britain

'Health' in modern society has recently been defined as "…the ability to adapt and self-manage" (Huber *et al*. 2011: 237). In medieval Britain however, social hierarchy and religious beliefs would have had an important influence on health. Social cohesion to the Christian faith brought widespread adherence to dietary regimes, in the form of fasting practices, as discussed in chapters 2 and 4. Therein however, the types of foods people consumed varied, depending on a number of factors, such as social class, personal choice or the availability of certain foodstuffs. Medieval society was largely dependent on self-sufficiency, with many occupations bound up in farming or manufacturing. Religious houses relied upon donations from benefactors or income from farming, manufacturing outputs and pilgrimages. Layfolk who worked in religious houses would have had roles such as cook, baker and farm worker. Apart from religious duties, ecclesiastics also performed a range of tasks that held more responsibility, such as almoner (alms-giver), infirmarian (care-giver) and cellarer (food-giver) (Lawrence 1989).

In medieval Britain, the livelihood of the peasantry was wholly dependent on their ability to work, with young children also contributing to the household income (Mate 2006). The transition from childhood to adulthood in medieval Britain appeared around the age of 12 for boys and for girls, with the onset of menarche (first menstrual bleeding), which varies according to genetic, biological and environmental factors (Pearson *et al.* forthcoming; Sofaer 2011). The ability to work may not have automatically reflected a young person's status as an adult (Lee 2008). However, considering boys and girls in medieval Britain could marry by the ages of 14 and 12 years respectively (Holloway and Kline 2009), it is assumed a certain level of adulthood was attained by these ages. Older sub-adults in this study (10.6-14.5 and 14-6-17.0 years) may have therefore been classed as young adults within their community, hence their social age within the context of medieval society is considered in this chapter.

8.3 Indicators of Bio-cultural or Familial Affinity

In order to answer the first research question proposed in chapter 1, it was essential to identify indicators of biological or familial affinity from evidence provided by osteometric data, non-metric traits and congenital anomalies. Although such evidence is suggested to reflect a genetic link, it is also important to remember that other factors such as diet, activity and the environment can affect skeletal traits (Larsen 1999; Zakrzewski 2011). Evidence from the burial record may also assist in interpreting the presence of familial links within a population, where lay and ecclesiastical groups may form distinctive burial patterns, as hypothesised from this research question.

8.3.1 Osteometric Analysis

Measurements of craniofacial bones have been used to suggest population affinities (Giles and Elliot 1963; Krogman and İşcan 1986). Importantly, it has been stated that using osteometric methods, such as cranial indices, to suggest population affinity is “highly simplistic and include the inherent assumption that this form of cranial variation is fixed in nature rather than being biologically plastic in response to a variety of both genetic factors and environmental stresses” (Zakrzewski 2011: 196).

Craniofacial morphology results from Portmahomack reflect both similarities and variation within and between periods, with the most common features being a dolichocrany (narrow) or mesocrany (average) head shape; meseny (average) or euryeny (broad) faces, leptorrhny (narrow) or platyrrhiny (broad) nasal apertures and hypsiconchy (narrow) orbits. Differences in craniofacial shapes from Portmahomack may indicate either natural variation or stress-related plasticity in craniofacial morphology. There is no conclusive evidence here to suggest that individuals from Portmahomack had familial affinities. This would be expected from the monastic phase (period 2-3), where monks would not usually be related. Furthermore, as the parish church community grew in the later lay phase (period 4), individuals from other areas may have settled at Portmahomack, especially during the 13th to 15th centuries when a change in religious focus (monastic to secular) took hold, thereby attracting more parishioners.

Craniofacial features from Norton include a brachycrany (broad) or mesocrany (average) head, euryeny (broad) or lepteny (narrow) face, leptorrhiny (narrow) nasal aperture and chamaeconchy (wide) or hypsiconchy (narrow) orbits. Similarities in nasal and orbital shapes were observed on adults, mostly from the 14th century, although overall, variation does occur. A number of lay individuals were buried at Norton, in particular those from the Dutton family in the 13th and 14th centuries (Greene 1989), which may explain the similarities in craniofacial shape during the 14th century. Overall, metric results from Norton appear to corroborate a pattern of both ecclesiastical and lay individuals buried within the same cemetery. Some lay individuals may have been related, yet differentiation occurs, hence familial affinity is difficult to suggest from this evidence alone. As at Portmahomack, the variation at

Norton would be expected from a skeletal assemblage that included ecclesiastics who were unlikely to be related, unless layfolk became canons on their deathbed. Although this practice did happen throughout medieval Britain (Burton 1994), there is no evidence to suggest family members converted during the same time at Norton.

From both Portmahomack and Norton, two main lower limb shapes occur on adults across all periods, being mostly platymeric (broad) or eurymeric (rounded) femora and eurycnemic (rounded) or mesocnemic (average) tibiae. No lower limb shape that would indicate pathological alteration was found. The lower limb shape evidence does not prove biological affinity, which to a certain extent, would be expected from burials that represent both lay and ecclesiastical individuals. The differences found in lower limb shape suggest natural variation or adaptive skeletal plasticity, within and among populations at Portmahomack and Norton.

8.3.2 Non-metric Analysis

From Portmahomack and Norton, zygomatic facial foramen and supraorbital foramen were the most prevalent cranial non-metric traits (NMT) observed. For post-cranial NMT, those observed from Portmahomack were mostly trochanteric fossa exostosis and lateral tibial squatting facets, and at Norton, trochanteric fossa exostosis and double anterior calcaneal facets. Common occurrence of certain NMT observed at Portmahomack, such as lateral tibial squatting facets from both monastic and lay phases, may suggest some biomechanical influence as a result of cultural behaviours, as a response to prolonged hyperdorsiflexion of the knees and ankles. It is plausible to suggest that evidence of prolonged squatting facets could be connected with repetitive kneeling positions, such as praying, which would have been an integral part of Christian life for both monks and the laity at Portmahomack.

Compared to Portmahomack, a greater variation of certain cranial NMT occurred at Norton, such as lambda and lambdoid ossicles, which were observed on a number of individuals from the 13th to 15th century. Such occurrences may suggest familial affinity. For example, one male and two females, who were buried in the northeast chapel, dated to the 15th century, all had a similar occurrence of cranial NMT, including lambda, lambdoid and asterion ossicles, and parietal, zygomatic and supraorbital foramina. The northeast chapel is suggested to belong to the Dutton family (Brown and Howard-Davis 2008); hence the burial and skeletal evidence appear to corroborate a familial affinity between these lay individuals. Multiple cranial NMT were also observed on two males from the 13th century at Norton, who are suggested to have been father and son, Adam and Geoffrey de Dutton (see chapter 3), again supporting skeletal evidence of a familial link. Although this evidence is only from a small number of individuals, it attests to the usefulness of comparing skeletal evidence, such as NMT, with burial evidence. This evidence supports the presence of certain lay family groups at Norton, who would have requested to be buried within the Priory, to be close to the ecclesiastics and for their souls to be prayed for, thereby assuring their divine afterlife (Greene 1989). Conversely, the fact that no association of NMT was found in other individuals at Norton simply attests to those that were unlikely to be related, such as ecclesiastics. Such evidence is more difficult to interpret from Portmahomack however, as no family groups were inferred from the burial evidence, apart from two males from lay period 4 that were tentatively suggested to be related (Carver 2012). However, no

NMT similarities were found between these two individuals to suggest familial affinity. Moreover, no familial affinity is suggested from the earlier monastic phase at Portmahomack, which is to be expected considering the monks were unlikely to be related.

8.3.3 Congenital Anomalies

A number of congenital anomalies observed on Norton skeletons may suggest familial affinity, such as the presence of hypodontia on the dentition of four adults, a condition which has been suggested to have a genetic link (Dhanrajani 2002). Absence of the 3rd metacarpal styloid process, found on three males from 14th and 15th century Norton, is suggested to be associated with the developmental anomaly, os styloideum (Prescher 2001). It is possible that these lay individuals shared a familial link, especially considering they were buried in parts of the nave and eastern cemetery that probably housed burials from the Dutton family (Greene 1989). Spina bifida occulta was observed on nine adults from the 13th to 15th centuries at Norton, which is in contrast to two cases observed from periods 1 and 2 at Portmahomack.

Another congenital condition, craniosynostosis, was also observed on two adult males from Norton. Again, these individuals were buried in the Dutton family area, suggesting possible familial affinity. This supports the burial evidence of a number of Christian layfolk buried at Norton who was members of the same family, and as aforementioned, requested to be buried within the Priory, attesting to their close relationship to the ecclesiastical community. Although this evidence cannot conclusively prove familial links between these individuals, the pattern of congenital anomalies is noteworthy. It is also interesting to note the majority of congenital anomalies found in this study were from Norton. This may suggest that at Portmahomack, although family groups would have inhabited the area, especially during the lay phases (periods 1, 4 and 5); there is little evidence in the form of congenital anomalies. Additionally, as the Portmahomack church grew from the 13th century, so would the community, including individuals from other areas, possibly settling into a new parish church community. Moreover, no conclusive evidence of a familial link from congenital anomalies were found from period 2-3 at Portmahomack, which as aforementioned, would be expected considering the majority of individuals were monastic brethren.

8.4 The Living Environment

Health in medieval Britain was partly influenced by where and how people lived and by occupation (Roberts 2009). Evidence of certain skeletal and dental pathologies have been used as indicators of health and lifestyle in medieval Britain, when addressing diseases that may have been caused by an individual's living environment (e.g. Roberts and Cox 2003; Roberts 2009; DeWitte *et al.* 2013). Certain diseases within the living environment include those that may have been caused by domestic, climatic or occupation-related exposures, such as respiratory disease.

The second research question in chapter 1 was: to what extent did the way of life of Christian communities have an impact on their skeletal remains? This relates to the living environment by reconstructing aspects of health and disease on individuals from Portmahomack and Norton, to ascertain if individuals differed depending on their lifestyles and roles within their Christian communities. As elucidated in chapters 2, 3 and 4, Christianity was such an integral part of life for people in medieval Britain, hence their living environment would have been influenced by religion. Such influences may therefore be reflected on the skeletal remains of those from Portmahomack and Norton.

8.4.1 Periosteal New Bone

Periosteal new bone (PNB) has often been associated with poor living conditions and susceptibility to infections due to trauma or disease (Larsen 1999; Roberts and Cox 2003). In this study, PNB that was not associated with specific infectious diseases, such as leprosy or tuberculosis, was observed on eleven males (10.7%) and three females (9.4%) from Portmahomack. Adults from all age groups and from periods 1 (lay), 2 (monastic) and 4 (lay) were affected, as were five sub-adults (lay periods 4 and 5) from most age categories (apart from 1.1-2.5 years). This suggests that a number of individuals, both lay and monastic, of all ages at Portmahomack were susceptible to PNB infection, although the cause cannot be determined. In contrast to Portmahomack, a greater number of males (44.7%) and females (40.7%) from all age categories were affected from the 13th, 14th and 15th centuries at Norton, although PNB was not observed on sub-adults. A greater prevalence of PNB at Norton may be associated with a denser populated society, resulting in individuals being more susceptible to infections or trauma. The majority of PNB on Portmahomack and Norton adults occurred on the leg bones, probably caused by occupation or activity-related trauma, considering no association to specific diseases was found.

Roberts and Cox (2003) reported a prevalence of 14.08% for periostitis in the late medieval period, with the greatest prevalence (44.12%) found at St Mary Spital, London (Conheeney 1992, in Roberts and Cox 2003: 235), which is a similar prevalence to that found at Norton (44.3%). This similarity is interesting considering both St Mary Spital and Norton were Augustinian Priories, both of which date from the 12th to 16th centuries and were run by secular canons. St Mary Spital was also a hospital, which would have accommodated a large number of patients, both lay and ecclesiastical, from the surrounding London area (Sheppard 1957). An infirmary was thought to have existed at Norton (Greene 1989), suggesting that here too the canons cared for the sick and needy. This skeletal evidence suggests that Augustinian communities such as St Mary Spital and Norton were affected by certain conditions in a similar way. The suggestion, that afflicted lay individuals were cared for by Augustinian canons, attest to the close relationships between ecclesiastics and the laity.

8.4.2 Rib Periosteal New Bone

PNB on the visceral surface of ribs has been suggested to be related to pulmonary TB (Roberts *et al*. 1994), although some studies, using DNA analysis, found no link between rib lesions and TB (Mays *et al*. 2002). Rib PNB is therefore not considered primary evidence for diagnosis of TB, as opposed to Pott's disease, which is more pathognomonic (Roberts *et al.* 1998; Roberts and Buikstra 2003). Rib lesions do however appear to be the result of response to some form of respiratory disease, such as asthma, bronchitis or pulmonary fibrosis, all of which can be caused and exacerbated by environmental pollutants (Roberts and Cox 2003; Prendergast and Ruoss 2006).

From Portmahomack and Norton males and females, the sex-specific prevalence of rib PNB that is not linked to tuberculosis is low. From Portmahomack, one male

(1.0%) from lay period 4, one female (3.1%) and one sub-adult (2.5%) from lay period 5 were affected. From Norton, one male (1.2%) from the 14th century and one female (3.7%) from the 15th century were affected. This suggests the majority of individuals from both sites were not exposed to high levels of domestic, environmental or occupational hazards linked with respiratory disease. Those affected may have been more susceptible to domestic allergens, such as dust or animal dander, harsh climatic influences or from exposure to occupation-related pollutants, all of which are contributory factors (Holt 1996; Roberts and Cox 2003). The female affected from Portmahomack was the wife of the mid-17th century minister William Mackenzie. Considering the minister was not affected by rib PNB, some division in lifestyles between the two is apparent. The minister's Christian duties may have kept him outside the domestic realm more so than his wife, who may have been exposed to domestic allergens to a greater extent. Therefore, even within the same family, Christian lifeways differed, dependent on the roles people played.

Roberts and Cox (2003) reported rib periostitis as a separate pathology in the Roman period only, with a total prevalence of 2.1% (n= 45) from multiple sites. This is higher than those reported from Portmahomack (1.4%, n=2,) and Norton (1.7%, n=2), although when individual sites are considered, the prevalence is similar to this study, with 1.8% (n=1) for Barrows Hill, Radley (Harman 1976, in Roberts and Cox 2003: 113), 1.3% (n=7) for the Eastern Cemetery site in London and 1.4% (n=5) for Winchester (Manchester and Roberts 1986, in Roberts and Cox 2003: 113*f.*). Similar to Portmahomack and Norton, two adults (0.8%) were also affected at the medieval friary site at Hull Magistrates Court (Holst *et al.* 2001). The results of rib PNB from this study are not atypical to those from other sites, irrespective of ecclesiastical or lay status. This suggests that if religious practices had any influence on people's health, it was not to the extent that would cause a high prevalence of conditions such as respiratory disease.

8.4.3 Maxillary Sinusitis and Nasal Concha Bullosa

Maxillary sinusitis is associated with chronic upper respiratory tract disease, although the exact cause is unknown. It is often linked to air pollution and exposure to allergens, which can be caused by occupation-specific activities or poor living conditions (Lewis *et al.* 1995; Holt 1996; Roberts 2007, 2009). The results from this study found that five males (4.9%) from periods 1 (lay), 2 (monastic) and 4 (lay) at Portmahomack were affected, although sinusitis was not observed on females or sub-adults. The predominance of males affected from the monastic phase may suggest occupation-specific causes, such as exposures to irritants from metal-, leather- or glass-working activities, evidence of which was found during excavation at Portmahomack (Carver 2008). Moreover, such activities may be linked to Christian lifeways, for example, the monks at Portmahomack were gilding mercury, and preparing calf skins to make vellum for monastic books (Carver and Spall 2004; Carver 2008). Such activities would have exposed them to manufacturing pollutants; hence religious influences could in this respect have had a direct effect on the upper respiratory problems of some individuals at Portmahomack.

From Norton, sinusitis was observed on one male (1.2%) from the 12^{th} century, two females (7.4%) from the 13^{th} and 14^{th} century and one sub-adult (7.7%), aged 6.6-10.5 (unknown period). These individuals may have been affected by domestic allergens or were servant workers at the Priory, with roles that resulted in chronic exposure to pollutants or poor air quality, such as inhaling allergens whilst gardening or smoke during cooking. Overall, low occurrences of sinusitis at Portmahomack and Norton suggest the majority of people were not exposed to allergens or pollutants to a significant level. This suggests that living conditions were adequate, which would be expected from high status layfolk and ecclesiastics, especially at Norton. A number of individuals from Portmahomack and Norton may have engaged in outdoor occupations, such as farming, hence respiratory health was generally good.

In all cases from Portmahomack and Norton, there was no connection between those with rib PNB and those with sinusitis, suggesting the upper or lower respiratory tracts were affected by certain exposures but not to the extent that both were affected. Additionally, dental disease may also be a contributory factor to sinusitis, where oro-antral fistulas for example, allow maxillary molar roots to penetrate into the sinus causing infection (Brook 2006). However, there was no connection between those with observed oro-antral fistula and sinusitis from both sites, suggesting environmental pollutants or allergens were contributory factors in these cases.

Roberts and Cox (2003) reported a prevalence of 4.7% (n=93) for sinusitis from the early medieval period and 13.3% (n=276) from the late medieval period. From Portmahomack and Norton, prevalence for adult sinusitis is 3.6% (n=5) and 2.6% (n=3) respectively. This suggests only a small minority of individuals from both sites were exposed to air or fuel pollutants. These are low occurrences, although it is important to note that the inability to inspect all sinus cavities on complete skulls may create bias in the overall prevalence of this pathology. Therefore, a greater number of individuals may have been affected than those identified in this study.

Nasal concha bullosa was observed on two males from lay period 4 at Portmahomack (1.9%) and one male from 13th century Norton (1.2%). This condition, which causes the expansion of the inferior nasal concha, is thought to predispose paranasal sinus infection (Kwiatkowska *et al*. 2011). However, no connection between nasal concha bullosa and sinusitis has been found in medieval populations (Mays *et al.* 2014). Only one case, a male from Portmahomack, had both sinusitis and nasal concha bullosa. Because this condition is rarely reported in the bioarchaeological literature, further evidence is needed to support or refute a link between nasal concha bullosa and sinusitis. However, the presence of nasal concha bullosa on individuals from Portmahomack and Norton may contribute to future studies of this condition and may link religious influences on lifeways to the prevalence of such conditions.

8.4.4 Infectious Diseases

Only a few cases of syphilis are reported from medieval Britain, with some cases being tentatively diagnosed as treponemal disease (*cf*. Mays *et al*. 2003; Roberts and Cox 2003). From late medieval Britain, prevalence of one possible case (3.23%) and eight actual cases (1.15%) of treponemal disease were reported, and those identified as possible syphilis (0.17%, n=2) and actual syphilis (0.34%, n=5) also occurred in low numbers (Roberts and Cox 2003). The single case of treponemal disease on an adult male from Norton (1.2%) fits this pattern of low occurrence, although the diagnosis here is tentative. This individual was dated to the 15th century, as were two individuals from Essex and Suffolk (Mays *et al*. 2003) and four individuals from

Norfolk (Stirland 1994), supporting cases of treponemal disease in pre-Columbian Britain. The individual affected from Norton was buried in the northeast chapel, reserved for the high status Dutton family, and it is probable that his infection was treated in the Priory infirmary by the canons. Such care given by an ecclesiastic to a lay patient suggests that the relationship between those of different status within a Christian community was bound up in religious reciprocity and obligation between the church and its benefactors.

Evidence of lepromatous leprosy was found on one adult male (1.2%) from Norton (NP50), with a tentative case suggested for another male (NP47). The burial of NP50 was buried in a stone coffin within the Chapterhouse; an area reserved for those of high status. It has been suggested that this burial pre-dated the fire of 1236 (Brown and Howard-Davis 2008), supporting the suggestion that this individual was Richard de Chester (d.1211), a wealthy lay benefactor to Norton (A. Abram, *pers.comm.*). Historical records describe Richard as a leper who was given the habit of a canon shortly before his death and was buried at Norton:

> *"…Roger [de Lacy,] had a certain brother, Richard, a name, to whom he gave him the estate in the usual way, and here, after a while he was a leper, and was buried in the chapter house of the canons of the Northton"*
>
> William Dugdale, *Monasticon Anglicanum* 6(1) (London, 1830: 315)

It seems in this case, despite his disease, this individual was regarded highly enough to be afforded a burial befitting his status. Considering only this burial from the Chapterhouse shows evidence of leprosy, it is plausible to suggest this individual is Richard de Chester. Additionally, this burial was surrounded by three smaller stone coffins (Figure 8.1) containing sub-adults, on which, evidence of scurvy (NP53), rickets (NP54) and cribra orbitalia (NP53 and NP54) was observed. Evidence of children being buried in association with adults with leprosy has been found at a number of sites in Britain including Kingsworthy, Hampshire (Chadwick Hawkes *et al*. 2003); Raunds Furnells, Northamptonshire (Boddington 1996), and Edix Hill, Cambridgeshire (Malim *et al*. 1998). It has been suggested these burials represent either unbaptised children who needed divine assistance, or the categorisation of sick individuals, who were seen to require care, both in life and death (Lee 2008). The sub-adult burials at Norton may have been purposefully situated alongside the leper burial to fulfil some form of religious requirement and to demonstrate care to an important benefactor.

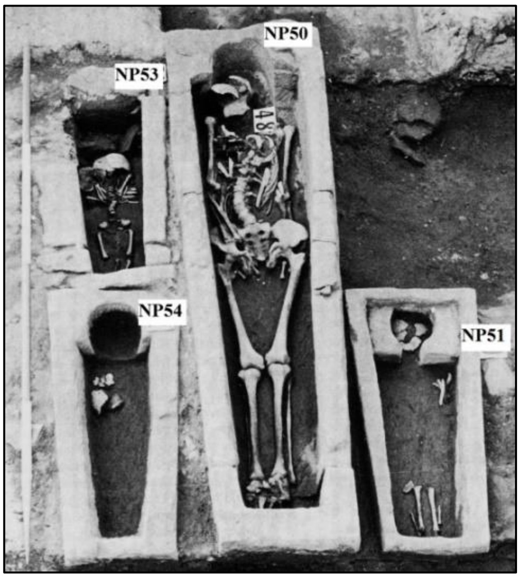


Figure 8.1: Adult leper and child burials from the Chapterhouse at Norton Priory (after Brown and Howard-Davis 2008: 137).

Roberts and Cox (2003) reported a prevalence of 1.07% (n=18), for probable cases of leprosy, from thirteen early medieval sites and 3.5% (n=116) from sixteen late medieval sites in Britain. The number of individuals affected from most sites was low, apart from St James and St Mary, Chichester (from the late medieval period), which had 83 probable cases of leprosy. This number is expected from a hospital used for the purpose of caring for lepers (Magilton 2008b). Although the primary purpose of ecclesiastics at Norton was not to care for those suffering from leprosy, their duty to benefactors and the provision of an infirmary (Greene 1989) would have allowed them to care for the sick, needy and diseased.

One possible case of tuberculosis (TB) on an adult male (1.0%) from the monastic phase at Portmahomack suggests that some brethren were either exposed to bovine TB through close proximity to animals or by contracting human TB from those infected. Skeletal changes to the pelvis of this individual may suggest bovine TB (*Mycobacterium bovis*) that affected the gastrointestinal tract. Another possible case on a sub-adult (2.5%) from lay period 4 was possibly also caused by such exposures. Proximity to animals would be part of daily life and a predominance of cattle bones at Portmahomack attest to this (Seetah 2011).

From Norton, TB affected four males (4.7%) and one female (3.7%) from the 14th and 15th centuries. The presence of PNB on multiple bones, including the visceral ribs and pelvis, may suggest that these individuals were exposed to human infection and in other cases, possibly animal infection. The majority of those affected were buried in the nave, suggesting lay status. One conclusive diagnosis of TB on an adult male is most likely the human form of TB (*Mycobacterium tuberculosis*), based on the bones affected, including rib PNB and dactylitis of the hand.

Low occurrences of TB were found from early medieval Britain, with a prevalence of 0.9% (n=18) from 13 sites and a maximum of 2 individuals affected per site

(Roberts and Cox 2003). The total number of individuals with TB increased in the later medieval period (n=60), with a prevalence of 0.88% from 15 sites; the greatest number affected being from Wharram Percy, Yorkshire (1.32%, n=9) (S. Mays, *pers.comm.*, in Roberts and Cox 2003: 231).

The low occurrence of TB from Portmahomack may suggest people were less exposed to infectious humans due to their remote location and small community, compared to those from Norton; a mitred abbey that would have attracted people from near and far. A denser community at Norton was probably a contributory factor, with a number of people including ecclesiastics, lay benefactors, workers and visitors occupying the Priory buildings. It is worth remembering however that only 5-7% of TB cases affects the skeleton (Aufderheide and Rodríguez-Martin 1998), hence more individuals from both sites may have contracted TB, but not to the extent where it manifested on the bones. One would expect that the type of Christian communities, whether small, large, rural or urban, relatively open or enclosed, were susceptible to certain exposures, which had an effect on their health and subsequently on others, especially where infectious diseases are concerned.

8.4.5 Vertebral Joint Disease

Aside from age degeneration as a contributory factor to vertebral joint disease (VJD), repetitive movements or trauma can lead to premature wear on the vertebrae (Jurmain 1990; Waldron 1994; Sofaer Derevenski 2000; Roberts and Cox 2003; Weiss and Jurmain 2007). Overall at Portmahomack, males were affected more on their vertebral bodies (55.3%) than facets (48.5%), as were females, at 37.5% and 34.4% respectively. Males from the monastic phase were affected more on the facets than bodies; however, this pattern is reversed in lay periods 1 and 4. This may suggest that monks from Portmahomack were engaging in different types of activities than the lay adults from periods 1 and 4, with the facets undergoing greater stress. A religious influence on the body is therefore suggested here, with the monks having to engage in activities specific to the needs of their monastic community. This may have included repetitive movements during vellum making, praying, scribing and even building and maintaining the monastery. Adults from the later lay phases appear to have had greater strain on the vertebral bodies, which may suggest heavy loading on the spine from occupations such as farming or fishing. This may reflect a Christian division in labour between monks affected from period 2-3 and the layfolk affected from periods 1 and 4.

Overall, males from Norton were affected more on their vertebral bodies (72.9%) than facets (47.1%), as were females at 55.6% and 51.9% respectively. However, this is reversed for lay females in the 14th century (compared to the 13th and 15th centuries), where joint disease to the facets dominate. Males aged 36-45 were most affected in their vertebral bodies, mostly in the thoracic and lumbar regions, whereas females, aged 46-59 were most affected in the cervical region. This may reflect a gendered-division in activities undertaken at Norton, with repetitive neck movements in females and strain on the mid-lower back in males resulting in differential vertebral wear. The vertebral facets affected most in males were found in the thoracic and cervical region and in the thoracic region for females, with both sexes aged 46-59 being most affected. This evidence attests to the varied impact on the health of people within the same Christian community. The age distribution and difference in prevalence between males and females from Norton may suggest younger males were engaged in strenuous labour, resulting in heavy mechanical loading and stress on the vertebral bodies. A number of male workers would have engaged in a range of tasks, with laymen farming and craft-working, and canons taking on roles of the cellarer (supplying food and drink), infirmarian (managing the sick and the infirmary) and gardener (tending to medicinal and culinary herbs) (Lawrence 1989), which may have contributed to an early onset or exacerbated existing VJD. A combination of heavy loading on the vertebral bodies and wear on facets for older females may suggest a combination of activity and age degeneration as causative factors for VJD at Norton.

Roberts and Cox (2003) reported a prevalence for spinal osteoarthritis of 12.1% (n=436) for 42 early medieval sites and 27.9% (n=344) for 11 late medieval sites in Britain. From Portmahomack and Norton, the overall prevalence for VJD was 51.1% and 68.8% respectively, which corresponds with prevalence from a number of individual medieval sites with significantly above-average incidence, such as Tidworth, Salisbury (50.0%) from the early medieval period (McKinley 1993d, in Roberts and Cox 2003: 196) and Blackfriars Friary, Ipswich (60.0%) from the late medieval period (Mays 1991b, in Roberts and Cox 2003: 281). This suggests that the overall prevalence of VJD found in this study follows a similar pattern to those found at some other medieval sites, but above the average noted by Roberts and Cox (2003). Variation in the types of joints and people affected need to be considered to avoid associating joint disease with single causative factors. Considering the similarity of VJD prevalence between other medieval sites, but also the variation of vertebral joints affected between ecclesiastics and layfolk found in this study, it is plausible to suggest some level of religious influence, either through activity or occupation, resulted in these changes on the skeletal body.

8.4.6 Extra-vertebral Osteoarthritis

From Portmahomack, 46.6% (n=48) of males were affected by extra-vertebral osteoarthritis (EVOA), with females being slightly less affected at 43.8% (n=14). Males from Portmahomack were affected mostly in the acromioclavicular, shoulder and hip joints, with the monks from period 2-3 more affected than lay males from periods 1 and 4. As with vertebral joint disease, these results may reflect a religious influence on the body, with the monks engaging in activities specific to the needs of their monastic community, yet different to those of the laity from the other periods. Females, mostly from lay period 4, were also affected the most in the acromioclavicular joints, as well as the proximal and distal humeri. There is an increase in EVOA from ages 36-45 to 60+, which may suggest natural age degeneration as the cause. However, the prevalence of shoulder and hip OA on Portmahomack males may suggest a contribution from forms of activity that involve repetitive movement of the arms and legs, such as manufacturing, building and even a lifetime of kneeling down to pray, reflecting a possible religious influence on the body. The EVOA evidence for females from Portmahomack suggests that repetitive upper body movements may have been a contributory factor, possibly associated with domestic or occupational activities. For both sexes, age degeneration may have also contributed to EVOA, although a number of younger individuals affected (e.g. aged 26-35) suggests this was not the primary cause.

Males from Norton were also more affected by EVOA (61.2%, n=52) than females (43.8%, n=14), mostly in the acromioclavicular and sternoclavicular joints, with high occurrences also on the shoulder and hip joints. Females from Norton were most affected by EVOA on the sternoclavicular joint, on some elbow articulations and knee joints. Males aged 36-45 from the 15th and 16th century were most affected by EVOA and for females, in the 13th and 14th century, aged 46-59. Overall, there is an increase in male EVOA from the 13th to 15th centuries, whereas female occurrence fluctuates, then peaks in the 14th century. The prevalence of EVOA suggests that work may have been a contributory factor, especially in males, where activities at home or at the Priory, such as farmer, cellarer or builder may have caused or exacerbated the condition. For females at Norton however, natural age degeneration may have contributed to EVOA, more so than in males.

Roberts and Cox (2003) reported an overall prevalence for extra-spinal joint disease of 8.3% (n=328) from early medieval sites and 14.08% (n=656) for late medieval sites, although wide variation of prevalence occurred from individual sites (*cf.* Roberts and Cox 2003: 197, 283). At Portmahomack and Norton, the overall prevalence for adults affected by EVOA was 44.9% (n=62) and 57.4% (n=63) respectively. This is a similar prevalence to those reported from some other medieval sites in Britain, such as School Street, Ipswich (46.3%, n=44) (Mays 1989), although noticeably different from other sites such as Hull Magistrates Court, where 19% of males and females were affected (Holst *et al.* 2001). This attests to the variation that can occur from conditions that have multifactorial causes and how such conditions affected medieval Christian communities differently.

8.4.7 Schmorl's Nodes

Schmorl's nodes (SN) affected males (42.7%, n= 44) more than females (28.1%, n= 9) from Portmahomack. The thoracic vertebrae were most affected by SN in both sexes, with the majority being slight, although a number of severe nodes were present on the thoracic and lumbar vertebrae. Males from the monastic phase (period 2-3) at Portmahomack were most affected by SN, suggesting mechanical loading on the vertebrae or other strenuous activity was a greater contributory factor in this period. When considering both SN and VJD results from period 2-3, it appears that monks from Portmahomack engaged in strenuous activities that differed to those from the later lay phase (period 4), resulting in joint disease, mostly on the facets, although compression occurred to the point of disc herniation. A number of males from lay period 4, and females to a lesser extent, was either engaging in strenuous activities, such as farming, or repetitive mechanical loading over a number of years, resulting in intervertebral disc herniation.

From Norton, SN affected 51 males (60.0%) and 12 females (44.4%), suggesting males were affected more than females. As at Portmahomack, prevalence decreased with severity, with mild nodes observed the most on thoracic vertebrae in males and mild to moderate nodes on female thoracic vertebrae. The majority of those affected by SN from Norton were aged 26-35, which is in stark contrast to older individuals affected at Portmahomack. This age prevalence spanned the 13th to 15th centuries and suggests that a number of adults, predominantly males, were subjected to repetitive mechanical loading on the vertebrae, possibly due to occupation- or activity-related stress on the body. Overall, adults most affected were from the 14th century, which may suggest individuals from this period were engaging in more strenuous or different types of activities around this time. These males may have been involved in farming Norton lands or renovating the Priory, which was elevated to abbey status in the 14th century, hence building work befitting its new status was required (Greene 1989). Again, this reflects a religious influence on the body, through activities undertaken for the Priory and Christian community.

Roberts and Cox (2003) reported a prevalence of 8.9% (n=207) for SN from early medieval Britain, although none were reported from the late medieval period. For Portmahomack and Norton respectively, a prevalence of 38.4% (n=53) and 54.8% (n=63) was reported in this study. The prevalence figures from Portmahomack and Norton appear greater than those reported by Roberts and Cox (2003), even when individual sites are taken into consideration. Although it has been suggested here, and in other studies (Robb *et al.* 2001; Jiménez-Brobeil *et al*. 2012; Novak and Šlaus 2011), that activity-related stress on the spine is the probable cause for SN, other causative factors need to be considered, such as a genetic predisposition (Dar *et al.* 2010; Plomp *et al*. 2012). Further investigation is beyond the scope of this study, however, as the aetiology of SN is still debated; more research on skeletal collections is needed to determine activity as a cause of SN. However, a religious influence on the skeletal body, through various activities within a Christian community, is considered in this study.

8.4.8 Miscellaneous Joint Conditions: Os acromiale

It is beyond the scope of this study to investigate markers of activity or biomechanical stress in the form of entheseal changes or asymmetry on bone (*cf.* Mariotti *et al*. 2004; Knüsel 2007; Villotti 2010). However, one condition observed in this study and worthy of discussion is os acromiale. Unilateral os acromiale of the right scapula was observed on five adult males (3.6%) from Portmahomack, with those most affected from the monastic phase. Os acromiale has been connected to specific occupational activities, such as archery, which was suggested for males from the medieval battle site of Towton (Knüsel 2007) and from King Henry VIII's ship, the *Mary Rose* (Stirland 1991, 2000). Asymmetry studies on bone to determine handedness have also been performed with mixed results. When studying asymmetry on skeletons from the *Mary Rose,* and from St Margaret in combusto, Norwich, Stirland (1993) found no upper limb asymmetry for the *Mary Rose* sample, suggesting even-handedness. However, those from Norwich presented conclusive results for right-handedness.

It appears that males from Portmahomack, especially monks from the monastic phase, were engaging in strenuous repetitive movements of the upper limb from a young age. Such movements therefore resulted in the failure of acromion fusion, due to continuous shoulder rotation in younger males, or trauma of the epiphysis due to biomechanical stress in older males. It is possible that right os acromiale on the monks from Portmahomack reflects right-handedness, with the opposite for layfolk from periods 1 and 4, where the left scapula was affected. As with vertebral joint disease and Schmorl's nodes, this evidence suggests different types of activities were undertaken by the monks compared to the layfolk at Portmahomack, possibly reflecting a change in how Christian communities engaged in activity and labour.

8.4.9 Neoplasms and Circulatory Disorders

Neoplasms are new bone growths or destructive lesions that manifest in either a benign or malignant form (Aufderheide and Rodríguez-Martín 1998). As there are many forms of cancer, so are there a number of risk factors, such as ultraviolet light (skin cancer), smoking or inhalation of environmental pollutants (lung cancer), and diet, age or a genetic predisposition (prostate or bowel cancer). Benign neoplasms were observed on six adults (5.2%) from 13th to 15th century Norton, in the form of an osteochondroma on one male tibia and button osteomas, mostly on the crania of the remaining adults. Button osteomas are one of the most common neoplasms found in the archaeological record and have been reported with a prevalence of 2.4% (n=49) from sixteen early medieval sites in Britain (Roberts and Cox 2003).

No benign neoplasms were found on Portmahomack individuals, although evidence of malignant neoplasms was found on four males (3.9%) from periods 1, 2 and 4, with two from the monastic phase (period 2). These neoplasms were identified as probable metastic carcinomas, with one identified as metastic prostate carcinoma on a monk from period 2. This neoplasm is extremely rare in the archaeological record, with very few examples from medieval Britain. The first case of prostatic carcinoma in medieval England was reported on an adult male from St. Gregory’s Priory, Canterbury (Anderson *et al*. 1992). More recently, evidence of a probable metastic carcinoma has been identified on an adult male from the Anglo-Saxon site of Huntingdon Castle Mound, Cambridgeshire (Vincent and Mays 2009). Additionally, Roberts and Cox (2003) reported a prevalence of 0.6% for metastic carcinoma from four early medieval sites in Britain, the number affected (n=5) being close to what was found from Portmahomack alone. The Christian communities at Portmahomack therefore appear to have been highly susceptible to malignant forms of cancer compared to other sites in Britain. Although it is difficult to understand why such significant occurrences were found from Portmahomack without knowing the exact cause, the prevalence is nevertheless noteworthy.

Evidence of a malignant neoplasm on one male from 14^{th} century Norton was identified as a probable multiple myeloma. Evidence of this neoplasm has also been found on an elderly female skeleton from the medieval lay cemetery at Abingdon, Oxfordshire (Wakely *et al.* 1998) and on an adult from the early medieval site of Addingham, West Yorkshire (Boylston and Roberts 1996). This neoplasm is rarely found in the archaeological record and clinical evidence reveals an incidence of 2–4 cases per 100,000 (Mulligan 2000). However, comparing modern case figures with those from antiquity is not ideal, because modern lifestyle factors (e.g. diet, drinking and smoking) are quite different to those in antiquity. The individual affected from Norton was buried within the northeast chapel, hence of supposed high status, possibly from the Dutton family. It is therefore plausible to suggest this individual, possibly a benefactor to Norton, was treated at the Priory infirmary and cared for there by the canons until his death.

Risk factors that resulted in malignant neoplasms found on the Portmahomack and Norton individuals may have included chronic exposure to environmental pollutants, a genetic predisposition, or their type of diet. Considering the diets at Portmahomack and Norton appear fairly homogeneous (see section 8.6.12) and relatively healthy compared to modern standards, diet alone does not seem to be the primary risk factor for these neoplasms. Moreover, a genetic predisposition is unlikely to be the cause of neoplasms found on the monks from Portmahomack, although it cannot be completely ruled out. As malignant neoplasms are rare in the archaeological record, further evidence from religious communities would prove useful to understand the aetiology of this condition, for example to rule out a genetic cause, and understand its impact on Christian communities.

Circulatory disorders can be caused by vascular deficiency, infection, genetics, cancer or trauma; the latter being a causative factor which is gaining predominance in palaeopathological literature (Aufderheide and Rodríguez-Martin 1998; Ortner 2003; Roberts and Cox 2003). Skeletal evidence of Scheuermann's disease suggests males were predominantly affected, although overall, there is little palaeopathological evidence for this condition (Aufderheide and Rodríguez-Martin 1998). For example, only single cases have been reported from early medieval West Heslerton, North Yorkshire (Cox 1999) and late medieval St Andrew's Church, Corbridge, Northumberland (Holst 2006).

This study found that Scheuermann's disease affected the mid-lower thoracic vertebrae of three adult males from the monastic phase at Portmahomack and an upper lumbar vertebra on an adolescent from 15th century Norton. The presence of this pathology on more than one individual in this study is therefore noteworthy and may suggest that although a genetic factor cannot be ruled out, the monks from Portmahomack and the adolescent from Norton may have been susceptible to traumatic conditions on the spine thorough strenuous activity. As aforementioned, the monks at Portmahomack would have been involved in building the monastery, which would have involved manual lifting of heavy material such as stone (Carver

2008) and may have therefore sustained traumatic conditions as a direct result of such strenuous labour. In this respect, Christian lifeways were possibly affected via obligations to their monastic community and to the church.

Unilateral Osgood-Schlatter's disease was present on one male from lay period 4 at Portmahomack. As with Scheuermann's disease, a male predominance and traumatic cause is suggested for this pathology (Aufderheide and Rodríguez-Martín 1998). Few cases of Osgood-Schlatter's disease are reported, with single cases from the Anglo-Saxon cemetery at Castledyke, Sheffield (Boylston *et al.* 1998) and the 12th to 13th century cemetery at Malmesbury Abbey, Wiltshire (Henderson 2011). The male affected from Portmahomack may have suffered severe strain on the patella ligament, resulting in an avulsion of the tibial tuberosity. This pathology is common in young males aged 10 to 15 years (Aufderheide and Rodríguez-Martín 1998) and given the age of this individual (18-25 years); it is probable that this occurred during childhood. Considering only one single case of Osgood-Schlatter's was found in this study, it appears that the lay Christian community from period 4 at Portmahomack, or more specifically, young males, were not highly susceptible to traumatic conditions such as this.

Intervertebral osteochondrosis is associated with trauma, although as with Scheuermann's disease, a genetic factor may predispose individuals to this pathology (Aufderheide and Rodríguez-Martín 1998). As with other circulatory disorders, very few cases are found in the palaeopathological literature. A single case has been found at the medieval site of Main Street, Torksey, Lincolnshire (Holst 2005) and three female cases from the Austin friary site at Hull Magistrates' Court (1316–1540) are reported (Holst *et al*. 2001). In this study, intervertbral osteochondrosis was observed on one adult female from lay period 4 at Portmahomack and on three adult males from 14th century Norton. Of the males affected from Norton, two were buried in the centre of the nave and one in the chapterhouse, the latter of which being identified as a member of the Dutton family who as aforementioned (section 8.4.4), suffered from leprosy. Other members of the Dutton family were also buried in the nave, which suggests that the males affected from Norton may have been susceptible to this condition due to a genetic predisposition. This suggests that members of the Christian community at Norton were not only susceptible to extrinsic health consequences, such as aforementioned infectious diseases, but intrinsic (genetic) ones too. Evidence of cranial non-metric traits supports this, elucidating that a number of individuals buried within the Dutton family chapel had a familial affinity.

Only one possible case of slipped femoral capital epiphysis was observed, on an adult male from lay period 4 at Portmahomack. As with other circulatory disorders, the aetiology is still unclear although a genetic or traumatic cause is suggested (Aufderheide and Rodríguez-Martín 1998). This pathology has been identified from the medieval hospital of St Giles, Brough, North Yorkshire, where it was identified on the skeleton of a priest (Knüsel *et al*. 1992). Overall, the low occurrence of these circulatory disorders may suggest that a combination of a genetic predisposition and strenuous biomechanical loading or strain were contributory factors, rather than just activity alone. At Portmahomack this may have been linked to traumatic episodes as a result of monastic obligations and lifeways, and at Norton, as a consequence of a genetic predisposition between family members.

8.4.10 Miscellaneous Conditions: Paget's Disease of Bone

From Norton, nine cases (7.8%) of Paget's disease of bone (PDB) were found, two of which were possible cases. Although the aetiology for PDB is still unknown, it has been associated with environmental (Lever 2002) and genetic factors (Visconti *et al.* 2010). A noticeably high percentage of PDB in contemporary Britain was found to concentrate around Lancashire towns, with the highest found in Lancaster (8.3%) and a lower prevalence found close to Norton, in Chester (4.2%). This study was based on PDB diagnosed from radiographs of individuals aged over 55 years (Barker *et al.* 1980); hence direct comparisons to this study may be misleading. However, this evidence is noteworthy considering the concentration of PDB found in contemporary northwest England and at medieval Norton.

Considering most reports of PDB from medieval Britain are single cases (*cf*. Roberts and Cox 2003), those from Norton are significantly high. Other multiple cases are reported from Barton on Humber (Lincolnshire), where fifteen cases of PDB were observed, with a prevalence of 1.7% (pre-1500 AD) and 3.1% (post-1500 AD) for those aged over 40 years (Rogers *et al.* 2002). Fourteen cases of PDB were observed at St Mary Graces Priory (London), where females (4.1%) were more affected than males (3.0%) (Waldron 1993). To date, only these three sites appear to represent high concentrations of PDB from medieval Britain, hence further evidence of PDB, especially from sites in northwest England, may prove highly significant to aid diagnosis. Moreover, considering the majority of those affected by PDB at Norton are most likely associated with the Dutton family, a genetic cause should be considered.

Although the majority of those affected by PDB from Norton had extensive skeletal changes, it is unlikely that it would have been to the extent of visible deformity in life. One exception may be an adult male (NP22) that was most affected by PDB from Norton, where extensive pagetic (pertaining to PDB) changes included enlarged bones, most notably the cranium. Such cranial enlargement however could be obscured with hair or headwear (Figure 8.2). This individual is suggested to be Sir Geoffrey de Dutton, a wealthy knight, crusader and lay benefactor to Norton in the 13th century (A. Abram, *pers.comm.*; L. Smith, *pers.comm.*). Whether any visibility of his condition altered social perceptions of him cannot be stated; however, he was assured a burial befitting his status despite his condition, which was also the case with the previously discussed individual with leprosy. This suggests a reciprocal relationship between the ecclesiastics and wealthy layfolk at Norton. Donations from lay benefactors assured burial in an important position and divine acknowledgement thereafter, in the form of prayers for the soul of the deceased. As well as PDB, this individual suffered a violent attack, which will be discussed further in section 8.5.2.

Figure 8.2: Facial reconstruction of NP22
by Richard Neave. Photograph: author's own.

Pathological bone from five adult males with PDB were analysed to provide a case study for the effects of pagetic bone on isotope values, compared to normal bone data from the same individual. Results found that three individuals had isotopic variation between pathological and normal bone isotope values. Katzenberg and Lovell (1999) attributed such variation to abnormal bone processes from various wasting diseases (e.g. respiratory failure). To date, no carbon and nitrogen isotope analysis on pagetic bone has been undertaken. New data from this study therefore contributes greatly to this area of research by suggesting that the disruption of normal bone turnover in PDB may also contribute to such isotopic variation. Furthermore, these data may contribute to future diagnoses of this condition, at the very least to rule out a dietary factor to the disease, especially considering that the isotope data from the normal bone samples suggest these individuals had a very similar diet. This research may also contribute to the effects of disease on Christian communities and how those of high status were treated in life and death, despite their condition. Therefore similar evidence would prove beneficial from other religious sites, to elucidate how Christian communities perceived and treated those with diseases such as PDB.

8.5 Trauma and Conflict

Trauma on bone can be due to a number of causes. For example, fractures can be caused by disease-weakened bone, such as PDB, rickets or osteoporosis (Aufderheide and Rodríguez-Martin 1998). Fractures may also be caused by occupational hazards, accidents or personal conflict (Novak 2007; Martin *et al*. 2013). Therefore, fractures may be the consequence of an individual's living environment (section 8.4), nutritional health (section 8.6) or inflicted trauma, although determining the cause is very difficult without conclusive evidence.

Weapon-related trauma however, may suggest battle-related or inter-personal conflict (e.g. Fiorato *et al*. 2007), or cultural practices, such as decapitation (e.g. Buckberry and Hadley 2007). The third research question proposed in chapter 1 asked what evidence is there for trauma and conflict in Christian communities. Evidence of inflicted trauma on individuals from religious communities is intriguing, as a certain level of adherence to a Christian way of life is suggested, especially away from the battlefield. However, the skeletal evidence from this study suggests otherwise, which is discussed below.

8.5.1 Fractures and Dislocations

Results from this study found that males (25.2%) were more affected by fractures than females (9.4%) at Portmahomack, with males aged 46-59 from the monastic phase being most affected. The majority of fractures from Portmahomack and Norton were avulsion or transverse types. Avulsion fractures are more likely to be caused by severe stress to ligament or tendon attachments (Resnick and Niwayama 1988). A number of avulsion fractures from Portmahomack were observed on the 5th metatarsal tuberosity, mostly from the monastic phase. This injury is often associated with plantarflexion and inversion of the foot, which can be caused by severe force bearing down on the foot, from a fall for example (Ritchie *et al*. 2011). As aforementioned, the monks at Portmahomack would have been involved in manual labour such as building the monastery (Carver 2008), and may have sustained fractures from falls during such activities. The individuals with this trauma also had lateral tibial squatting facets, which alternatively, may suggest the continuous pressure on the ankles and feet was caused by prolonged squatting due to other forms of activity, such as repetitive kneeling to pray. Evidence of trauma, and other health indicators discussed in this chapter, are important as they refute the image of all medieval monks being lazy, obese and greedy (Wishart 2009), as do other bioarchaeological studies (e.g. Patrick 2014).

Avulsion fractures also occurred on the 3rd metacarpal styloid process of three adult males from lay period 4 at Portmahomack. This type of injury has been associated with hammering with a large object gripped in the palm (Marzke and Marzke 1987). This injury may therefore reflect some form of occupational trauma sustained by the lay men, such as blacksmithing or stone carving, which may have even been associated with the restructuring of the church during the 13th century. This is plausible considering bone from one of the males affected has been radiocarbon dated to AD 1150-1280 (Carver 2008). Transverse fractures occurred mostly on rib midshafts of males from the monastic phase at Portmahomack, all of which were healed at the time of death, suggesting they were not life-threatening injuries. Rib fractures may be caused by occupational hazards or direct trauma, in the form of a blow to the body, for example (Lovell 1997). It therefore seems that in the monastic phase at Portmahomack, monks were engaging in dangerous or at least strenuous activities that resulted in fractures, mainly to the thorax and feet. A number of these fractures were possibly the result of conflict (see section 8.5.2). Individuals from the later lay phase at Portmahomack were also affected by fractures, occurring on the hands, legs and feet and more likely to be associated with occupation or activity.

Only males from Norton (12.9%) were affected by fractures, observed mostly on those aged 46-59 from the 14th and 15th centuries. A range of fracture types occurred, mostly on the legs, arms and hands, including, avulsion, oblique, greenstick and transverse fractures. These fractures, apart from the latter, are caused by indirect trauma as a result of stress on the bone during bending (greenstick), rotation (oblique), tension or repetitive force (avulsion) (Lovell 1997). The variation in fracture types and location affected on Norton males suggests activity or occupational hazards, such as farming, were the cause. Today, injuries caused by cattle are not uncommon. In the past 10 years, 37 people have been killed by cattle and around 100 farm workers are injured by cattle each year (IOSH Rural Industries Group 2014). It is therefore plausible to suggest that medieval farming duties, especially those involving cattle, would have also had a certain level of danger (Judd and Roberts 1999). Building work could also be dangerous, resulting in falls or an impact from heavy objects resulting in fractures. The majority of males affected by fractures from Norton were buried in the nave, west front or north aisle, suggesting they were of lay status. These individuals may have therefore been workers at the Priory and engaged in hazardous tasks that resulted in trauma. Their dedication was however acknowledged by their burial within the Priory grounds, reflecting their close connection to Norton.

Fractures have been observed from a number of medieval sites, with varying prevalence’s. From Hull Magistrates Court, Holst *et al.* (2001) reported a prevalence of 13%, with the most common area affected being the ribs. From Llandough, Glamorgan, 11% of the population were affected by fractures (Loe and Robson-Brown 2005), and from Whithorn Cathedral Priory, Southwest Scotland, 7% were affected by fractures (Cardy 1997). These prevalence figures are similar to those found at Norton, yet half of what was found at Portmahomack, suggesting the monks at Portmahomack were highly susceptible to traumatic injuries. Bones most affected by fractures in early medieval Britain were found on upper long bones, followed by lower limb and skull fractures. The highest rate of fractures in late medieval Britain occurred on the ribs, closely followed by the ulna and radius (Roberts and Cox 2003), similar to those observed in this study. Overall, the nature of these fractures may suggest a traumatic consequence due to occupational hazards from farming, building or manufacturing activities, all of which are occupations that would have been undertaken by the Christian communities at Portmahomack or Norton.

A number of dislocations were observed from Norton, on both males (8.2%, n= 7) and females (11.1%, n= 3), mostly from the 14th and 15th centuries. The majority of these dislocations occurred on the lateral clavicle and humeral head, suggesting some severe strain to the shoulder area. Evidence of dislocations have been found at Castledyke (0.5%) (Boylston *et al*. 1998) and at Hull Magistrates Court where the greatest prevalence was also found on the shoulder (0.6%) (Holst *et al*. 2001). Roberts and Cox (2003) reported a prevalence of 0.7% for dislocations from six early medieval sites in Britain, with one individual affected per site. The number of adults affected (n=10) by upper body dislocations at Norton is therefore noteworthy and may suggest that adults were engaging in high-risk activities, although trauma as a result of violence cannot be ruled out. Overall, it appears that a number of adults from Norton were susceptible to either activity- or occupation-related hazards, with males being vulnerable to fractures and females more affected by dislocations. Such evidence may suggest a gendered-division in the types of occupations undertaken by adults at Norton and also attests to the vulnerability of Christian communities that lived and worked within Portmahomack and Norton.

A number of other trauma-related pathologies were observed from Portmahomack and Norton, including spondylolysis, myositis ossificans traumatica and vertebral compression. Vertebral compression can be a secondary condition to disease such as osteoporosis, although there was no connection between those from Portmahomack affected by osteoporosis and those with evidence of vertebral compression, suggesting other forms of stress on the vertebral body were the cause. Myositis ossificans traumatica is a haematoma ossification caused as a result of injury to a ligament, tendon or muscle attachment (Resnick and Niwayama 1988: 4247). Two males, one from period 4 Portmahomack and one from 14th century Norton, were affected. These individuals possibly engaged in repetitive strenuous activities that resulted in trauma, suggesting a probable response to occupational or habitual activities.

In most cases, fractures appear to be well-healed with no sign of major deformity, suggesting medical care was available (Grauer and Roberts 1996). One possible exception was found on an elderly male from the monastic phase at Portmahomack. Here, healed oblique apposition fractures to the left tibia and fibula are misaligned resulting in a shortening of the left leg, with possible secondary osteoarthritis to the left hip joint. Other exceptions include non-united fractures to the clavicle of two monks from Portmahomack. This evidence suggests that either medical knowledge at the monastery did not include re-setting fractured bones or for whatever reason, these individuals did not have access to such treatment. A lack of medical knowledge is however not apparent from those affected by fractures at Norton, suggesting medical practices within the infirmary were more than adequate, which would be expected from a mitred abbey.

8.5.2 Sharp-force Trauma

Sharp-force trauma was observed on two males from the monastic period 2-3 and on three males from the later lay phase at Portmahomack. Archaeological evidence of a Viking raid on the monastery between 780 and 830 (Carver 2008), and skeletal evidence suggests two monks from period 2-3 were victims of this raid. The nature of the cuts on the crania of the monks suggests the assailants attacked facing one male, and from behind on the other. The monk attacked from behind appears to have died from his injuries as there is no evidence of bone healing. The cause of the blade wounds to lay males from period 4 is unknown, although one is suggested to be a partial trepanation (S. Mays, *pers.comm.*) or a blade wound (J. Buckberry, *pers.comm.*). Another lay male from period 4 is suggested to have been of high status and based on the severity of the unhealed cuts to this individual's face; a violent, close-contact attack is suggested. This is also suggested for another lay male from period 4, who suffered blade wounds to the skull and femora. Although the status of this individual is unknown, he appears to have been interred with some consideration with his arms crossed neatly over his lower torso (Carver 2012). This evidence suggests that both ecclesiastics and the laity were vulnerable to violence, with those from the monastic phase being purposefully targeted for their resources and most likely, for their lack of defence capabilities. Moreover, males affected from the later lay phase at Portmahomack may have been targeted because of their importance within the parish church community.

The earliest account of Viking raids in Britain was recorded in the 9th century *Anglo-Saxon Chronicle* that mentioned the 'plunder and slaughter' of monks at Lindisfarne in 793 (Smyth 1984). There is scant documentary evidence of such raids on Scottish monasteries, although the *Annals of Ulster* recorded that Olaf of Dublin took hostages from raids on Pictish territories in 866 (Smyth 1984). There is very little conclusive archaeological evidence for Viking raids on medieval Christian sites (Edwards 1996) and even less that can correlate both archaeological and osteological evidence, as in this study. Overall, this study suggests that Christian lifeways could have been affected in severely traumatic ways across different forms of social strata, with a religious way of life offering no protection to such violence.

Evidence of a blade wound was observed on the right frontal bone of a sub-adult from Portmahomack (period 4). There are very few cases of sharp-force trauma to sub-adults from medieval Britain, although a number of cranial fractures have been reported (Lewis 2014). The majority of blade wounds to sub-adults have been observed on post-cranial bones, as at St Peter's Church, Barton-upon-Humber (Waldron 2007) and at Lincoln Castle (Curtis-Summers 2014). One exception to this was a blade wound observed on a sub-adult mandible from the Late Roman cemetery of Lankhills (Clough and Boyle 2010). The evidence of cranial sharp-force trauma to the sub-adult from Portmahomack therefore represents a rare case from the archaeological record. This individual was aged 6.6-10.5 years and may have been considered a young adult within the community. Such trauma may have been the consequence of occupational-related hazards, if children were put to work at such an age, although violence is a strong possibility. As with the adults affected from Portmahomack, this sub-adult was highly vulnerable to trauma, despite being part of a close-knit Christian lay community. Inter-personal violence occurred throughout the medieval period in Scotland, deriving from family, civil or even religious feuds

(Wormald 1980; Carver 2008; Grant 2014), hence such evidence of violence from Portmahomack is unexpected, yet unsurprising.

One important discovery from Norton was found, in the form of a peri-mortem blade wound to the right transverse processes of the 1st to 8th thoracic vertebrae on a male, aged 46-49 from the 13th century. As aforementioned, this individual is thought to be Sir Geoffrey de Dutton, who also had extensive Paget's disease and appeared to have been subjected to a violent attack. Due to the severity of the blade wound; it is unlikely that armour was worn at the time; hence this individual was not engaged in battle-related conflict (M. Loades, *pers.comm.*). The extensive pagetic thickening of a number of bones on his upper body may suggest he struggled to defend himself, subsequently sustaining severe injuries. The status of this individual, as a knight and wealthy benefactor to Norton may have resulted in this violent encounter. In contrast to Portmahomack, which was susceptible to a Viking raid and inter-personal violence, the evidence from Norton suggests an isolated case of a violent encounter. There is no documentary evidence to elucidate the cause of this attack, although violence occurred across Cheshire during this time, such as that between the king's men and the bishop's men of Chester in 1238 (Lewis and Thacker 2003) and on multiple occasions between ecclesiastics of Combermere Abbey and lay and monastic outsiders (Baggs *et al*. 1980). Moreover, legal disputes occurred on numerous occasions at Norton (Greene 1989; Brown and Howard-Davis 2008), which may have resulted in violence. This suggests that despite Christian communities striving to adhere to religious practices, their lifeways reflect a disparity between the ideal Christian life and an actual hazardous one.

Approximately three disarticulated crania from Norton were suggested to have evidence of trepanations (B. Connolly, *pers.comm.*). Although this evidence has not been found on any articulated skeletons from Norton, it does support the suggestion that some form of medical attention was given by the canons at Norton (Brown and Howard-Davis 2008). Moreover, one disarticulated trepanned cranium was found with a male burial from the 14th century. This may suggest that at least around this time, surgical procedures were being undertaken at Norton, and considering the trepanned cranium was discovered within the northeast chapel which is associated with the Dutton family, trepanations may have been performed on wealthy lay benefactors. This suggests that the canons at Norton adhered to the Rule of St Augustine that required them to care for the sick, especially those with such close connections to the Priory.

8.6 Diet and Nutrition-Related Stresses

Skeletal and dental evidence of diet and nutrition, as well as stable isotope dietary reconstructions, are discussed here to elucidate aspects of medieval lifeways that may have been affected by diet. Access to certain foodstuffs in medieval Britain was influenced by economy, climate, status and religion, with Christian feast days and rules on fasting being an integral part of medieval life. The final research question proposed in chapter 1 asked: to what extent did diet differ between communities that followed different Christian practices and in addition, are there any dietary stresses that can be specifically tied to Christian practices? Stable isotope evidence may suggest a uniform diet within Christian communities or a change in diet that reflected different Christian practices. Moreover, this evidence may support skeletal indicators of nutrition-related stress. Overall, this evidence may elucidate religious influences on different groups (men/women, young/old, ecclesiastical/lay) within Christian communities.

8.6.1 Dental Calculus

Roberts and Cox (2003) have suggested that the occurrence of calculus in early to late medieval Britain may have been caused more by a lack of oral hygiene than a protein-rich diet. Additionally, other scholars suggest that calculus is associated with a protein-rich diet and can also result in complications due to periodontal disease (Hillson 1996). A prevalence of 35% was found from the early medieval sites in Britain and 59% from late medieval sites (Roberts and Cox 2003).

From Portmahomack, prevalence of calculus was observed on males (53.4%) more than females (28.1%), although no period-specific statistical difference occurred. However, stable isotope data suggest some males were consuming more animal protein than females during lay period 4 at Portmahomack (see section 8.6.12), suggesting a gendered-division in diet. This could possibly be due to a division of labour, where males were engaging in greater levels of manual work, thereby needing adequate sustenance such as great consumption of meat. Manorial accounts from later medieval estates attest to this increase in dietary protein to sustain agricultural workers (Dyer 1988a). Sub-adults from lay periods 4 and 5 were affected by calculus (17.5%), with at least one individual affected from most age groups. Sub-adults may not have been consuming animal meat to the same extent as adults, although stable isotope results from some older sub-adults at Portmahomack suggest otherwise (see section 8.6.12).

A similar prevalence of calculus was observed between males (71.8%) and females (70.4%) from Norton, which is significantly greater than that reported by Roberts and Cox (2003) and suggests a more homogenous intake of animal protein, especially during the 14th and 15th centuries. Three sub-adults were affected (23.1%), two aged 14.6-17.0 years, which may suggest that by this age, older children were consuming meat to a similar extent as adults, supporting the idea that older sub-adults may have been regarded socially as adults and consuming foods similar to that of older individuals. During the 14th and 15th centuries an increasing number of individuals from the Dutton family were being buried at Norton. It is plausible to suggest that there was more social conformity towards religious dietary practices at both Norton and Portmahomack, although a gendered-division in diet at Norton is suggested.

8.6.2 Dental Caries

Dental caries is often associated with the consumption of foods high in sugars and fermentable carbohydrates (White and Folkens 2005), found in bread for example. Similar prevalence of caries was found on males (21.4%) and females (21.9%) from Portmahomack, with monks from period 2-3 being slightly more affected than lay males from period 4. However, statistical differences were found from period 4 males and females, with the latter affected more by carious lesions. This may suggest a gendered-division in diet, with females consuming more cariogenic foods such as bread, whereas males may have consumed less bread but more meat.

Similar sex-specific prevalence of dental caries was found on males (30.6%) and females (37.0%) at Norton across all periods. However, statistically, females were more affected by caries overall and also in the 14th and 15th centuries, again suggesting a gendered-division in diet. Only one sub-adult (2.5%), aged 6.6-10.5 from Portmahomack (period 4) had evidence of caries. Caries was also observed on three sub-adults (23.1%) from Norton, two aged 6.6-10.5 years (unknown period) and one aged 2.6-6.5 years from the 14th century.

Considering sugar was an elite foodstuff that was not widely used in Britain until the late medieval period (Woolgar 1999; Newhauser 2013), the cause of caries at Portmahomack was probably due to consuming carbohydrates such as bread and pottage, with sweeteners in the form of honey and fruits, contributing to a lesser extent. The presence of quern stones and evidence of flour production at Portmahomack (Carver 2008) attests to this. A similar situation may be suggested for those affected at Norton, with ecclesiastics consuming bread as part of their daily diet. A number of those who were considered high status at Norton had very few or even no carious lesions, although calculus was present on all but one female from the 14th century. This suggests high status lay individuals at Norton may have had a more varied diet than the ecclesiastics, including greater access to animal protein.

8.6.3 Dental Enamel Hypoplasia (DEH)

Poor nutrition or illness during childhood is suggested to be the main cause of DEH (Aufderheide and Rodríguez-Martin 1998; Larsen 1999). Because enamel cannot remodel once formed during childhood, DEH can be observed on adult dentition to identify indicators of childhood stress (Hillson 1996). From Portmahomack, DEH affected mostly males (27.2%) across all age groups, with females (9.4%) less affected overall. Males were significantly more affected than females from lay period

4 and compared to males from the earlier monastic phase. Only one sub-adult (period 4) was affected by DEH, suggesting most children from period 4 at Portmahomack had less childhood stress than adults possibly reflecting a generational shift in nutritional health during this period. Moreover, the monks at Portmahomack appear to have had better childhood health than adults from lay period 4, which may be linked to a diachronic change in weaning practices (see sections 8.6.10 and 8.6.11) or environmental factors that caused greater childhood illness during period 4. In this respect, a shift in the health of Christian communities at Portmahomack is suggested, which may be linked to religious views on childhood care and health. If oblates were accepted into the monastery and raised to a better standard than the lay children in the later phase, this may explain such disparity.

From Norton, a greater prevalence of DEH was found on females (11.1%) compared to males (9.4%), a reversal to what was found at Portmahomack. Also, males from the 14th century were more affected by DEH than males from the 15th century at Norton. This may suggest that childhood nutrition or health improved with time at Norton, possibly associated with a shift in economic resources or subsistence strategies. Although there is no evidence that the Black Death of the mid-14th century affected those at Norton, widespread economic and subsistence changes across mid-late medieval Britain (Woolgar 2010) may have subsequently affected communities like those from Norton.

Roberts and Cox (2003) reported a DEH prevalence of 18.8% from 24 early medieval sites in Britain and 35.4% from 23 late medieval sites. Prevalence from these sites however has a wide range, which is expected considering some sites are ecclesiastical or lay (or both) and some are rural or urban (*cf*. Roberts and Cox 2003). At Hull Magistrates Court, 44% of males and 40% of females were affected by DEH (Holst *et al*. 2001). Compared to DEH observed from Portmahomack and Norton, this suggests little disparity between male and female childhood nutrition and health.

It appears that a number of adults from both Portmahomack and Norton had some form of illness or stress during childhood, most notably on period 4 lay males from Portmahomack. In addition to the aforementioned suggestion of a difference in weaning practices between periods, children from Portmahomack may have had restricted diets, with their main foodstuff being cereal-based until they reached a certain age whereby their ability to work entitled them to a more protein-rich diet. This may have also been the case at Norton, although to a lesser extent; children may have had some access to terrestrial and possibly aquatic protein, especially during Christian fast days, which amounted to over 150 days of the year (Grant 1988; Fagan 2006).

8.6.4 Abscesses, Granulomas and Periodontal Disease

From Portmahomack, abscesses were observed on 19.4% of males and 6.3% of females, mostly on those aged 46-59. Monks from period 2-3 were significantly more affected by abscesses than lay males from period 4, and the latter were more affected than females from the same period. Evidence of dental granulomas was observed on 23.3% of males and 9.4% of females from Portmahomack. As with dental abscesses, a significant difference was found, with monks from period 2-3 more affected than males from lay period 4, who in turn were more affected than period 4 females. An abscess was observed on a younger child (2.6-6.5 years), and two granulomas were observed on an older child (10.6-14.5 years), both from period 4 Portmahomack. A contribution from foods that would lead to caries and subsequent abscess formation, such as bread and pottage, may be the cause of those affected, with early medieval monks being more affected by caries, abscesses and granulomas than later medieval layfolk from Portmahomack.

From Norton, only males were affected by dental abscesses (11.8%), with those from most age groups and mostly from the 14th and 15th centuries affected. A number of males (11.8%) and females (22.2%) from most age groups, across all periods, were also affected by dental granulomas. A significant difference was found between males and females affected by dental granulomas, with females having a greater prevalence. This evidence may suggest some gendered-division in diet at Norton, if the type of foods consumed were a contributory factor. The absence of both abscesses and granulomas on sub-adult dentition may suggest children from Norton were not consuming foods that exacerbated dental health or that their oral hygiene was to a sufficient standard.

Roberts and Cox (2003) reported a prevalence of 2.8% of dental abscesses from early medieval Britain and 3.2% from the late medieval period. However, there is variation between sites (*cf.* Roberts and Cox 2003), reflecting differences in diet and/or oral hygiene between communities of different social strata. The evidence from Portmahomack and Norton may therefore reflect different attitudes to the types of foods consumed, and possibly how foods were prepared by these Christian communities over different time periods. This is supported by the different prevalence of dental abscesses and granulomas between early medieval monks and later medieval layfolk at Portmahomack and between males and females at Norton.

From Portmahomack, periodontal disease affected 24.3% of males and 15.6% of females, with monks aged 46-59 from period 2-3 and lay men from period 4 mostly affected. However, females from period 4 were affected across different age groups, and were statistically found to be more affected than males from the same period. A statistical difference in dental caries was also found, revealing that females were more affected than males from lay period 4; hence a dietary factor may be suggested as a precursor for periodontal disease from this period at least. This may suggest gendered-division in diet during period 4 at Portmahomack and a more homogenous diet between monks during the earlier monastic phase. These communities on a whole however appear to have been adhering to Christian rules, such as fasting practices, but were no doubt governed by the food resources available to them and the activities needed to acquire such resources.

A low occurrence of periodontal disease was observed on males (4.7%) and females (7.4%) from Norton, mostly on those aged 36-45, across the 13th to 15th centuries. Although a significant difference for dental calculus was found between males and females at Norton, it does not appear to be the primary causative factor for periodontal disease at Norton. This suggests there were other contributory factors to the onset of periodontal disease, such as poor oral hygiene. The prevalence of periodontal disease at Norton is however lower than that found at Portmahomack, which may be associated with those of higher status at Norton having better oral hygiene. This may be linked to different perceptions on what ‘cleanliness is next to godliness' meant by different Christian communities. Many people kept clean for religious beliefs, to be closer to God for example, rather than for hygienic reasons (Rosen 1993). However, how cleanliness was perceived by one Christian community may differ greatly to another, with dental hygiene low on the agenda for some.

For periodontal disease in early medieval Britain, Roberts and Cox (2003) reported a prevalence of 27.0%, and 37.53% from late medieval Britain. As with other dental pathologies, there is wide variation between sites (*cf.* Roberts and Cox 2003), reflecting differences in social strata, cultural practices and religious influences. These factors may have influenced the types of foods consumed and the level to which oral hygiene was practiced, subsequently affecting dental health.

8.6.5 Dental Wear

Dental wear is not necessarily classed as a dental pathology and often not reported in palaeopathological literature, apart from when used as an ageing method (e.g. Boylston and Roberts 1996; Roberts and Cox 2003; Vincent and Mays 2009). However, severe wear can be associated with the onset of dental caries when the pulp cavity is exposed (Lukacs, 1989). Severe occlusal wear occurred on 43.7% of males and 18.8% of females from Portmahomack and on 32.9% of males and 29.6% of females from Norton. The most severely affected, past the cemento-enamel junction, was found on monks from period 2-3 at Portmahomack, the severity of which did not occur to the same level on adults from lay periods 1 and 4. Quern stones were recovered from Portmahomack and evidence of a water mill, dating to around the 6th to 8th century was reported, suggesting different forms of mechanical grain production at Portmahomack (Carver 2008). The evidence of severe occlusal wear on the monks' teeth suggests that coarse cereals (e.g. bread) was being consumed, whereas more refined flour was probably used by the later lay phase, resulting in less occlusal wear from that period.

Bread and ale were some of the main food staples of religious diet and at Norton; some grain was being ground on-site, although a water mill was used for more refined processing at the Priory (Greene 1989). This may suggest coarse breads were distributed to those of lower status at Norton and as alms to the poor in the community; a practice which was expected of secular canons in medieval Britain (Yorke 2006). The consumption of coarse sticky carbohydrates, such as bread, was widespread in medieval Britain, and combined with a lack of oral hygiene, this would have contributed to both severe wear and carious lesions on the teeth of individuals from both Portmahomack and Norton.

8.6.6 Stature

Stature is predetermined by genetics, although skeletal evidence of extrinsic factors, such as illness or an inadequate diet may hinder attaining optimum height in humans (Zakrzewski 2003; Roberts and Cox 2003). Assessing adult stature may be more beneficial, compared to sub-adult stature, because there is no complication associated with growth that may potentially hinder interpretations of sub-adult stature (Martin *et al.* 2013). Average male stature from Portmahomack (170cm) and Norton (173cm) is similar to national averages reported by Roberts and Cox (2003), for early and late medieval Britain, of 172cm and 171cm respectively. Both Portmahomack and Norton female average stature is 156cm, which is approximately 5cm shorter than the nation average for the early medieval period and 3cm shorter than females from the late medieval period (Roberts and Cox 2003).

Portmahomack adult average stature decreased from periods 1 to 4 (6^{th} to 15^{th} century), an overall pattern which has been found from the early to late medieval periods in Britain (Roberts and Cox 2003). A pattern of decreasing height over time has also been found within other cultural groups and has been linked to a complex hierarchical society, where nutritional resources were varied (e.g. Zakrzewski 2003). No decrease in average stature was found on Norton adults, which may suggest a homogenously adequate diet over time. A decrease in stature at Portmahomack may suggest that childhood diet during the monastic phase was better than the later lay phase, resulting in monks obtaining optimum height compared to layfolk from period 4. This is also supported by a greater prevalence of male DEH in the later lay phase, suggesting childhood illness or deficient diets occurred more so in this period, although the stable isotope data does not support the latter (see section 8.6.12). This difference in stature may be linked to a more diverse social structure during later lay periods at Portmahomack compared to the earlier monastic phase, with a shift in the types of food consumed being dependent on religious influences and social status within the community. In contrast, adults from Norton appear to have less varied stature, suggesting a more homogenous diet that may have been linked to widespread Christian dietary practices in the later medieval periods that differed to those from Portmahomack.

8.6.7 Diffuse Idiopathic Skeletal Hyperostosis (DISH)

Although the aetiology of DISH is still debated, it has been associated with type II diabetes, obesity and a rich diet, often linked to a high status or monastic way of life (Waldron 1985; Rogers and Waldron 2001). Roberts and Cox (2003) reported that DISH affected mostly males from seven early medieval (1.8%) and eighteen late medieval (3.3%) monastic and lay sites in Britain. Boylston and Weston (2002) found three males and one female were affected by DISH from the Augustinian friary at Warrington. However, based on their assumption that DISH is associated with a monastic diet and that the burials were likely to be of layfolk; no attempt was made to interpret the cause of this condition. A link between a monastic way of life and DISH was not found from a stable isotope study on lay and monastic skeletal material from nine sites in medieval Britain (Spencer 2000). Moreover, Spencer (2000) stated that the high prevalence of DISH within monastic communities is more likely to reflect an older male demographic, rather than an ecclesiastical diet, which has also been suggested in other studies (*cf*. Stroud 1993; Mays 2006b).

DISH was observed on two males (1.4%) from lay period 4 at Portmahomack and on five males (4.3%) from the 14^{th} and 15^{th} centuries at Norton, all aged 36-45 and 46-59. A monastic link to DISH can be ruled out from Portmahomack because those from the monastic phase were not affected. One male from Norton who was affected by DISH is tentatively identified as a canon, although this is not enough evidence overall to link a religious lifestyle to this condition. The cause of DISH observed on the individuals from this study may be linked to type II diabetes exacerbated by a rich diet, with certain individuals consuming noticeable amounts of animal protein, which is suggested from the stable isotope data (see section 8.6.12).

8.6.8 Gout

Gout is caused by an inflammatory reaction to sodium urate crystals and is most commonly found in middle-aged and elderly males (Rogers and Waldron; 1995; Ortner 2003; Roberts and Manchester 2005). The exact aetiology of gout is still unclear, although a genetic predisposition, diet and/or other environmental factors appear to contribute to this condition (Aufderheide and Rodríguez-Martin 1998; Ortner 2003). From the early medieval monastic cemetery at Llandough, Glamorgan, evidence of gout was found on one male, aged 36-45 (Loe and Robson-Brown 2005). Gout was also found on two males from Hull Magistrate Court (Holst *et al.* 2001). Overall, there are very few cases of gout from medieval Britain reported in the palaeopathological literature (Roberts and Cox 2003).

In this study, gout was observed on one male from 14th century Norton, aged 36-45. This condition appeared to be in a remission stage suggested by the presence of healed bone around the lesions. The presence of gout is not enough evidence alone to suggest this individual had an excessive diet. Moreover, the stable isotope data from this individual are lower than other males and females from the same period, suggesting his diet was not excessive compared to others. Additionally, the healed lesions suggest this individual may have adhered to the recommendations of a physician to refrain from consuming rich food and drink. Such recommendations were encouraged in the medieval period to restore humoral balance (Woolgar 1999; Freedman 2007); hence such positive steps may have been taken to avoid this painful condition returning. It is likely that this individual was treated at the infirmary by the canons of Norton, who would have been versed in applying medical treatments (Baggs *et al*. 1980) to ailments such as gout by applying herbal poultices, bloodletting and maybe even a controlled diet. This evidence therefore suggests that religious influence, in the form of medical care, may have had an impact on this individual.

8.6.9 Rickets

Rickets is caused by prolonged vitamin D deficiency during childhood, 90% of which is sourced from sunlight on the skin and around 10% from diet (Giuffra *et al*. 2013), although a dietary source of vitamin D is of great importance when access to sunlight is limited (Roberts and Cox 2003). Evidence of healed rickets was observed on the femora of an adult male from the medieval battlefield site of Towton, Yorkshire (Holst 2004). At Warrington friary, healed rickets was also observed, on one adult and one sub-adult (Boylston and Weston 2002), and from Wharram Percy, unhealed rickets was observed on eight sub-adults (Ortner and Mays 1989). Roberts and Cox (2003) reported a prevalence of 0.73% (n=25) from nine late medieval sites in Britain, although overall, there is scarce evidence of rickets from the medieval period. This scarcity may reflect the socio-economic situation during the medieval period, with outdoor occupations, such as farming, being prevalent; hence sufficient levels of vitamin D were maintained. Where cases do occur, consequences of keeping children wrapped in swaddling or indoors to do certain chores may have resulted in vitamin D deficiency. Examples of keeping children indoors would include oblates that would have been accepted into the monastery at a very young age and trained in prayer, script-writing and monastic chores, hence being indoors for long periods of time thereby affecting normal skeletal growth and potentially contributing to vitamin D deficiency.

From Portmahomack, one possible case of healed rickets was found on an adult male (0.7%) from lay period 4 and three cases of rickets on sub-adults (7.5%) from lay periods 4 and 5. From Norton, healed rickets was observed on four males (3.5%) from the 14th and 15th centuries and one sub-adult case of rickets (7.7%) from the 14th century. It is interesting to note that those affected from both Portmahomack and Norton date from the 14th and 15th centuries, which was a time in Britain when changes in social status and occupation was emerging, partly due to the widespread devastation of the Black Death in the mid-14th century. Workers gained more freedom to demand higher wages, and for some families, to even break away from the deep-rooted role of the peasant land-worker, allowing them to engage in different roles in manufacturing and commerce (Dyer 1988a; Woolgar 2010). Occupations in towns and monasteries, such as brewers, butchers, scribes and blacksmiths, would require workers, including children in some cases, to spend long periods indoors. As aforementioned, this would result in lack of exposure to sunlight, which would be detrimental to normal bone development during childhood. A number of children at Portmahomack and Norton may have therefore had chores that required them to be indoors for long periods of time. A direct link to religious influences on these cases cannot be determined, especially on the lay individuals from Portmahomack. However, at Norton it is plausible to suggest some of the servants within the Priory may have included young children from the lay Christian community. A combination of childhood illness, dietary deficiency and lack of sunlight may have been the cause of rickets at Portmahomack and Norton.

8.6.10 Scurvy

Scurvy is caused by a deficiency of vitamin C, which is found in fresh fruit, vegetables and to a lesser extent in animal foods (Ortner 2003; Mays *et al.* 2013). Two possible cases of scurvy were observed on sub-adults from Roman and early medieval levels at the Mason’s Yard site, Lincoln Castle (Curtis-Summers 2014). Scurvy was also identified on two sub-adults from the early medieval ecclesiastical site of Inchmarnock, southwest Scotland (Henderson 2008). Overall, there is a low occurrence of scurvy throughout medieval Britain, suggesting that either access to fresh foods was adequate (Dyer 1989; Roberts and Cox 2003; Henderson 2008), or that skeletal changes have been misdiagnosed as other conditions, such as cribra orbitalia (Roberts and Cox 2003). From Portmahomack, scurvy was identified on two monks (1.4%) from period 2-3 and on six sub-adults (15%), aged 0-1 years from lay periods 4 and 5. One possible case of scurvy was also observed on a sub-adult, aged 1.1-2.5 from 14th century Norton. The prevalence of scurvy on new-born’s from Portmahomack and on the sub-adult from Norton may suggest a lack of breastmilk or early weaning, consequently leaving some children from these Christian communities more susceptible to nutritional illness (see section 8.6.11). Overall, the prevalence of scurvy from this study is low, which suggests the majority of people from Portmahomack and Norton had diets adequate in vitamin C, a number of which were homogenous and appear to conform to Christian dietary practices (see section 8.6.12).

8.6.11 Cribra Orbitalia and Porotic Hyperostosis

Cribra orbitalia (CO) and porotic hyperostosis (PH) manifest as porosity on the orbital roof and outer cranial vault respectively, with iron-deficiency anaemia often suggested to be the cause (Stuart-Macadam 1985; Roberts and Manchester 2005). However, recent studies suggest that vitamin B_{12} deficiency during infancy, with nutrient losses from gastrointestinal infections, is more likely the cause (Walker *et al.* 2009). Prevalence of CO has been presented from a number of medieval sites in Scotland, such as Inchmarnock (37%) (Henderson 2008), Chapelhall, Argyll (no perentage, n=1) (Roberts 2000) and at Whithorn Cathedral Priory (30%) (Cardy 1997). From England, prevalence for CO was calculated for males, females and sub-adults respectively at Hull Magistrates Court (8%, 17%, 27.5%) (Holst *et al*. 2001), Fishergate (17%, 37%, 64%) (Stroud 1993) and at Blackfriars (10%, 15%, 10%) (Wiggins *et al.* 1993). Roberts and Cox (2003) reported a prevalence of 7.6% (n=404) for early medieval Britain and 10.82% (n=640) from late medieval Britain.

From Portmahomack, CO was observed on three males (2.2%), including one lay male from period 1 and on two monks from period 2. CO was also observed on five sub-adults (12.5%) from lay period 4, yet no adults from this period were affected. From Norton, CO was observed on eight (7.0%) males from the 12^{th} to 15^{th} centuries, and on four (30.8%) sub-adults from the 14^{th} century. PO has been observed on three sub-adults from St Andrew, Fishergate (Stroud 1993), one adult female from Chapelhall, Argyll (Roberts 2000) and on an adult male from the Mason's Yard, Lincoln Castle (Curtis-Summers 2014). From Portmahomack, PO was observed on one sub-adult from lay period 4, and on seven males (6.1%) and one sub-adult (7.7%) from the 14^{th} and 15^{th} centuries at Norton.

The presence of CO and PO on individuals from Portmahomack and Norton suggests they were susceptible to poor nutrition and/or infections, such as exposure to polluted water, affecting the gastrointestinal tract. However, whether this resulted in iron-deficiency anaemia cannot be determined in this study. A greater number of individuals from Norton however were affected, compared to Portmahomack. This may suggest they had greater exposures to environmental pollutants and infections, possibly due to living near a large ecclesiastical centre, with its environs equating more to a suburban population than the remote coastal community at Portmahomack.

Evidence of childhood nutritional stress or illness from Portmahomack and Norton may be linked to weaning practices. During the medieval period in Britain, people followed the recommendations of Greco-Roman physicians, such as Galen and Soranus, to wean children off breastmilk around 2-3 years of age (Fildes 1986). However laborious tasks performed by mothers may have influenced their weaning practices. For example, Sellen and Smay (2001: 71) stated that the "maternal work pattern" hypothesis predicts that earlier weaning will occur where mothers are separated from their children for long periods of time whilst working. There is evidence for this in 14th century England, where children of the lower classes were left alone whilst the mother was working (Hanawalt 1977). Even if mothers took their children into the field, they would not have much time or energy to breastfeed them (Fildes 1986), which would encourage working mothers to wean as quickly as possible. The nutritional and immunological protection of breastmilk is vital to the new-born child (Lewis 2007); providing benefits against diarrhoeal pathogens, caused by poor hygiene (Katzenberg *et al*. 1996). It may be plausible to suggest that some females from Portmahomack and Norton may have weaned their children off breastmilk early, to return to work. For example, engaging in outdoor chores, such as farming, or within the Priory (at Norton), would have meant females worked for long hours, subsequently resulting in early weaning; a possible consequence of contributing to their Christian community. Future isotope studies on sub-adult bone from both sites, to reconstruct weaning ages, may elucidate this.

8.6.12 Stable Isotope Evidence of Diet

Evidence from stable carbon and nitrogen isotope analysis, presented in chapter 7, is compared to isotope studies from a selection of sites in Europe and discussed here to provide a greater understanding of diet within medieval ecclesiastical and lay communities.

8.6.12.1 Faunal Diets

All faunal samples from Portmahomack and Norton have $\delta^{13}C$ and $\delta^{15}N$ values that are consistent with those from the British Holocene (Müldner and Richards 2005, Richards *et al.* 2006; Jay and Richards 2007). The results reflect natural variation in isotope values for aquatic species, and a predominantly C_3 diet for domestic terrestrial herbivores, with no C_4 component. However, $\delta^{15}N$ variation is evident from some terrestrial species. For example, one cattle sample from lay period 4 at Portmahomack had a $\delta^{15}N$ value greater than cattle from monastic period 2-3, reflecting a trophic level increase. This difference was also found when compared to cattle data from other sites, including Newark Bay (Barrett and Richards 2004), East Lothian (Jay and Richards 2007) and Kirkhill, Fife (Modzelewski 2008). Isotope data for cattle from Norton revealed a slight variation in $\delta^{13}C$ and $\delta^{15}N$ values, although not to the extent that would deviate from a typical C_3 terrestrial herbivore diet.

From lay period 4 at Portmahomack, red deer had elevated $\delta^{15}N$ values compared to roe deer, suggesting a varied grazing pattern from a range of habitats including upland, lowland and possibly even coastal areas. The single red deer sample from Norton had similar $\delta^{13}C$ values to those from Portmahomack and slightly lower $\delta^{15}N$ values. Overall, these results were within normal variation, suggesting a C_3 herbivore diet typical of that found from the British Holocene (e.g. Jay and Richards 2007).

As with other herbivore results in this study, sheep/goat isotope data for Portmahomack and Norton reflect a diet of C_3 plants, with no input from C_4 vegetation. However, there is wide variation in $\delta^{15}N$ values, from lay period 4 at Portmahomack and between periods at Norton, reflecting a trophic level difference. For example, there is wide variation between one 15th century sheep sample and one from the 14th century of $\Delta^{15}N_{max-min}$ 3.2‰, reflecting a trophic level difference. As with cattle, such variation may suggest different feeding strategies over time or consuming plants that may have elevated $\delta^{15}N$ values, although more samples would need to be analysed to further investigate this variation. Sheep/goat may have been brought to the sites from other geographical areas, hence variation in $\delta^{15}N$ values. Such variation also been found at Wharram Percy and St Giles, with data from the latter revealing a trophic level difference in sheep $\delta^{15}N$ values (Müldner and Richards 2005). Differences in regional resources and socio-economic practices may account for variation in herbivore isotopic values. For example, the Dornoch Firth and Morrich More, located to the west of Portmahomack, have some of the most extensive areas of salt marsh in Britain (The Joint Nature Conservation Committee 2009). Coastal salt-marshes are suggested to have been more extensive in the past than they are today (Britton *et al*. 2008). Therefore, herbivores from Portmahomack may have grazed on fodder from the nearby coast, resulting in increased $\delta^{15}N$ values. Moreover, $\delta^{15}N$ values in chaff and cereal straw are suggested to be lower and more variable than in grain (Bogaard *et al.* 2007), which may also account for differences in herbivore $\delta^{15}N$ values. This evidence may reflect different animal husbandry strategies between different religious centres, with Norton for example, having a greater amount of land than the monastic estate at Portmahomack; hence different feeding strategies may have been adopted.

Pig samples from lay period 4 at Portmahomack had higher $\delta^{15}N$ values compared to those from monastic period 2-3, suggesting a diachronic change in the types of foods consuming in the later lay phase. There is also wide variation in pig $\delta^{15}N$ values from the pre-dissolution group at Norton, with a trophic level increase between some samples. The period for this group is unknown, which may explain such variation, especially if pigs were consuming human food waste from different periods, where human diets may have differed. Alternatively, some pigs may have been raised in different geographical regions or were possibly wild woodland pigs. This is suggested from historical records that state the Baron of Halton (1190-1211) granted the canons at Norton to keep their pigs with his '…demesne swine in all my woods…' (Greene 1989: 53). However, $\delta^{13}C$ values are not divergent enough to suggest a canopy effect, which results in less enriched $\delta^{13}C$ values (van der Merwe 1982). The $\delta^{15}N$ data from a bear sample at Norton is similar to that of the pigs, although more enriched in $\delta^{13}C$ values. Although the natural habitat of bears in medieval Europe was woodland (Brown and Pluskowski 2011) this enrichment in $\delta^{13}C$, compared to pigs from Norton, does not suggest a canopy effect. However, further studies on similar woodland species would be needed to confirm this.

One dog sample from lay period 4 at Portmahomack had $\delta^{13}C$ and $\delta^{15}N$ values that were closer to that from the earlier monastic phase, both of which were similar to isotope data of dogs from Broxmouth, East Lothian (Jay and Richards 2007). However, isotope data for a second dog sample from lay period 4 was noticeably different from its counterpart in $\delta^{13}C$ and $\delta^{15}N$ values (see section 7.4.2.1.5), reflecting isotope values closer to that of humans from lay period 4. Omnivorous terrestrial species from Portmahomack and Norton were consuming a range of foodstuffs, some which may have included meat and possibly fish or shellfish from human waste or scavenged from the coastline; a similar pattern which has been suggested in other isotope studies (Richards *et al*. 2006; Kosiba *et al.* 2007). The variation in omnivore isotope values suggests that these animals were left to feed freely around the ecclesiastical estates of Portmahomack and Norton. In some cases, as with pigs from Norton, animals were managed through reciprocal agreements with Baronial estates, attesting to economic as well as religious relationships between ecclesiastics and the laity.

The majority of herbivores and omnivores from monastic period 2-3 at Portmahomack have lower $\delta^{15}N$ values than those from lay period 4, which may be due to a different socio-economic strategy, with herbivores from the monastic phase being confined to inland grazing and omnivores reflecting a diachronic change in human diet. Salt marsh areas are also present along the River Mersey (Natural England 2013), which during the medieval period reached the boundaries of Norton (Greene 1989). It is therefore plausible to suggest herbivores grazed near these salt marsh areas, which may account for the enrichment in some herbivore $\delta^{13}C$ and $\delta^{15}N$ values.

The greatest prevalence of faunal remains was from cattle bones at both Portmahomack and Norton followed by pig and sheep/goat bones (Greene 1989; Seetah 2011). One exception was from lay period 4 at Portmahomack, where fish bones predominated, followed by cattle, dog, sheep/goat and pig bones (Seetah 2011). This supports the human isotope data from various periods at Portmahomack and Norton (see sections 8.6.12.2 and 8.6.12.3). The principal component of herbivore diet was from C_3 plants, although isotopic variation suggests differences in feeding patterns, which has been reported at other medieval sites in Britain (e.g. Müldner and Richards 2005, Richards *et al.* 2006). As aforementioned, this evidence may be linked to variation in animal husbandry practices between different Christian communities, which may be related to the resources available and the usages of these animals. For example, a preference for beef during the monastic phase at Portmahomack, then a shift to fish consumption in the later lay period may have resulted in a change of animal husbandry strategies, possibly related to a shift in religious fasting practices, therefore meeting the needs of these Christian communities.

Although there is slight variation in aquatic isotope data from this study, it is not to the extent that would suggest atypical results. From Portmahomack, freshwater fish have similar $\delta^{13}C$ and $\delta^{15}N$ values, the latter of which is similar to terrestrial omnivore values from this study. However, freshwater isotope values can be hugely diverse, even more so than in marine ecosystems (Fry 2006; Sharp 2007), depending on the species and environment. Average $\delta^{13}C$ and $\delta^{15}N$ values for freshwater fish (pike) from the Dominican Priory at Beverley (Müldner and Richards 2005) reflected more than one trophic level increase compared to freshwater fish data from this study, attesting to such isotopic variation. Until the late medieval period, freshwater fish was reserved for those of high status, including religious houses (Dyer 1988b; Woolgar 1999; Threlfall-Holmes 2005), many of which had their own fish ponds with strict access rights (Bond 1988). Although no freshwater fish bone samples were recovered during excavation at Norton, historical evidence suggests the presence of a 'canons fishpool' where freshwater fish could be easily acquired (Greene 1989: 50).

There is some variation in $\delta^{13}C$ and $\delta^{15}N$ values for total marine fish (n=15) analysed from Portmahomack, although when divided into periods 2-3 and 4, this difference is within normal variation for marine isotope values from the British Holocene (Tauber 1981; Shoeninger and DeNiro 1984; Richards *et al*. 2006). It has been suggested that the River Mersey would have provided a rich source of fish and shellfish, to which the canons at Norton would have had easy access (Greene 1989). Despite this, only eleven fish bones were excavated from the pre-dissolution levels at Norton and only one cod bone was available for analysis at the time of sampling for this study. Marine fish bone samples from medieval Chester Cathedral were therefore analysed to provide a marine isotopic baseline for which to compare human diets from Norton. A number of Chester cod samples had similar $\delta^{13}C$ values to that of the Norton cod sample. However, there was a noticeable amount of variation in both $\delta^{13}C$ and $\delta^{15}N$ values for the Chester fish samples, with some being a whole trophic level apart. Overall however, isotope data from the marine mammal and fish samples from

Portmahomack, Norton and Chester Cathedral reflect natural variation and are consistent with those from other British sites, such as Newark Bay, Orkney (Richards *et al*. 2006), East Lothian (Jay and Richards 2007), Wharram Percy and Beverley Priory (Müldner and Richards 2005). This reflects the variation in the types of aquatic foods consumed between ecclesiastical sites, which may be related to the resources available and also to different interpretations of how to adhere to Christian fasting practices.

Fish consumption in Britain increased after the 8th century, due to population growth, an increase in the fishing trade and a rising demand for fish to replace meat on fast days (Barrett and Richards 2004; Fagan 2006). In contrast to freshwater fish, which was usually reserved for high status tables, marine fish was available across all social strata. A range of fresh marine fish was available to those of high status, especially those who lived near the coast; whereas preserved fish were available to those who lived inland. In the mid-late medieval period, the increased popularity of salted fish resulted in greater access to the peasantry, who could not afford fresh fish. This enabled Christians in medieval Britain to follow the Rule of fasting and when possible, consume fish instead of meat on fast days, which the Church encouraged, to promote the Christian faith and strengthen social cohesion (Woolgar 1999, 2000; Jotischky 2011).

8.6.12.2 Human Diets: Portmahomack

Compared to faunal $\delta^{15}N$ values in this study, average human isotope data from Portmahomack reflects a trophic level increase above herbivores and pigs, by at least +3‰, although in some cases, by up to around +6‰. For example, the average $\delta^{15}N$

value for adults from the monastic phase is more enriched compared to cattle by +6.1‰. Additionally, the average $\delta^{15}N$ value for adults from the lay phase is more enriched compared to sheep/goat by +7.1‰. Moreover, over half the population of adults from Portmahomack were affected by calculus, which is suggested to be caused by a protein-rich diet (Hillson 1996). This evidence suggests a significant amount of terrestrial protein such as beef, lamb, and pork was being consumed by individuals at Portmahomack. Such a pattern is expected from a self-sufficient Christian community that shared the need to maintain a steady production of food resources, whilst conforming to Christian practices relating to food consumption, especially on feast and fast days.

A gendered-division in diet is suggested between adults from lay period 1 at Portmahomack. Although no significant difference in $\delta^{13}C$ values was found between males and females from this period, male $\delta^{15}N$ values are significantly more divergent than the female data. The isotope data therefore suggests that a number of males from this period had a greater input of terrestrial protein, although no difference relating to age was found in this group. Moreover, no evidence of caries was found on adults from this period, although males had a greater prevalence of calculus than females. This evidence may suggest a gendered-division in diet, either because of social norms or a necessity for males to consume greater amounts of animal protein for sustenance, due to divisions in labour. It is not known what religious practices this early lay group at Portmahomack would have followed; therefore any association with religious influences on diet cannot be affirmed.

Overall, the majority of adults from lay periods 4 and 5 at Portmahomack are more enriched in both $\delta^{13}C$ and $\delta^{15}N$ values than adults from lay period 1 and those from monastic period 2-3. For $\delta^{13}C$, this most likely reflects an input of marine protein, rather than C_4 foods, such as sugar, which is not native to Britain and was only available to high status households from the late medieval period (Woolgar 1999; Newhauser 2013). It has been suggested that increased $\delta^{13}C$ values in herbivores reflects seaweed consumption (Balasse *et al*. 2006, 2009). However, the $\delta^{13}C$ values for cattle from Portmahomack are closer to those for average terrestrial C_3 plant data (26.5‰), which is also reflected in the human diets. Additionally, compared to the marine fish isotope data, a number of adults from lay period 4 are more enriched in $\delta^{15}N$, supporting the suggestion of marine fish consumption during this period. There is isotopic variation however within the lay period 4 individuals, with $\delta^{13}C$ and $\delta^{15}N$ values from six adults being similar to those from periods 1 and 2-3, which may suggest that they were not consuming the same types of food as the majority of adults from lay period 4. Interestingly, two males from this group were aged 18-25, which may indicate that their isotope values are reflecting a childhood dietary signature. Trabecular bone turnover rates are greater in children than in adults at 35%/yr and 18%/yr respectively (Valentin 2003). Moreover, rib bone was analysed from these two individuals, which can reflect an individual's diet from at least the last 10 years of life (Libby *et al*. 1964; Stenhouse and Baxter 1979). Therefore, it is plausible that the isotope data from these two individuals reflects a childhood diet. However, two other males aged 18-25 from the same period are more enriched in $\delta^{15}N$ to the extent of a whole trophic level increase. This attests to the variation that can occur within a community, although it also highlights the importance of considering bone turnover rates when interpreting stable isotope data. Failure to identify such issues in bioarchaeology, as well as those concerning social versus biological age, may result in misinterpreting the lifecourse of past people (Pearson *et al.* forthcoming). Overall, the majority of adults from lay period 4 are noticeably enriched in $\delta^{13}C$ and $\delta^{15}N$ compared to earlier periods, reflecting a diachronic change in diet with the introduction of marine foods by this time. The increase in fish consumption during the later lay phase at Portmahomack coincides with growing populations and an increase in the fish trade, probably connected to the growing widespread adherence to Christian fasting practices in Britain (Barrett and Richards 2004). This evidence may therefore reflect a shift in religious dietary influences over time at Portmahomack, from that of Irish origin during the early medieval monastic phase to one that possibly followed the Benedictine Rule of fasting during the mid-late medieval lay phase. The lack of fish in the monks' diet at Portmahomack is also in stark contrast to other isotope studies from later medieval monastic sites, which is discussed further in section 8.6.12.4.

There is a slight enrichment of $\delta^{15}N$ with increased age from the monastic period at Portmahomack, with those aged 60+ statistically more enriched than those aged 18-25, although as aforementioned; this difference may be due to variation in bone turnover rates. An overall homogeneous diet is suggested from this period, which is to be expected from a monastic community, where diet was influenced by the church. The Benedictine Rule of fasting may not have been followed by the monks at Portmahomack, although it is suggested to have been introduced by St Wilfrid to Lindisfarne in the early 8th century (Charles-Edwards 2002). Early medieval Portmahomack and Lindisfarne were both daughter houses of Iona (Yorke 2006) that revealed little archaeological evidence of fish consumption (Carver 2008; O'Sullivan

2001). It is therefore possible to suggest monks at Portmahomack were following an early form of the Benedictine Rule of fasting or one based on early Irish penitentials that did not require meat to be replaced with fish on fast days. However, early medieval texts suggest that foregoing the consumption of dairy was not compulsory on fast days, so some animal protein may have still been consumed (Frantzen 2014). One caveat to note here is that the consumption of dairy and meat protein from the same animal cannot be distinguished isotopically (O'Connell and Hedges 1999). As well as cattle being used for meat consumption, dairy farming was practiced at Portmahomack, based on the mortality pattern of cattle (Seetah 2011). Marine and freshwater fish bones have been recovered from monastic levels at Portmahomack, although in scant quantities compared to the later lay phase (Seetah 2011). This evidence, along with the isotope data, suggests that aquatic protein was not consumed, at least not in significant quantities, during the monastic phase at Portmahomack. However, one monk from period 2-3 had $\delta^{13}C$ and $\delta^{15}N$ values that are more similar to adults from lay period 4. It is plausible to suggest this individual was a senior monk, thereby having privileged rights to aquatic foods that were not afforded to the majority of the monastic brethren. Alternatively, he may have originated from another geographical region where eating fish was more common, although overall, fish consumption was rare in early medieval Britain (Barrett and Richards 2004; Fagan 2006).

One sub-adult, aged 10.6-14.5 years, from the monastic phase at Portmahomack had a $\delta^{13}C$ value that was identical to the male average data for that period and minimal difference compared to male average $\delta^{15}N$ values ($\Delta^{15}N_{max-min}$ 0.4‰). This suggests the child's diet was almost identical to that of the monks from this period. Moreover, this individual may have been offered to the monastery as an oblate, thereby adopting a monastic diet. However, although the practice of accepting oblates was common at most medieval monasteries (Mays 2006b), no other sub-adult burials were found from this period (Carver 2008). This suggests that oblates either survived into adulthood or that this practice was rarely adopted, if at all.

No significant isotopic difference in diet relating to sex was found from the later lay phase at Portmahomack. Additionally, no significant difference relating to age was found between females from this period. However, a significant difference was found between some lay male age groups from period 4, most notably those aged 26-35. From this age group, average $\delta^{13}C$ and $\delta^{15}N$ values were more enriched than those aged 46-59, and their average $\delta^{15}N$ values were significantly higher than males aged 18-25. This may suggest a labour-division in diet, where those aged 26-35 required more terrestrial protein in their diets to sustain them during work. As aforementioned, those aged 18-25 may have isotope values that reflect their childhood diets, hence the lowest average $\delta^{15}N$ value of males from period 4. The two adults from period 5 had isotope values that were closer to a group of individuals from period 4 that had low $\delta^{13}C$ and $\delta^{15}N$ values and to those from the earlier monastic phase. This is interesting to note, considering the adults from period 5 are thought to be Minister William Mackenzie and his wife. Their diets therefore reflect some differentiation in the types of foods consumed during the lay phases at Portmahomack, which may have been influenced by religious practices, with some individuals choosing to consume freshwater fish instead of marine fish or foregoing all animal protein consumption on fast days, for example.

Average $\delta^{13}C$ and $\delta^{15}N$ values for sub-adults from period 4 are almost identical to adults from the same period, with only slight variations between average male and female isotope data. Compared to the aforementioned group of lay adults that have isotope values more similar to monks from period 2-3, lay sub-adults from period 4 are more enriched in both $\delta^{13}C$ and $\delta^{15}N$, by a whole trophic level in at least four individuals. This suggests that some sub-adult diets may have included more marine protein than a number of adults from the same period. Moreover, one sub-adult is greatly enriched in both $\delta^{13}C$ and $\delta^{15}N$ compared to the other sub-adults and compared to a large majority of adults, by a whole trophic level in some cases. Sub-adults sampled in this study for isotope analysis were aged between 10.6-14.5 and 14.6-17.0 years. Combined with the isotope data, this may suggest that some sub-adults either belonged to higher status lay families or engaged in work, hence consuming greater amounts of terrestrial and marine protein. This may reflect attitudes towards children within Christian communities, for example, children were deemed ready for work by the age of 12 years, hence needing greater sustenance than younger children (Mate 2006; Hamilton 2011). These results attest to the importance of considering sub-adults in stable isotope studies, to understand attitudes towards children from medieval Christian communities and to reconstruct aspects of food consumption across the whole lifecourse and not just during adulthood (Pearson *et al*. forthcoming).

8.6.12.3 Human Diets: Norton Priory

Compared to faunal $\delta^{15}N$ values, human isotope data from Norton reflects a trophic level increase above herbivores and pigs, by at least +3‰. Human $\delta^{13}C$ values compared to those of fauna suggest a diet consisting of predominantly C_3 foods and enrichment towards marine values. This suggests terrestrial foods such as beef, lamb, and pork were being consumed, as were marine and probably freshwater fish. Overall, it appears adults from Norton had a homogeneous diet across most periods, although there are variations within. From the 12th and 13th century, adult $\delta^{13}C$ and $\delta^{15}N$ values are very similar and although there is slight variation between adults and between age groups from the 13th century, it is not to a significant level. This probably reflects the uniformity of food consumption at the early phases of the Priory, where the majority of burials were male, possibly of ecclesiastical status.

Similar to isotope data from the previous century, adult $\delta^{13}C$ and $\delta^{15}N$ values from the 14th century have no wide variation and no significant differences between age groups or between male and female data. Additionally, there was no significant difference in the diets of those of supposed ecclesiastical and high status layfolk, compared to the average isotope values from each period, again attesting to a fairly homogeneous diet at Norton. However, there is a significant difference in $\delta^{13}C$ values between adults from the 13th and 14th centuries, with individuals from the 13th century more enriched in $\delta^{13}C$. This may suggest that either people were consuming more marine foods in the 13th century or that adults from the 14th century were consuming different types of fish, hence the variation. This may also be linked to the community from 13th century Norton following certain religious influences on the types of fasting foods consumed that may have altered by the 14th century. The enrichment in $\delta^{13}C$ for those from the 13th century is unlikely to be attributed to C_4 foods such as sugar, due to it being widely unattainable to households in Britain during this period. As aforementioned, cattle at Norton may have been fed on fodder that included seaweed, thereby increasing $\delta^{13}C$ values (Balasse *et al*. 2006, 2009).

However, the inclusion of seaweed in the diet of cattle would need to be in significant quantities, to reflect high $\delta^{13}C$ values that are closer to aquatic values, which does not appear to be the case for cattle from Norton. Overall, it appears that the similarities in isotope values at Norton reflect a homogenous diet, influenced by social cohesion to religious practices, such as consuming fish during fast days.

Adults from the 15th century at Norton appear to have had a more varied diet than the previous periods, although not to a significant level. However, a significant difference between males and females occurred in both $\delta^{13}C$ and $\delta^{15}N$ values, suggesting that males were consuming greater quantities of terrestrial and marine protein than females. C_4 foods such as sugar cane was still extremely rare in 15th England, which suggests that the prevalence of caries at Norton was most likely caused by consuming foods such as bread, cereals, honey and fruits, rather than sugar. However, the consumption of sugar by those of high status, such as abbots or wealthy benefactors, cannot be ruled out. A number of males that have high $\delta^{13}C$ and $\delta^{15}N$ values from this period were buried in the Dutton family chapel, suggesting lay individuals of high status. However, there is wide variation from this period, with other individuals also buried in the chapel having low isotope values in comparison. Generally, a diet similar to earlier periods is suggested for those from the 15th century, although a greater inclusion of marine fish is apparent in some male diets. By the early 16th century at Norton, it appears that ecclesiastics and layfolk were still adhering to a religious diet, with terrestrial foods that befitted their status and the inclusion of fish to replace meat on fast days. Historical evidence supports this in the form of visitation documents (AD 1524), which recorded canons at Norton confirming that the Augustinian Rule was being observed (Greene 1989). A change in diet at Norton may have only occurred following the Reformation, when religious fasting practices were modified to reflect greater social and political influences on diet, such as the abolition of holy feast days by King Henry VIII in 1536 (Smith 2012).

Overall, a fairly homogeneous diet at Norton is suggested, consisting of C_3-based cereals used in bread and pottage and terrestrial protein, such as beef, lamb and pork. Moreover, it has been suggested that there is little evidence from Norton for dairy farming before the mid-16th century and that meat was the primary use for cattle (Greene 1989). Isotopic variation does occur, especially between the 13th and 14th centuries and between males and females from the 15th century, suggesting a number of individuals had greater access to terrestrial and marine protein. This is however expected from the complex community that was associated with Norton, including ecclesiastics, wealthy lay benefactors and Priory workers (including peasants). In contrast, individuals at Portmahomack had a more noticeable diachronic change in diet over time, which is supported by a number of other isotope studies, which will be discussed in the next section.

8.6.12.4 Human Diets: Site Comparisons

Isotope data from a selection of medieval archaeological sites in Europe are presented here to provide comparisons to the Portmahomack and Norton isotope results. When isotope data from Portmahomack is compared to data from early-mid medieval sites (4th to 12th centuries), a pattern emerges that supports the suggestion of a diachronic change in diet from the Iron-Age to late medieval periods in Europe (e.g. Barrett *et al.* 1999, 2001; Barrett and Richards 2004; Müldner and Richards

2005; 2007a; 2007b; Richards *et al.* 2006). Average $\delta^{13}C$ values from periods 1 (lay) and 2-3 (monastic) at Portmahomack reflects similar results to those from the Pictish sites of Lundin Links, Fife (Modzelewski 2008) and Westness, Orkney (Barrett and Richards 2004), the Anglo-Saxon sites of Belle Vue, York (Müldner and Richards 2007a) and Berinsfield, Oxon (Privat *et al.* 2002), and from the Viking sites of Dublin, Ireland (Knudson *et al.* 2012) and Birka, Sweden (Linderholm *et al.* 2008) (Figure 8.3). Overall this data reflects a predominantly C_3 terrestrial-based diet, with significant levels of animal protein intake. This supports evidence that a noticeable increase in fish consumption did not occur until the mid-medieval period, influenced by a growing population, deep-sea fishing and widespread adherence to Christian fasting practices (Barrett *et al.* 2004; Barrett and Richards 2004).

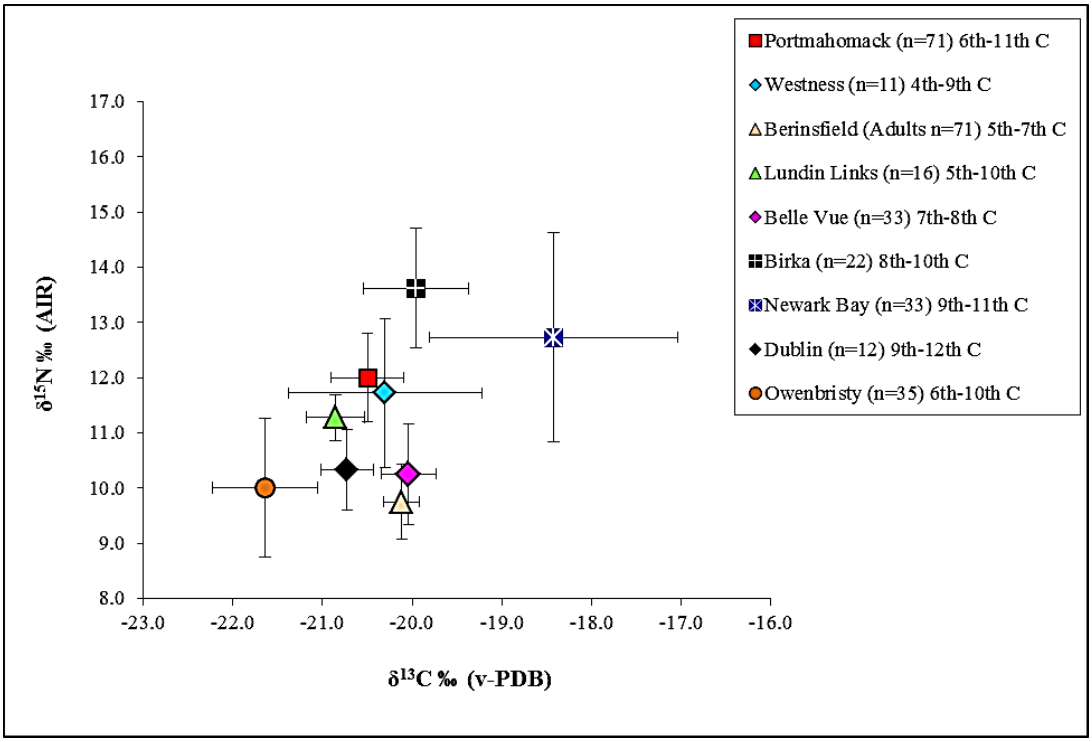


Figure 8.3: Average human $\delta^{13}C$ and $\delta^{15}N$ values from sites comparable to early medieval Portmahomack (periods 1-3).

Isotope results from Westness have been interpreted to suggest that some marine protein was consumed, although the dominant form of subsistence during the Pictish phase was arable and pastoral farming (Barratt and Richards 2004). Average $\delta^{15}N$ values from Westness (Barrett and Richards 2004) and Lundin Links (Modzelewski 2008) are closest to those from periods 1 (lay) and 2-3 (monastic) at Portmahomack. However, despite these being coastal sites, the isotope data does not reflect a significant input in marine consumption. The lack of fish consumption in these early periods may suggest these coastal dwellers either did not have the means to exploit marine resources or chose not to do so. This may reflect dietary regimes within Christian communities that preceded widespread adherence to the Benedictine Rule on fasting, when fish as a meat replacement became popular. In comparison to the early periods at Portmahomack, the sites of Berinsfield (Privat *et al.* 2002), Belle Vue (Müldner and Richards 2007a), Dublin (Knudson *et al.* 2012) and Owenbristy, Co Galway (Geber 2010), all have lower $\delta^{15}N$ values, with Owenbristy having the lowest $\delta^{13}C$ values, suggesting a diet that consisted of predominantly vegetation, rather than meat (Geber 2010). Owenbristy has been suggested to be an ecclesiastical site (Lehane and Delaney 2010), hence the predominant cereal-based diet there may reflect Irish religious influences that in some cases involved strict fasting regimes, following that of St Columbanus, for example (Fraser 2009).

Overall, the isotope values from these sites are within the same trophic level as those from periods 1 (lay) and 2-3 (monastic) at Portmahomack. Those with low $\delta^{15}N$ values suggest predominant consumption of C_3 plants, such as barley and wheat, with some terrestrial animal protein. However, at Dublin and Berinsfield, some inclusion of fish consumption is suggested (Knudson *et al*. 2012; Privat *et al*. 2002).

Two sites that stand out the most compared to periods 1-3 at Portmahomack are the Viking sites of Birka and Newark Bay (Linderholm *et al.* 2008; Barrett and Richards 2004). Birka has the highest average $\delta^{15}N$ value, which reflects people of high status consuming freshwater fish, rather than marine fish and vice versa for those buried with weapons (Linderholm *et al.* 2008). Newark Bay has the most enriched $\delta^{13}C$ values, which reflects high marine protein intake (Barratt and Richards 2004), more so than all other comparable sites from the early medieval period. Interestingly, those of closest geographical location and date to Portmahomack (Westness and Lundin Links) appear to have very similar diets of predominantly terrestrial foods but no fish consumption (Barratt and Richards 2004; Modzelewski 2008), despite their coastal location. This pattern may reflect religious influences on the diets of Christian communities in northeast Scotland around this time, possibly from an amalgamation of strict dietary regimes from Ireland and emerging influences from the Roman church, via monasteries such as Lindisfarne.

The isotope values from the Irish (Owenbristy and Dublin) and English (Belle Vue and Berinsfield) sites appear to reflect different types of terrestrial foods consumed compared to periods 1 (lay) and 2-3 (monastic) at Portmahomack, with perhaps lesser amounts of terrestrial animal protein consumed (Müldner and Richards 2007a; Privat *et al.* 2002; Geber 2010; Knudson *et al.* 2012). The Viking sites of Newark Bay and Birka however, stand out as having a significant amount of fish in their diets (Barrett and Richards 2004; Linderholm *et al.* 2008), attesting to the isotopic variation from early-mid medieval sites in Europe. These comparisons are interesting to note, especially considering those from the monastic phase at Portmahomack did not appear to consume any, or negligible amounts of marine protein. The monks at

Portmahomack appear to have had diets that were similar to those from nearby Pictish sites, consisting of predominantly C_3 plants and terrestrial protein. This suggests that the monks from Portmahomack did not follow the practice of replacing prohibited meat with fish on fast days, which became a widespread practice in later medieval Britain (Woolgar 1999, 2000; Jotischky 2011).

In contrast to earlier periods at Portmahomack, isotope results from Period 4 (lay) reflect a significant increase in marine consumption, with $\delta^{13}C$ values reflecting this shift. Average $\delta^{13}C$ values from lay period 4 Portmahomack and from all periods at Norton, both of which being contemporaneous, are similar to Newark Bay, Orkney (Barratt and Richards 2004), St Andrew Priory, Fishergate, York (Müldner and Richards 2007b), and the high status group at Whithorn Cathedral Priory (Müldner *et al.* 2009) (Figure 8.4). There are marked differences in $\delta^{15}N$ values, at Koksijde, Belgium (Polet and Katzenberg 2003) and most notably at Owenbristy (Geber 2010). Owenbristy has an average $\delta^{15}N$ value that is a whole trophic level below those from period 4 Portmahomack ($\Delta^{15}N_{max-min}$ 4.4‰), and 12^{th} to 16^{th} centuries at Norton ($\Delta^{15}N_{max-min}$ 3.0‰). As seen from the earlier period at Owenbristy, a diet with little meat consumption may reflect strict Irish Christian dietary regimes amongst the ecclesiastical community.

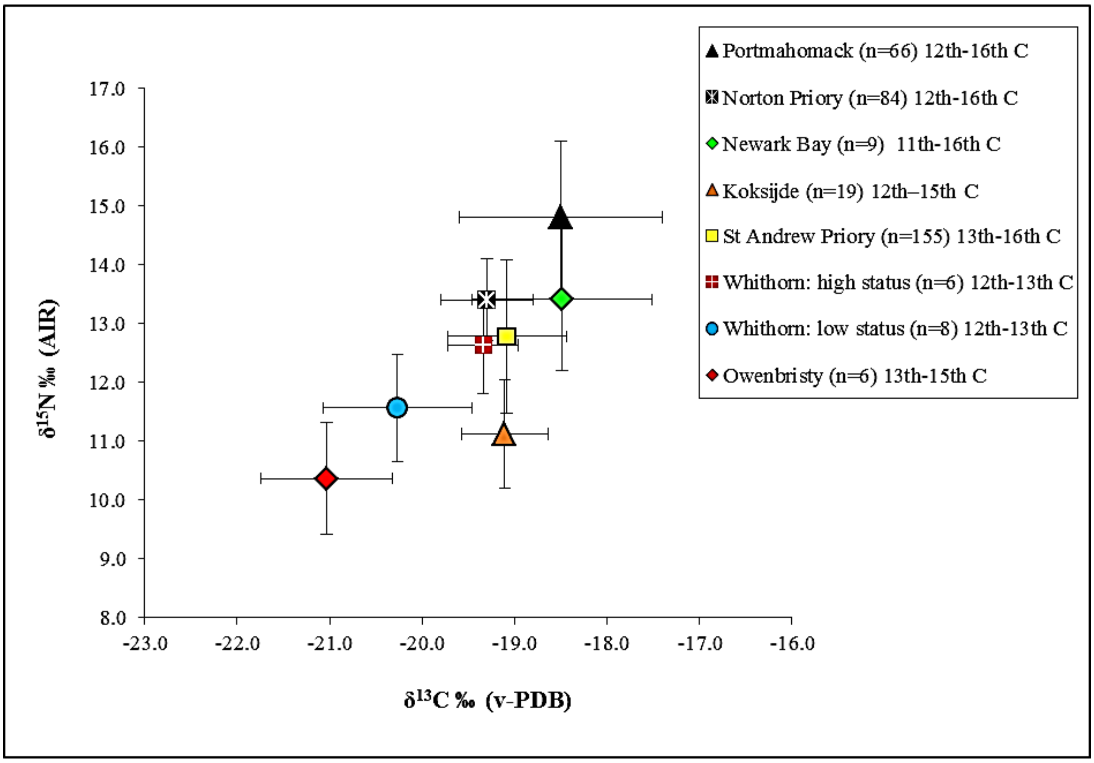


Figure 8.4: Average human δ^{13}C and δ^{15}N values from sites comparable to mid-late medieval Portmahomack (period 4) and Norton Priory (12^{th}-16^{th} century).

Isotope data from Newark Bay has been suggested to reflect significant amounts of marine consumption, resulting in a 'strong marine spike' (Barratt and Richards 2004: 264). From St Andrew Priory, the isotopic data has been suggested to reflect 'varying amounts' of marine consumption (Müldner and Richards 2007b: 168). Isotope results from Whithorn Cathedral Priory appear to reflect greater amounts of marine protein in the diets of high status ecclesiastics compared to low status layfolk (Müldner *et al*. 2009). Compared to all the sites presented here, lay period 4 at Portmahomack has the highest average δ^{15}N value overall, with an average δ^{13}C value more enriched than most sites, reflecting a significant amount of fish consumption. Average δ^{15}N values from Norton are also more enriched than some sites; most notably, Owenbristy (Geber 2010) and Koksijde (Polet and Katzenberg 2003). The δ^{13}C and δ^{15}N values from Norton are however, very similar to other religious sites, namely the high status group from Whithorn Cathedral Priory (Müldner *et al.* 2009) and St

Andrew Priory (Müldner and Richards 2007b). The religious orders from Norton (Augustinian), Whithorn (Premonstratensian) and St Andrew (Gilbertine) all followed the Rule of St Augustine. This Rule was not as strict in its dietary regime, compared to that of St Benedict; however, the isotopic similarities between these three sites attest to the general uniformity of diet within a religious community. The lay community during the 13th to 16th century at Portmahomack also followed the Augustinian Rule under the Premonstratensian order. However, the isotope enrichment from this group compared to Norton, Whithorn and St Andrew reflects greater consumption of fish, possibly reflecting different levels of religious influence on dietary practices.

These comparisons provide an overview of diet at ecclesiastical and lay sites in medieval Europe, which suggests that significant amounts of marine protein was consumed at most mid-late medieval sites, including Portmahomack and Norton. This increase in marine consumption has been associated with population growth and an increase in the fish trade, but more pertinent to this study, the widespread adherence to Christian fasting practices (Barrett *et al.* 2004; Barrett and Richards 2004; Müldner and Richards 2005; 2007a; 2007b). It is plausible to suggest that the growing adherence to fasting practices during the mid-late medieval period intensified the demand for fish; hence an increase in the fish trade occurred. The isotope evidence also suggests that the diet of monks from the early monastic phase at Portmahomack was similar to that of other sites in northeast Scotland during that time, which suggests some regional uniformity in Christian diets. Overall, human diets from Portmahomack and Norton do not appear to be deficient enough to result in severe nutritional stress, which supports the low occurrence of conditions such as rickets and scurvy. However, sub-adult dietary reconstructions are needed to provide an overall understanding of the relationship between diet and nutritional illness; results presented in this study suggest extrinsic factors, such as environment and occupation-related pollutants may have caused nutritional stress. Conversely, diets rich in terrestrial protein, which have been found in this study, may have caused or exacerbated conditions, such as calculus and DISH.

8.7 Chapter Conclusion

This chapter has discussed the bioarchaeological evidence from this study, which has included evidence for bio-cultural or familial affinity, with possible considerations for such, especially from evidence of non-metric traits at Norton. Conditions that may have been caused or exacerbated by the living environment have been presented, with occupation-, activity- or environment-related factors suggested as possible causes. Such conditions include vertebral joint disease and extra-vertebral osteoarthritis that may have been occupation-related, with some differences in the types of occupation proposed between the monks and layfolk at Portmahomack for example, and between individuals of different ages and sexes from both sites. Evidence of infections has also been found, such as rib PNB and maxillary sinusitis, suggesting respiratory disease that may have been caused by exposure to occupation-related or environmental pollutants. The presence of malignant neoplasms on a number of individuals, especially at Portmahomack, suggests vulnerability to contributory factors from the living environment. Moreover, malignant neoplasms are extremely rare in the archaeological record; hence the multiple cases found in this study provide an important contribution to our understanding of the prevalence and aetiology of cancer in antiquity.

Individual cases have been highlighted that may elucidate social or religious influences through burial practices of those with serious conditions, such as those from Norton with leprosy or Paget's disease. Trauma and conflict have been reviewed to interpret the possible cause of fractures for example, such as conflict-, occupation- or activity-related trauma. The presence of violence at Portmahomack and Norton was also evaluated from blade wound evidence on a number of individuals of both ecclesiastical and lay status. Sharp-force trauma on monks from Portmahomack represents rare cases that combine both archaeological and skeletal evidence of Viking attacks on monasteries. A cranial blade wound observed on a sub-adult from mid-late medieval Portmahomack represents the type of trauma that is scarcely found on sub-adult skeletons in the archaeological record, hence contributing to our current understanding of childhood trauma in medieval Britain.

Finally, diet and nutrition-related stresses were discussed, with evidence of childhood illness or dietary deficiency identified in some cases; DEH and scurvy at Portmahomack for example. Moreover, stable isotope data elucidated dietary evidence on the skeleton, such as the consumption of a high animal protein diet as a possible contributory factor to calculus on a number of males from Portmahomack. Overall, osteological results have revealed a number of conditions that were caused or exacerbated by the living environment (e.g. joint diseases, neoplasms, infections), from trauma or conflict (e.g. fractures and blade wounds), and from diet or nutritional-related stresses (e.g. scurvy, calculus, DEH).

Stable isotope results elucidated variations in diet that reflected differences between some age- sex- and period-specific groups. The isotope data revealed a change in diet over time at Portmahomack; no fish were consumed by the early medieval monks, yet a significant increase in fish consumption by the layfolk in the mid-late medieval period. Where relevant, skeletal and stable isotope evidence was also compared to those found from other archaeological studies to provide context when interpreting medieval lifeways. For example, comparisons from skeletal evidence found prevalence of PNB infections from Norton were similar to St Mary Spital, both of which were Augustinian Priories. Overall, low prevalence of infectious diseases such as TB, syphilis and leprosy occurred at medieval sites, which was also the case for Paget's disease, with only three sites, including Norton, observing multiple cases. Isotope data from early medieval Portmahomack compared to other sites from this period found similarities in the types of foods consumed, but no fish consumption. By the mid-later medieval period, although there is clear evidence of fish consumption at most sites, there is greater variation, with the Norton isotope data similar to other religious sites, whereas in comparison, fish consumption by the layfolk at Portmahomack appears to be greater still, reflecting a significant amount of fish being consumed by this time and also how religious influences on diet were interpreted differently by some Christian communities.

Importantly, this chapter has discussed the evidence from this study that provides an answer to the overall research question proposed in chapter 1: to what extent can Christian lifeways be reconstructed through bioarchaeology? By using multidisciplinary methods that provide archaeological, historical, skeletal and stable isotope evidence, there are many aspects of Christian lifeways that can be reconstructed. For example, skeletal evidence can elucidate familial affinities, as at Norton; a difference in cultural and religious practices reflected within the living environment of monastic and lay groups at Portmahomack, and evidence of violence, reflecting interpersonal conflict and vulnerability at Portmahomack and Norton. From stable isotope evidence, differences in Christian dietary practices are suggested, with a diachronic change in diet at Portmahomack, yet a more homogeneous diet at Norton, reflecting conformity to different fasting practices within different Christian communities during the early to late medieval period. Such evidence attests to the usefulness of a multidisciplinary bioarchaeological study to reconstruct past lifeways and interpret the impact that religious influences had on medieval Christian communities. The findings discussed here, and the associated research questions proposed in chapter 1, will form a basis for the final conclusions in the following chapter.

Chapter 9

CONCLUSIONS AND FURTHER WORK

9.1 Introduction

This chapter summarises the findings of this study, following the four research questions and associated hypotheses proposed in chapter 1, along with concluding remarks relating to how social and religious influences may be reconstructed through bioarchaeology. Final conclusions to the overall research question of this thesis will also be presented and recommendations for further work offered thereafter.

9.2 Research Synthesis

A number of discoveries from this research elucidate to how medieval Christian lifeways had an effect on the skeletal body. Moreover, the burial evidence has proved invaluable in interpreting certain bio-cultural, religious or social aspects of medieval lifeways at Portmahomack and Norton Priory.

9.2.1 Bio-cultural or Familial Affinity: Concluding Remarks

The first research question proposed in chapter 1 was: To what extent can bioarchaeology be used to infer bio-cultural or familial affinity? The hypothesis associated with this question was that lay communities tend to bury their dead in family groups, with males and females identified by their skeletal remains. Ecclesiastical communities however, would be represented by a predominance of male burials with no familial relationships.

Skeletal evidence of bio-cultural or familial affinity was suggested on some adults from Norton, supported by burial evidence that suggested they were members of the Dutton family. As proposed in the hypothesis, no familial associations were identified in the monastic population at Portmahomack and the later lay populations did not show familial similarities, presumably because of the sample size and the genetic variation in the population. Osteometric and non-metric evidence from Portmahomack and Norton also suggests some level of natural variation or adaptive skeletal plasticity within and among populations. For example, tibial squatting facets were prevalent during the monastic and later lay phases at Portmahomack, and variation in lower limb shape occurred overall from both sites. This study has therefore found that bioarchaeological evidence of familial affinity can be suggested for individuals from Norton but not from Portmahomack. The evidence presented in this study attests to the usefulness of applying bioarchaeological methods, and where possible, burial evidence, to address aspects of bio-cultural or familial affinities from past populations.

9.2.2 The Living Environment: Concluding Remarks

The second research question offered in chapter 1 was: To what extent did the way of life of Christian communities have an impact on their skeletal remains? The hypothesis proposed here was that the living environment of individuals differed depending on their lifestyles and roles within their Christian communities, which had an impact on their skeleton. It was also hypothesised that conditions such as infectious disease were more prevalent in more densely populated Christian communities compared to those from rural areas. Moreover, skeletal differences between monastic and lay communities may reflect occupation-related divisions.

Skeletal health indicators relating to the living environment have shown that there are differences depending of the lifestyles and roles of individuals within their respective Christian communities. In agreement with the aforementioned hypothesis, monks from Portmahomack engaged in different occupations or activities than those from the lay phases, evidenced from joint diseases, and sinusitis, for example. Some younger males at Norton were more affected by vertebral joint disease than older females, suggesting a gendered- or age-division in labour. Both monastic and lay individuals at Portmahomack had a significantly higher prevalence of malignant cancers than at Norton, suggesting a greater susceptibility to this disease. However, people from Norton were more susceptible to non-specific infections and infectious diseases than at Portmahomack. This supports the hypothesis that the more densely populated Christian community at Norton were more vulnerable to infectious diseases, than the rural community at Portmahomack. Evidence of Paget's disease from Norton is also noteworthy, considering Norton is one of only three known sites in Britain that offer skeletal evidence of multiple cases. Moreover, a stable isotope case study presented in this research found some difference between Pagetic and normal bone isotope values, which may also contribute to the present understanding of Paget's disease.

Skeletal evidence on sub-adults from Portmahomack and Norton suggest they were not greatly affected by their living environment, although some indicators of infection and strain were observed. This study suggests that sub-adults were not exposed to extrinsic factors to the same level that affected adult health and skeletal markers were minimal. However, this may be due to death occurring before pathological markers manifested on the bones of some sub-adults.

9.2.3 Trauma and Conflict: Concluding Remarks

The third question proposed in chapter 1 was: What evidence is there for trauma and conflict in Christian communities? The associated hypothesis was that it might be expected that there is little evidence of interpersonal violence from ecclesiastical and lay communities that closely followed Christian doctrines. Similarly, we might expect ecclesiastical figures to show no evidence of violence.

A number of fractures on individuals that reflect occupation-, activity- or conflict-related trauma were found in this study, and evidence of blade wounds from Portmahomack and Norton attest to people's vulnerability to violence. Monks from Portmahomack sustained serious injuries from a Viking attack around the late 8th century, and later medieval layfolk were also subjected to weapon-related violence. A severe blade wound to a wealthy benefactor from Norton suggests he was also the victim of a traumatic attack. Evidence of a cranial blade wound on a sub-adult from Portmahomack suggests either a work/activity-related accident or some form of violent encounter. Such evidence attests to the important contribution of sub-adult skeletal material when considering the lifecourse of past individuals and the effects of childhood trauma.

To a certain extent, this study rejects the hypothesis that little evidence of interpersonal violence is expected from those that followed Christian doctrines. The evidence suggests that despite the individuals from Portmahomack and Norton being part of Christian communities, interpersonal violence occurred. Monks from Portmahomack were targeted because of their monastic status and the individual from Norton, possibly because of his social status or connection to the Priory.

Although these communities followed strict Christian doctrines, this study suggests that people were still vulnerable to violence from outside and possibly within their own community. Such violence does not suggest a disregard of Christian values, for indeed many medieval conflicts, such as the Crusades, were fought for the Christian faith. However, skeletal evidence of violence, on the monks at Portmahomack for example, provides important insights on how monastic communities were susceptible to conflict, especially from those with different beliefs, such as Viking raiders.

9.2.4 Diet and Nutrition-related Stresses: Concluding Remarks

The final question proposed in chapter 1 was: To what extent did diet differ between communities that followed different Christian practices, and were these practices followed similarly by men/women, young/old, ecclesiastical/lay status? Additionally, it was also questioned if there were any dietary stresses that can be specifically tied to Christian practices. The associated hypothesis suggested that if Christian practices were carefully followed, we might expect to see uniformity in diet and nutrition within a population and no differences would be expected between certain groups.

The presence of a number of dental pathologies from Portmahomack and Norton reflected how diet, and in some cases, a lack of oral hygiene, affected people during the medieval period. For example, this study found that dental abscesses affected period 4 lay males more than females at Portmahomack, whereas females were affected more by caries and periodontal disease. This may suggest a gendered-division in diet, with males having greater access to animal protein. The isotope data from lay period 1 at Portmahomack shows that some males ate more animal protein than females, although for the later periods it does not suggest any significant differences between male and female diets, suggesting that poor oral hygiene was a contributory factor to the prevalence of calculus. A significant difference in isotope values between both sexes from 15th century Norton was found, with males consuming more meat than females, which may have contributed to the prevalence of male dental calculus and the higher rate of caries in females. Stable isotope data also suggested some age-divisions in diet, especially at Portmahomack, possibly related to divisions in labour or status.

The presence of DEH on a number of individuals suggest some form of childhood illness or nutritional stress occurred, especially at Portmahomack where a greater prevalence was found on period 4 males compared to period 4 females and compared to males from the earlier monastic phase. Skeletal conditions relating to dietary deficiency or infection occurred on a number of sub-adults from Portmahomack and Norton. The presence of rickets, for example, may have been associated with keeping children indoors for long periods, hence deficient in vitamin D from lack of sunlight. Cribra orbitalia may have been the result of children being weaned off breastmilk early, leaving them more susceptible to nutritional stress or illness. However, further studies would be needed to support this (see section 9.4).

This study found skeletal indictors associated with rich diets, such as gout and DISH. DISH was found on individuals from both Portmahomack and Norton, probably exacerbated by a rich animal protein diet, which is supported by the isotopic data. There is no evidence from this study to suggest a religious way of life caused the onset of DISH, although it does suggest a link between a meat-rich diet and individuals of high status, especially at Norton.

The isotope data in this study has reconstructed the diets of two Christian communities which differed in the religious orders they followed. A significant diachronic change in diet occurred at Portmahomack, with no fish, or a negligible amount, consumed by the monks, whereas those from the later lay phase were consuming significant amounts of fish, as were those from mid-late medieval Norton. This evidence reflects an increase in fish demand during the mid-late medieval period due to changing religious influences on fasting and the growing popularity for replacing meat with fish on fast days. Such evidence attests to the usefulness of providing primary data in bioarchaeological studies to reconstruct aspects of religious influences on Christian lifeways.

This study rejects the hypothesis that Christian communities had uniformity in their diet, mostly at Portmahomack, where differences were observed between monastic/lay, male/female and young/old groups. Although generally, a greater uniformity in diet occurred at Norton, some divisions between male and female diets, and between periods, were observed. This study has found that 'the monastic diet' is too simplistic a term to apply to the medieval period, which spanned over 1000 years and included a range of different religious orders, rules and practices. By providing stable isotope data, this study has detected striking (Portmahomack) and subtle (Norton) dietary differences that has enabled investigations into the types of food consumed and the religious or social influences therein.

9.3 Final Conclusion

I finally return my overall research question: To what extent can Christian lifeways be reconstructed through bioarchaeology using the case study sites of Portmahomack and Norton Priory? This research has provided primary evidence to suggest the lifeways of these Christian communities can be reconstructed, from how the living environment affected the skeletal body to how religious influences that changed over time had an effect on diet and lifestyle, hence identifying religious practices as socially entwined with the formation of identities. Aspects of medieval religious life are often considered through historical or archaeological evidence, in the form of contemporary writings or ecclesiastical architecture, for example. It is now timely however to focus on obtaining primary evidence from skeletal and chemical analyses. This study has shown that using multidisciplinary methods in bioarchaeology provides a powerful tool in reconstructing past lifeways of Christian communities. The link between bioarchaeology and religion is a new area that should be explored further. This study attests to this by focusing on communities from ecclesiastical sites and using a multidisciplinary approach that has resulted in a greater understanding of the influences that religion had on medieval Christian lifeways.

9.4 Further Work

Although this study has strived to address multiple aspects of medieval Christian lifeways to provide a comprehensive study, a number of potential research areas have emerged that warrant further investigation.

9.4.1 Paget’s Disease of Bone

The scarcity of Paget’s disease cases from archaeological contexts and its high concentration of clinical cases in northwest England warrant the identification of further cases and apply isotope analysis to Pagetic bone to add to the existing body of data found in this study. These investigations may prove highly significant to understand the high prevalence of Paget's disease from Norton and contribute to its aetiology, which is still unknown.

9.4.2 Markers of Activity

It was not the primary focus of this study to investigate markers of activity or biomechanical stress, in the form of entheseal changes or asymmetry on bone. However, such studies on the Portmahomack and Norton skeletal collection may prove beneficial to further elucidate aspects of occupation or activity and to gain a greater understanding of how Christian lifeways had an impact on the body.

9.4.3 Sub-adult Isotope Analysis

Due to limited resources, adults were prioritised for dietary reconstructions in this study, hence only a small sub-sample of sub-adults were selected for isotope analysis. However, it emerged during this study that carbon and nitrogen isotope analysis on sub-adults would be highly beneficial to gain a greater understanding of childhood diets within Christian communities, especially to investigate if their diets were influenced by fasting practices. Isotope analysis on sub-adults may also support skeletal indicators of childhood nutritional stresses, for example, by identifying early weaning, which may elucidate social or religious influences on childhood weaning and feeding practices that medieval Christian communities followed.

9.4.4 Adult Isotope Analysis on Tooth Collagen

Analysing tooth collagen for carbon and nitrogen isotopes from the permanent molars of adults from Portmahomack and Norton can reconstruct their childhood diet versus that from adulthood (derived from bone collagen) to investigate any change in diet over the lifecourse of an individual. This may prove beneficial with known ecclesiastics, which may reflect a childhood to adulthood conformity to a religious way of life in terms of their diet. A sub-sample of adult tooth collagen from Portmahomack was analysed in a previous study (Curtis-Summers *et al*. 2014) and although the results showed some changes in diet over the lifecourse, further analysis would be needed on the whole collection to enable broader interpretations.

9.4.5 Strontium and Oxygen Isotope Analysis

Although strontium and oxygen isotope analysis on the Portmahomack skeletal collection was underway at the time of this study (J. Montgomery, *pers.comm*.), the data was not available for presentation here. Once such data are published, consideration of provenance and mobility may prove beneficial to further understand past lifeways at Portmahomack. Moreover, strontium and oxygen isotope analysis on the Norton skeletal material may enable interpretations of provenance and levels of mobility within a large Christian community. People who visited Norton and became part of its community would have been expected to adhere to the Augustinian way of life. Provenance studies may therefore identify individuals whose origins and religion may have been far removed from that at Norton. Moreover, by combining such data with the evidence presented in this study, a broad understanding is gained of the influences that society and religion had on Christian communities in medieval Britain. This research has shown that investigating religion through bioarchaeology provides an important source of information that is often overlooked when reconstructing past lifeways. The identities of Christian communities in medieval

Britain were entwined with religious practices, the subtleties of which can be elucidated, as revealed in this study.

REFERENCES

References

Abram, A. 2007. *The Augustinian Canons in the Diocese of Coventry and Lichfield and their Benefactors 1115-1320*. Unpublished PhD thesis, University of Wales, Lampeter.

Acsádi, G.Y., and Nemeskeri, J. 1970. *History of Human Lifespan and Mortality*. Budapest: Akademiai Kiado.

Adamson, M.W. 2004. *Food in medieval times*. Westport, Connecticut: Greenwood Press.

Agarwal, S.C., and Glencross, B.A. (eds.). 2011. *Social Bioarchaeology*. Oxford: Wiley-Blackwell.

Aitken, M.J. 1990. *Science-based dating in archaeology*. London: Longman.

Alcock, L. 2003. *Kings & Warriors, Craftsmen & Priests in Northern Britain AD 550-850*. Edinburgh: Society of Antiquaries of Scotland Monograph Series.

Allen, J. R., and Anderson, J. [1903] 1993. *The Early Christian Monuments of Scotland*. Balgavies: Pinkfoot Press.

Ambrose, S.H. 1990. 'Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis.' *Journal of Archaeological Science* 17 (4): 431-451.

Ambrose, S.H. 1991. 'Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs.' *Journal of Archaeological Science* 18 (3): 293–317.

Ambrose, S.H., 1993. 'Isotopic Analysis of Paleodiets: Methodological and Interpretive Considerations.' In Sandford, M.K. (ed.), *Investigations of Ancient Human Tissue: Chemical Analyses in Anthropology*. New York: Gordon and Breach: 59-130.

Ambrose, S.H. 2000. 'Controlled Diet and Climate Experiments on Nitrogen Isotope Ratios of Rats.' In Ambrose, S.H., and Katzenberg, M.A. (eds.), *Biogeochemical Approaches to Paleodietary Analysis.* New York: Kluwer Academic/Plenum Publishers: 243-259.

Ambrose, S.H., and Norr, L. 1993. 'Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate.' In Lambert, J.B., and Grupe, G. (eds.), *Prehistoric Human Bone - Archaeology at the Molecular Level.* Berlin: Springer-Verlag:1–37.

Andersen, J.G., and Manchester, K.M. 1992. 'The Rhinomaxillary Syndrome in Leprosy: a Clinical, Radiological and Palaeopathological Study.' *International Journal of Osteoarchaeology* 2: 121-129.

Anderson, T. 2004. 'Dental treatment in Medieval England.' *British Dental Journal* 197 (7): 419-425.

Anderson, T., Wakely, J., and Carter, A. 1992. 'Medieval Example of Metastatic Carcinoma: A Dry Bone, Radiological, and SEM Study.' *American Journal of Physical Anthropology* 89: 309-323.

Andrews, J., Briggs, A., Porter, R., Tucker, P., and Waddington, K. 1997. *The History of Bethlem*. Oxon: Routledge.

Armit, I. 2006. *Scotland's Hidden History*. Stroud: Tempus Publishing Limited.

Arnold, C.J. 2005. *An Archaeology of the Early Anglo-Saxon Kingdoms* (3rd edition), London: Taylor & Francis.

Arnold, C. 2008. *Bedlam: London and Its Mad*. London: Simon & Schuster UK Ltd.

Aufderheide, A.C., and Rodríguez-Martin, C. 1998. *The Cambridge Encyclopedia of Human Paleopathology*. Cambridge: Cambridge University Press.

BABAO: British Association of Biological Anthropology and Osteoarchaeology. *Code of Ethics and Code of Practice:* http://www.babao.org.uk/index/ethics-and-standards. Accessed 31st October 2010.

Baeten, J., Jervis, B., De Vos, D., and Waelkens, M. 2013. 'Molecular evidence for the mixing of Meat, Fish and Vegetables in Anglo-Saxon coarseware from Hamwic, UK.' *Archaeometry* 55 (6): 1150-1174.

Baggs, A.P., Kettle, A.J., Lander, S.J., Thacker, A.T., and Wardle, D. 1980. 'Houses of Cistercian monks: The abbey of Combermere.' In Elrington, C.R., and Harris, B.E., (eds.), *A History of the County of Chester: Volume 3*. London: 150-156. Published online: http://www.british-history.ac.uk/vch/ches/vol3/pp150-156. Accessed 3rd March 2015.

Baggs, A.P., Kettle, A.J., Lander, S.J., Thacker, A.T., and Wardle, D. 'House of Augustinian canons: The abbey of Norton.' In Elrington, C.R., and Harris, B.E., (eds.), *A History of the County of Chester: Volume 3*. London: 165-171. Published online: http://www.british-history.ac.uk/vch/ches/vol3/pp165-171. Accessed 18th June 2015.

Baillie, M.G.L. 1991. 'Marking in marker dates: towards an archaeology with historical precision.' *World Archaeology* 23: 233-43.

Baillie, M.G.L. 1994. 'Dendrochronology raises questions about the nature of the AD 536 dust-veil event.' *The Holocene* 4 (2): 212-217.

Balasse, M., Tresset, A., and Ambrose, S.H. 2006. 'Stable isotope evidence ($\delta^{13}C$, $\delta^{18}O$) for winter feeding on seaweed by Neolithic sheep of Scotland.' *Journal of Zoology* 270: 170-176.

Balasse, M., Mainland, I., and Richards, M.P. 2009. 'Stable isotope evidence for seasonal consumption of marine seaweed by modern and archaeological sheep in the Orkney archipelago (Scotland).' *Environmental Archaeology* 14 (1): 1-14.

Balzer, A., Gleixner, G., Grupe, G., Schmidt, H.L., Schramm, S., and Turban-Just, S. 1997. '*In vitro* decomposition of bone collagen by soil bacteria: the implications for stable isotope analysis in archaeometry.' *Archaeometry* 39 (2): 415-429.

Barnes, E. 2012a. *Atlas of Developmental Field Anomalies of the Human Skeleton: A Paleopathology Perspective*. New Jersey: Wiley-Blackwell.

Barnes, E. 2012b. 'Developmental Disorders in the Skeleton.' In Grauer, A.L. (ed.), *A Companion to Paleopathology*. Chichester: Wiley-Blackwell: 380-400.

Barker, D.J., and Gardner, M.J. 1974. 'Distribution of Paget's disease in England, Wales and Scotland and a possible relationship with vitamin D deficiency in childhood.' *British Journal of Preventive and Social Medicine* 28: 226-32.

Barker D.J., Chamberlain, A.T., Guyer, P.B., and Gardner, M.J. 1980. 'Paget's disease of bone: The Lancashire focus.' *British Medical Journal* 280: 1105-1107.

Barrett, J.H., Beukens, R.P., and Nicholson, R.A. 2001. 'Diet and ethnicity during the Viking colonization of northern Scotland: evidence from fish bones and stable carbon isotopes.' *Antiquity* 75: 145-154.

Barrett, J.H., Nicholson, R.A., and Cerón-Carrasco, R. 1999. 'Archaeo-ichthyological Evidence for Long-term Socioeconomic Trends in Northern Scotland: 3500 BC to AD 1500.' *Journal of Archaeological Science* 26: 353-388.

Barrett, J.H., and Richards, M.P. 2004. 'Identity, Gender, Religion and Economy: New Isotope and Radiocarbon Evidence for Marine Resource Intensification in Early Historic Orkney, Scotland, UK.' *European Journal of Archaeology* 7 (3): 249-271.

Bartlett, R. 2001. 'Medieval Britain & Ireland'. In Cunliffe, B., Bartlett, R., Morrill, J., Briggs, A., and Bourke, J. (eds.), *The Penguin Atlas of British and Irish History. From Earliest Times to the Present Day*. London: Penguin Books: 52-111.

Bass, W.M. 1995. *Human Osteology. A Laboratory and Field Manual* (4th edition). Columbia: Missouri Archaeological Society.

Benedictow, O.J. 2004. *The Black Death, 1346-1353: the complete history*. Woodbridge: The Boydell Press.

Bibliothèque Nationale de France: http://www.bnf.fr/fr/acc/x.accueil.html. Accessed 11th September 2014.

Bliss, W.H., and Twemlow, J.A., (eds.). 1902. *Calendar of Entries in the Papal Registers Relating to Great Britain and Ireland: Papal Letters Volume IV, A.D. 1362-1404*. London: H.M.S.O. and Irish Manuscripts Commission 1893-1998.

Bocherens, H., Fizet, M., Mariotti, A., Lange-Badre, B., Vandermeersch, B., Borel, J.P., and Bellon, G. 1991. 'Isotopic biogeochemistry (^{13}C, ^{15}N) of fossil vertebrate collagen: application to the study of a past food web including Neandertal man.' *Journal of Human Evolution* 20: 481-492.

Boddington, A. 1996. *Raunds Furnells: The Anglo-Saxon church and churchyard*. Swindon: English Heritage Archaeological Report 7.

Bodleian Library, University of Oxford: http://www.bodley.ox.ac.uk/dept/scwmss/wmss/medieval/mss/buchanan/e/003.a.htm. Accessed 6th October 2014.

Bogaard, A., Heaton, T.H.E., Poulton, P., and Merbach, I. 2007. 'The impact of manuring on nitrogen isotope ratios in cereals: archaeological implications for reconstruction of diet and crop management practices.' *Journal of Archaeological Science* 34: 335-343.

Bond, C.J. 1988. 'Monastic Fisheries.' In Aston, M. (ed.), *Medieval Fish, Fisheries and Fishponds in England*. Oxford: BAR British Series 182 (i): 69-112.

Borie, E, Watanabeb, C.A., Orsib, I.A., and Fuentesaa, R. 2014. 'Idiopathic bilateral antral exostoses: A rare case in maxillary sinus.' *International Journal of Surgery Case Reports* 5: 624-627.

Bos, K.I., Schuenemann, V.J., Golding, G.B., Burbano, H.A., Waglechner, N., Coombes, B.K., McPhee, J.B., DeWitte, S.N., Meyer, M., Schmedes, S., Wood, J., Earn, D.J.D., Herring, D.A., Bauer, P., Poinar, H.N., and Krause, J. 2011. 'A draft genome of *Yersinia pestis* from victims of the Black Death.' *Nature* 478: 506-510.

Boylston, A. 2004. 'Recording of weapon trauma.' In Brickley, M., and McKinley, J.I. (eds.), *Guidelines to the Standards for Recording Human Remains*. IFA Paper No. 7. BABAO and the Institute of Field Archaeologists: 40-42.

Boylston, A. 2008. 'The Human Bone.' In Brown, F., and Howard-Davies, C. (eds.), *Norton Priory: Monastery to Museum, Excavations 1970-87*. Lancaster Imprints 16: 149-182.

Boylston, A., and Roberts, C.A. 1996. 'The Human Bone.' In Adams, M., Excavation of a pre-Conquest Cemetery at Addingham, West Yorkshire. *Medieval Archaeology* 40: 173-180.

Boylston, A., and Weston, D. 2002. 'The human bone.' In Heawood, R., Howard-Davis, C., Boylston, A., and Weston, D. (eds.), 'Excavations at Warrington Friary, 2000.' *Journal of the Chester Archaeological Society* 77: 131-185.

Boylston, A., Wiggins, R., Roberts, C.A. 1998. 'Human skeletal remains.' In Drinkall, D., and Foreman, M. (eds.), *The Anglo-Saxon cemetery at Castledyke South, Barton-on-Humber*. Sheffield Excavation Reports 6. Sheffield: Sheffield Academic Press: 221-236.

Bradley, I. 1999. *Celtic Christianity: Making Myths and Chasing Dreams*. Edinburgh: Edinburgh University Press.

Brandt, K.D., Lohmander, L.S., and Doherty, M. 1998. 'Introduction: the concept of osteoarthritis as failure of the diarthrodial joint.' In Brandt, K., Doherty, M., and Lohmander, L.S. (eds.), *Osteoarthritis*. Oxford: Oxford University Press: 70-73.

Brickley, M., and McKinley, J.I. (eds.). 2004. *Guidelines to the Standards for Recording Human Remains*. IFA Paper No. 7. BABAO and the Institute of Field Archaeologists.

Brickley, M.B., and Buckberry, J. 2015. 'Picking up the pieces: Utilizing the diagnostic potential of poorly preserved remains.' *International Journal of Paleopathology* 8: 51-54.

Britton, K., Müldner, G., and Bell, M. 2008. 'Stable isotope evidence for salt-marsh grazing in the Bronze Age Severn Estuary, UK: implications for palaeodietary analysis at coastal sites.' *Journal of Archaeological Science* 35: 2111-2118.

Brody, S.N. 1974. *The Disease of the Soul: Leprosy in Medieval Literature*. London: Cornell University Press.

Brook, I. 2006. 'Sinusitis of Odontogenic Origin.' *Otolaryngology–Head and Neck Surgery* 135 (3): 349-355.

Brooke, C. 2003. *The Age of the Cloister: The Story of Monastic Life in the Middle Ages*. Stroud: Sutton Publishing Ltd.

Brooks, S., and Suchey, J.M. 1990. 'Skeletal age determination based on the os pubis: a comparison of the Acsádi-Nemeskéri and Suchey-Brooks.' *Human Evolution* 5 (3): 227-238.

Brookhaven National Laboratory. *Hierarchical structures in bone*: www.bnl.gov/nsls2/sciOps/chemSci/softMatter.asp. Accessed 19th September 2014.

Brothwell, D. 1981. *Digging up Bones* (3rd edition). Oxford: Oxford University Press.

Brothwell, D. 2012. 'Tumors: Problems of Differential Diagnosis in Palaeopathology.' In Grauer, A.L. (ed.), *A Companion to Paleopathology*. Chichester: Wiley-Blackwell: 420-433.

Brothwell, D., and Møller-Christensen, V. 1963. 'Medico-historical aspects of a very early case of mutilation.' *Danish Medical Bulletin* 10: 21-25.

Brothwell, D., and Zakrzewski, S. 2004. 'Metric and non-metric studies of archaeological human bone.' In Brickley, M., and McKinley, J.I. (eds.), *Guidelines to the Standards for Recording Human Remains*. IFA Paper No. 7. BABAO and the Institute of Field Archaeologists.

Brown, A. 2003. *Church and Society in England, 1000-1500*. Social History in Perspective. Hampshire: Palgrave Macmillan.

Brown, A., and Pluskowski, A. 2011. 'Detecting the environmental impact of the Baltic Crusades on a late-medieval (13th-15th century) frontier landscape: palynological analysis from Malbork Castle and hinterland, Northern Poland.' *Journal of Archaeological Science* 38: 1957-1966.

Brown, F., and Howard-Davies, C. (eds.). 2008. *Norton Priory: Monastery to Museum, Excavations 1970-87*. Lancaster Imprints 16.

Buckberry, J.L., and Chamberlain, A.T. 2002. 'Age estimation from the auricular surface of the ilium: A revised method.' *American Journal of Physical Anthropology* 119: 231-239.

Buckberry, J.L., and Hadley, D.M. 2007. 'An Anglo-Saxon Execution Cemetery at Walkington Wold, Yorkshire.' *Oxford Journal of Archaeology* 26: 309-329.

Buehler, M.J. 2006. 'Nature designs tough collagen: Explaining the nanostructure of collagen fibrils.' *Proceedings of the National Academy of Sciences of the United States of America* 103 (33): 12285-12290.

Buikstra, J.E., and Ubelaker, D.H. (eds.). 1994. *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archaeological Survey Research Series 44. Fayetteville: Arkansas Archaeological Survey.

Buikstra, J.E., and Beck, L.A. (eds.). 2006. *Bioarchaeology: The Contextual Analysis of Human Remains*. New York: Academic Press.

Burgess, C. 1985. 'Population, climate and upland settlement.' *British Archaeological Reports* 143: 195-229.

Burton, J. 1994. *Monastic and Religious Orders in Britain, 1000-1300*. Cambridge: Cambridge University Press.

Burton, J., and Kerr, J. 2011. *The Cistercians in the Middle Ages*. Woodbridge: The Boydell Press.

Cameron, M.L. 1993. *Anglo-Saxon Medicine*. Cambridge Studies in Anglo-Saxon England 7. Cambridge: Cambridge University Press.

Campbell, B.M.S. 2010. 'Nature as historical protagonist: environment and society in pre-industrial England.' *Economic History Review* 63 (2): 281-314.

Cardy, A. 1994. *Whithorn: the late medieval cemetery*. Unpublished skeletal report.

Cardy, A. 1997. 'The human bones.' In Hill, P. (ed.), *Whithorn and St. Ninian: The Excavation of a Monastic Town, 1984-91*. Stroud: Sutton Publishing Ltd.: 519-562.

Carswell, R.C. 2006. 'Gildas' In Koch, J.T. (ed.), *Celtic culture: a historical encyclopedia, Volume* 3. Santa Barbara: ABC-CLIO: 806-810.

Carver, M.O.H. 1989. 'Digging for ideas.' *Antiquity* 62 (241): 666-674.

Carver, M.O.H. (ed.). 1996. *Bulletin of the Tarbat Discovery Programme No.2*: http://www.york.ac.uk/depts/arch/staff/sites/tarbat/bulletins/bulletin2/contents.html. Accessed 10th February 2015.

Carver, M.O.H. 1998. 'Conversion and Politics on the Eastern Seaboard of Britain; some archaeological indicators.' In Crawford, B.E. (ed.), *Conversion and Christianity in the North Sea World*. Fife: University of St Andrews: 11-40.

Carver, M.O.H. 1999a. *Surviving in Symbols. A Visit to a Pictish Nation*. Edinburgh: Canongate Books Ltd.

Carver, M.O.H. 1999b. 'Exploring, Explaining, Imagining: Anglo-Saxon Archaeology 1998.' In Karkov, C.E. (ed.), *The Archaeology of Anglo-Saxon England: Basic Readings*. New York: Garland Publishing Inc.: 25-52.

Carver, M.O.H. (ed.). 2003. *The cross goes north: the age of conversion in Northern Europe 300-1300*, Woodbridge: Boydell Press.

Carver, M.O.H. 2004. 'An Iona of the East: The Early-medieval Monastery at Portmahomack, Tarbat Ness.' *Medieval Archaeology* 48: 1-30.

Carver, M.O.H. 2006. *Tarbat Discovery Programme, Data Structure Report, March 2006*: http://www.york.ac.uk/depts/arch/staff/sites/tarbat/bulletins/datareports/2006.html. Accessed 4th December 2014.

Carver, M.O.H. 2008. *Portmahomack: Monastery of the Picts*. Edinburgh: Edinburgh University Press.

Carver, M.O.H. 2012. *Tarbat Discovery Programme, Sector 4 Data Structure Report, October 2012* (Unpublished).

Carver M.O.H., and Spall, C.A. 2004. 'Excavating a *parchmenerie*: archaeological correlates of making parchment at the Pictish monastery at Portmahomack, Easter Ross.' *Proceedings of the Society of Antiquaries of Scotland* 134: 183-200.

Carver M.O.H., Garner-Lahire, J., and Spall, C.A. Forthcoming. 'Portmahomack: Capturing change in North-east Scotland, 6th to 16th century.' *Society of Antiquaries of Scotland*.

Chadwick Hawkes, S., Grainger, G., Biddulph, E., and Dodd, A. 2003. *The Anglo-Saxon Cemetery at Worthy Park, Kingsworthy, near Winchester, Hampshire*. Oxford: Oxford University School of Archaeology Monograph 59.

Charles-Edwards, T.M. 2002. *Early Christian Ireland*. Cambridge: Cambridge University Press.

Clancy, T.O. 2001. 'The real St Ninian.' *Innes Review* 52: 1-28.

Clough, S., and Boyle, A. 2010. 'Inhumations and disarticulated human bone.' In Booth, P., Simmonds, S., Boyle, A., Clough, S., Cool, H., and Poore, D. (eds.), *The Late Roman Cemetery at Lankhills, Winchester. Excavations 2000-2005*. Oxford: Oxford Archaeology North: 339-403.

Cockayne, T.O., (ed.). 1864-6. *Leechdoms, Wortcunning and Starcraft of Early England*, 3 volumes. London: Rolls Series.

CofE/EH. 2005. *Guidance for Best Practice for Treatment of Human Remains Excavated from Christian Burial Grounds in England*. London: Church of England and English Heritage. Published online: https://www.english-heritage.org.uk/publications/human-remains-excavated-from-christian-burial-grounds-in-england/. Accessed 2nd November 2010.

Collins, M.J., Riley, M.S., Child, A.M., and Turner-Walker, G. 1995. 'A Basic Mathematical Simulation of the Chemical Degradation of Ancient Collagen.' *Journal of Archaeological Science* 22: 175-183.

Collins, M.J., Nielsen–Marsh, C.M., Hiller, J., Smith, C.I., Roberts, J.P., Prigodich, R.V., Wess, T.J., Csapò, J., Millard, A.R., and Turner-Walker, G. 2002. 'The survival of organic matter in bone: a review.' *Archaeometry* 44: 383-394.

Conheeney, J. 1992. '*Draft of human bone report for St Mary Spital publication*.' London Museum of Archaeological Services archive report HUM/05/92. Unpublished report.

Cooper, C., Harvey, N.C., Dennison, E.M., and van Staa, T.P. 2006. 'Update on the Epidemiology of Paget's disease of bone.' *Journal of Bone and Mineral Research* 21: 3-8.

Coppack, G. 1998. *The white monks: the Cistercians in Britain 1128-1540*. Stroud: Tempus.

Coppack, G. 2006. *Abbeys & Priories*. Stroud: Tempus.

Corning, C. 2006. *The Celtic and Roman Traditions: Conflict and Consensus in the Early Medieval Church*. Hampshire: Palgrave Macmillan.

Cox, M. 1999. 'The human bones.' In Haughton, C., and Powlesland, D. (eds.), *West Heslerton: The Anglian cemetery. The excavation and discussion of the evidence, volume 1*. Yedingham, North Yorkshire: The Landscape Research Centre Ltd.: 172-188.

Cox, M. 2000. 'Ageing Adults from the Skeleton.' In Cox, M., and Mays, S. (eds.), *Human Osteology in Archaeology and Forensic Science*. London: Greenwich Medical Media: 61-81.

Crawford, S. 2009. 'Settlement and Social Differentiation.' In Stafford, P. (ed.), *A Companion to the Early Middle Ages: Britain and Ireland, c.500-1100,* Blackwell Companions to British History. Chichester: Wiley-Blackwell: 432-445.

Cubitt, C. 2009. 'The Institutional Church.' In Stafford, P. (ed.), *A Companion to the Early Middle Ages: Britain and Ireland, c.500-1100*. Blackwell Companions to British History. Chichester: Wiley-Blackwell: 376-394.

Curtis-Summers, S. 2014. *Osteological Analysis of Human Remains from the Mason's Yard, Lincoln Castle*. Report compiled for FAS Heritage, York, on behalf of Lincolnshire County Council. Unpublished report.

Curtis-Summers, S., Montgomery, J., and Carver, M.O.H. 2014. 'Stable isotope evidence for dietary contrast between Pictish and Medieval populations at Portmahomack, Scotland.' *Medieval Archaeology* 58: 21-43.

Dar, G., Masharawi, Y., Peleg, S., Steinberg, N., May, H., Medlej, B., Peled, N., and Hershkovitz, I. 2010. 'Schmorl's nodes distribution in the human spine and its possible etiology.' *European Spine Journal* 19: 670-675.

David, P., and Beardshaw, C. 2004. *More Hidden Gardens*. London: Cassell Illustrated.

Davies, W. 1992, 'The Myth of the Celtic Church.' In Edwards, N., and Lane, A. (eds.), *The Early Church in Wales and the West*. Oxford: Oxbow: 12-21.

DeNiro, M.J. 1985. 'Postmortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction.' *Nature* 317: 806-809.

DeNiro, M.J. 1987. 'Stable isotopy and archaeology.' *American Scientist* 75: 182-191.

DeNiro, M.J., and Epstein, S. 1976. 'You are what you eat (plus a few per mil): the carbon isotope cycle in food chains.' *Abstract with Programs - Geological Society of America Annual Meeting* 8: 834-835.

DeNiro, M.J., and Epstein, S. 1978. 'Influences of diet on the carbon isotope distribution in animals.' *Geochimica et Cosmochimica Acta* 42: 495-506.

DeNiro, M.J., and Epstein, S. 1981. 'Influence of diet on the distribution of nitrogen isotopes in animals.' *Geochimica et Cosmochimica Acta* 45: 341-351.

Derwich, M. 2000. 'Benedictines: General or Male.' In Johnston, W.M. (ed.), *Encyclopedia of Monasticism*, Volume 1: A-L. London: Fitzroy Dearborn Publishers: 137-143.

Dettwyler, K.A. 1991. 'Can Paleopathology Provide Evidence for "Compassion"?' *American Journal of Physical Anthropology* 84: 375-384.

DeWitte, S.N. 2010. 'Age patterns of mortality during the Black Death in London, A.D. 1349-1350.' *Journal of Archaeological Science* 37: 3394-3400.

DeWitte, S.N., Boulware, J.C., and Redfern, R.C. 2013. 'Medieval Monastic Mortality: Hazard Analysis of Mortality Differences Between Monastic and Nonmonastic Cemeteries in England.' *American Journal of Physical Anthropology* 152: 322-332.

Dhanrajani, P.J. 2002. 'Hypodontia: Etiology, clinical features, and management.' *Oral Surgery* 33 (4): 294-302.

Dias, G., and Tayles, N. 1997. 'Abscess cavity: a misnomer.' *International Journal of Osteoarchaeology* 7: 548-554.

Dias, G.J., Prasad, K., and Santos, A.L. 2007. 'Pathogenesis of Apical Periodontal Cysts: Guidelines for Diagnosis in Palaeopathology.' *International Journal of Osteoarchaeology* 17: 619-626.

Dolin, P. 1997. 'Disease prevalence.' *Community Eye Health* 10 (22): 27-29.

dos Santos, J., Burkowb, I.C., and Jobling, M. 1993. 'Patterns of growth and lipid deposition in cod (*Gadus morhua L.*) fed natural prey and fish-based feeds.' *Aquaculture* 110: 173-189.

Downham, C. 2012. 'Religious and Cultural Boundaries between Vikings and Irish: The Evidence of Conversion'. *The March in the Islands of the Medieval West*. Leiden: Brill: 15-34.

Driver, J.T. 1971. *Cheshire in the Later Middle Ages*. Chester: Cheshire Community Council.

Duffy, S. (ed.). 2005. *Medieval Ireland: An Encyclopedia*. Oxon: Routledge.

Dugdale, W. 1830. *Monasticon Anglicanum: Volume 6, part 1*. Gallica Bibliothèque Numérique. Published online: http://gallica.bnf.fr/ark:/12148/bpt6k133603q. Accessed 26th November 2014.

Dyer, C.C. 1988a. 'Changes in Diet in the Late Middle Ages: the Case of Harvest Workers.' *Agricultural Historical Review* 36 (1): 21-37.

Dyer, C.C. 1988b. 'The consumption of freshwater fish in medieval England.' In Aston, M., (ed.), *Medieval Fish, Fisheries and Fishponds in England*. Oxford: BAR British Series 182 (i): 27-38.

Dyer, C.C. 1989. *Standards of living in the later Middle Ages: Social change in England c.1200-1520*. Cambridge: Cambridge University Press.

Dyer, C.C. 1998. 'Did the Peasants Really Starve in Medieval England?' In Carlin, M., and Rosenthal, J.T. (eds), *Food and Eating in Medieval Europe*. London: The Hambledon Press: 53-71.

Dyer, C.C. 2006. 'Gardens and Garden Produce in the Later Middle Ages.' In Woolgar, C.M. (ed.), *Food in Medieval England: Diet and Nutrition*. Oxford: Oxford University Press: 27-40.

Edwards, N. 1996. *The Archaeology of Early Medieval Ireland*. Oxon: Routledge.

Edwards, N. 2009. 'The Archaeology of the Early Medieval Celtic Churches: an Introduction.' In Edwards, N. (ed.), *The Archaeology of the Early Medieval Celtic Churches*. Society for Medieval Archaeology Monograph 29/Society for Church Archaeology Monograph 1. Leeds: Maney: 1-18.

Ellis, H. 2009. *The Cambridge Illustrated History of Surgery*. Cambridge: Cambridge University Press.

Etchingham, C. 1999. *Church Organisation in Ireland, A.D. 650 to 1000*. Maynooth: Laigin Publications.

Fagan, B. 2006. *Fish on a Friday. Feasting, Fasting and the Discovery of the New World*. New York: Basic Books.

Faure, G., and Mensing T.M. 2005. *Isotopes: Principles and Applications* (3rd edition). New Jersey: John Wiley & Sons Inc.

Field, A. 2009. *Discovering Statistics Using SPSS* (3rd edition). London: SAGE Publications Ltd.

Fildes, V.A. 1986. *Breasts, Bottles, and Babies: A History of Infant Feeding*. Edinburgh: Edinburgh University Press.

Finlay, N. 1999. 'Disability and Archaeology.' *Archaeological Review from Cambridge* 15 (2).

Finnegan, M. 1978. 'Non-metric variation of the infracranial skeleton.' *Journal of Anatomy* 125 (1): 23-37.

Fiorato, V., Boylston, A., and Knüsel, C. (eds.). 2007. *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* (2nd edition). Oxford: Oxbow Books.

Fleming, R. 2011. 'Land use and people.' In Crick, J., and van Houts, E. (eds.), *A Social History of England, 900-1200*. Cambridge: Cambridge University Press: 15-37.

Fletcher, R. 1998. *The Conversion of Europe: From Paganism to Christianity 371-1386 AD*. London: Fontana Press.

Foster, S. M. 2004. *Picts, Gaels and Scots*. London: B.T. Batsford/Historic Scotland.

Fouracre, P. 2009. 'Britain, Ireland, and Europe, c.500-c.750.' In Stafford, P. (ed.), *A Companion to the Early Middle Ages: Britain and Ireland, c.500-1100,* Blackwell Companions to British History. Chichester: Wiley-Blackwell: 126-142.

Frantzen, A.J. 2014. *Food, Eating and Identity in Early Medieval England*. Anglo-Saxon Studies 22. Woodbridge: The Boydell Press.

Fraser, J.E. 2009. *From Caledonia to Pictland. Scotland to 795*. The New Edinburgh History of Scotland, Volume I. Edinburgh: Edinburgh University Press.

Freedman, P. 2007. 'Some Basic Aspects of Medieval Cuisine.' *Annales Universitatis Apulensis, Series Historica* 11 (1): 44-60.

Fry, B. 2006. *Stable Isotope Ecology*. New York: Springer.

Fry, B., and Sherr, E.B. 1988. '$\delta^{13}C$ measurements as indicators of carbon flow in marine and freshwater ecosystems.' In Rundel, P.W., Ehleringer, J.R., and Nagy, K.A. (eds.), *Stable Isotopes in Ecological Research*. New York: Springer: 196-229.

Fuller, B.T., Fuller, J.L., Sage, N.E., Harris, D.A., O'Connell, T.C., and Hedges, R.E.M. 2005. 'Nitrogen balance and $\delta^{15}N$: why you're not what you eat during nutritional stress.' *Rapid Communications in Mass Spectometry* 19: 2497-2506.

Fuller, B.T., Molleson, T.I., Harris, D.A., Gilmour, L.T., and Hedges, R.E.M. 2006. 'Isotopic Evidence for Breastfeeding and Possible Adult Dietary Differences from Late/Sub-Roman Britain.' *American Journal of Physical Anthropology* 129: 45-54.

Geber, J. 2010, 'Diet analysis.' In Lehane, J., and Delaney, F. (eds.), *Archaeological excavation report E3770 – Owenbristy, Co Galway. Cashel and burial ground*. Eachtra Archaeology Report 8: 180-5.

Gilchrist, R. 1995. *Contemplation and action: the other monasticism*. London: Leicester University Press.

Gilchrist, R. 2005. *Norwich Cathedral Close: the evolution of the English cathedral landscape*. Woodbridge: Boydell.

Gilchrist, R. 2012. *Medieval Life: Archaeology and the Life Course*. Woodbridge: The Boydell Press.

Gilchrist, R., and Sloane, B. 2005. *Requiem, the medieval monastic cemetery in Britain*. London: The Museum of London Archaeology Service.

Giles, E., and O. Elliott. 1963. Sex determination by discriminant function analysis of crania. *American Journal of Physical Anthropology* 21: 53-68.

Giuffra, V., Vitiello, A., Caramella, D., Fornaciari, A., Giustini, D., and Fornaciari, G. 2013. 'Rickets in a High Social Class of Renaissance Italy: The Medici Children.' *International Journal of Osteoarchaeology*.
DOI: 10.1002/oa.2324

Glencross, B.A. 2011. 'Skeletal Injury Across the Life Course: Towards Understanding Social Agency.' In Agarwal, S.C., and Glencross, B.A. (eds.), *Social Bioarchaeology*. Oxford: Wiley-Blackwell: 390-409.

Graham-Campbell, J., and Batey, C.E. 1998. *Vikings in Scotland: an archaeological survey*. Edinburgh: Edinburgh University Press.

Grant, A. 1988. 'Food, Status and Religion in England in the Middle Ages: an Archaeozoological Perspective.' *Anthropozoologica, second numéro spécial*: 139-146.

Grant, A. 2014. 'Murder will Out: Kingship, Kinship and Killing in Medieval Scotland.' In Boardman, S., and Goodare, J. (eds.), *Kings, Lords and Men in Scotland and Britain, 1300-1625: Essays in Honour of Jenny Wormald*. Edinburgh: Edinburgh University Press: 193-223.

Grauer, A.L. (ed.) 2012. *A Companion to Paleopathology*. Chichester: Wiley-Blackwell.

Grauer, A.L., and Roberts, C.A. 1996. 'Paleoepidemiology, Healing, and Possible Treatment of Trauma in the Medieval Cemetery Population of St. Helen-on-the-Walls, York, England.' *American Journal of Physical Anthropology* 100: 531-544.

Greene, J.P. 1989. *Norton Priory: The Archaeology of a Medieval Religious House*. Cambridge: Cambridge University Press.

Greene, J.P. 2005. *Medieval Monasteries*. London: Continuum.

Green, M. 2010. 'Introduction.' In Kalof, L. (ed.), *A Cultural History of the Human Body in the Middle Ages*. Oxford: Berg: 1-16.

Grupe, G. 2001. 'Archaeological Microbiology.' In: Brothwell, D.R., and Pollard, A.M. (eds.), *Handbook of Archaeological Sciences*. Chichester: Wiley & Sons Ltd.: 351-358.

Grupe, G., Balzer, A., and Turban-Just, S. 2000. 'Modeling Protein Diagenesis in Ancient Bone: Towards a Validation of Stable Isotope Data.' In Ambrose, S.H., and Katzenberg, M.A. (eds.), *Biogeochemical Approaches to Paleodietary Analysis*. New York: Kluwer Academic/Plenum Publishers: 173-187.

Hall, D.W. 1987. 'St Nicholas Farm (St Andrews and St Leonards parish), leper hospital.' In Proudfoot, E.V.W. (ed.), *Discovery & Excavation in Scotland*. Edinburgh: The Council for British Archaeology in Scotland: 14.

Hamerow, H. 2002. *Early medieval settlements: the archaeology of rural communities in Northwest Europe 400-900*. Oxford: Oxford University Press.

Hamilton, S. 2011, 'Rites of passage and pastoral care.' In Crick, J., and van Houts, E. (eds.), *A Social History of England, 900-1200*. Cambridge: Cambridge University Press: 290-308.

Hammond, P. 2005. *Food & Feast in Medieval England*. Stroud: Sutton Publishing Ltd.

Hanawalt, B.A. 1977. 'Child Rearing Among the Lower Classes of Late Medieval England.' *Journal of Interdisciplinary History* 8: 20-22.

Harman, M. 1976. 'Human Skeletal Report.' In Chambers, R.A., and Boyle, A. *Excavations at Barrows Hills, Radley. Volume II: Romano-British Cemetery*. Unpublished report.

Harvey, B.F. 1993. *Living and dying in England, 1100-1540: the monastic experience*. Oxford: Oxford University Press.

Harvey, B.F. 2006. 'Monastic Pittances in the Middle Ages.' In Woolgar, C.M. (ed.), *Food in Medieval England: Diet and Nutrition*. Oxford: Oxford University Press: 215-227

Hassett, B.R. 2014. 'Missing Defects? A Comparison of Microscopic and Macroscopic Approaches to Identifying Linear Enamel Hypoplasia.' *American Journal of Physical Anthropology* 153: 463-472.

Heale, M. 2004. *The Dependent Priories of Medieval English Monasteries*. Studies in the History of Medieval Religion 22. Woodbridge: The Boydell Press.

Heath, P. 1973. *Bishop Blythe's Visitations*, Staffordshire Record Society, 4th series: 7.

Heaton, T.H.E. 1999. 'Spatial, Species, and Temporal Variations in the $^{13}C/^{12}C$ Ratios of C_3 Plants: Implications for Palaeodiet Studies.' *Journal of Archaeological Science* 26: 637-649.

Heaton, T.H.E., Vogel, J.C., von la Chevallerie, G., and Collett, G. 1986. 'Climatic influence on the isotopic composition of bone nitrogen.' *Nature* 322: 822-823.

Hedges, R.E.M. 2002. 'Bone diagenesis: an overview of processes.' *Archaeometry* 44: 319-328.

Hedges, R.E.M., Clement, J.G., David, C., Thomas, L., and O'Connell, T.C. 2007. 'Collagen Turnover in the Adult Femoral Mid-Shaft: Modeled From Anthropogenic Radiocarbon Tracer Measurements.' *American Journal of Physical Anthropology* 133: 808-816.

Henderson, D. 2008. 'The Human Remains from the Church and Graveyard.' In Lowe, C. (ed.), *Inchmarnock: an early historic island monastery and its archaeological landscape*. Edinburgh: Society of Antiquaries of Scotland: 209-221.

Henderson, D. 2011. 'Skeletal Assemblage.' In Hart, J., and Holbrook, N. (eds.), 'A medieval monastic cemetery within the precinct of Malmesbury Abbey: excavations at the Old Cinema Site, Market Cross.' *Wiltshire Archaeological & Natural History Magazine*, volume 104: 166-192.

Herren, M.W., and Brown, S.A. 2002. *Christ in Celtic Christianity: Britain and Ireland from the Fifth to the Tenth Century*. Woodbridge: The Boydell Press.

Hershkovitz, I., Latimer, B., Dutour, O., Jellema, L.M., Wish-Baratz, S., Rothschild, C., and Rothschild. B.M. 1997. 'Why do we fail in aging the skull from the sagittal suture?' *American Journal of Physical Anthropology* 103: 393-399.

Higgitt, J. 1982. 'The Pictish Latin inscription at Tarbat in Ross-Shire.' *Proceedings of the Societies of Antiquaries of Scotland* 112: 300-321.

Hill, P. 1997. *Whithorn and St Ninian: The Excavations of a Monastic Town, 1984-91*. Stroud: Sutton Publishing Ltd.

Hill, P. 2001. 'Whithorn, Latinus and the Origins of Christianity in Northern Britain.' In Hamerow, H., and MacGregor, A. (eds.), *Image and Power in the Archaeology of Early Medieval Britain. Essays in honour of Rosemary Cramp*. Oxford: Oxbow Books: 23-32.

Hillson, S.W. 1986. *Teeth*. Cambridge: Cambridge University Press.

Hillson, S.W. 1996. *Dental Anthropology*. Cambridge: Cambridge University Press.

Hines, J. 2003. 'Medieval Britain and Ireland in 2002: Editor's Note.' *Medieval Archaeology* 47: 199-200.

Hoefs, J. 1987. *Stable Isotope Geochemistry* (3rd edition). Berlin: Springer-Verlag.

Holick, M.F. 2004. 'Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease.' *American Journal of Clinical Nutrition* 80 (supplement): 1678S-1688S.

Holloway, J.B., and Kline, D.T. 2009. 'Literary and Cultural Contexts: Major Figures, Institutions, Topics, Events, Movements.' In Kline, D.T. (ed.), *The Medieval British Literature Handbook*. London: Continuum: 49-81.

Holmes, M. 2012a. Tarbat (TR98): *The Fish Bone*. Unpublished report.

Holmes, M. 2012b. Tarbat (TR98): *The Shellfish*. Unpublished report.

Holmes, M. 2014. *Animals in Saxon & Scandinavian England, Backbones of Economy and Society*. Leiden: Sidestone Press.

Holst, M. 2004. *Osteological Analysis Towton Hall & Towton Battlefield, Towton, North Yorkshire*. York Osteoarchaeology Ltd. Unpublished report.

Holst, M. 2005. *Osteological Analysis Main Street, Torksey, Lincolnshire*. York Osteoarchaeology Ltd. Unpublished report.

Holst, M. 2006. *Osteological Analysis St Andrew's, Corbridge, Northumberland*. York Osteoarchaeology Ltd. Unpublished report.

Holst, M., Isaac, L., Roberts, C., and Boylston, A. 2001. *Hull Magistrates' Court (HMC94): Report on the human skeletal remains*. Unpublished report for Humberside Archaeology Unit.

Holt, R.G. 1996. 'Effects of Air Pollution on the Upper Aerodigestive Tract.' *Otolaryngology-Head and Neck Surgery* 114 (2): 201-204.

Horrox, R. 1999. ‘Purgatory, prayer and plague: 1150-1380.’ In Jupp, P.C., and Gittings, C. (eds.), *Death in England: an illustrated history*. Manchester: Manchester University Press: 90-118.

Huber, M.A.S., Knottnerus, J.A., Green, L., van der Horst, H., Jadad, A.R., Kromhout, D., Leonard, B., Lorig, K., Loureiro, M.I., van der Meer, J.W.M., Schnabel, P., Smith, R., van Weel, C., and Smid, H. 2011. ‘How should we define health?’ *British Medical Journal* 343 (4163): 235-237.

Hubert, J. (ed.), 2000. *Madness, Disability and Social Exclusion. The archaeology and anthropology of ‘difference’*. One World Archaeology 40. Oxon: Routledge.

Hughes, K. 1981. ‘The Celtic Church: is this a valid concept?’ *Cambridge Medieval Celtic Studies* 1 (summer), 1-20.

Hunter Blair, P. 1990. *The World of Bede*. Cambridge: Cambridge University Press.

Hutton, R. 1993. *The Pagan Religions of the Ancient British Isles: their Nature and Legacy*. Oxford: Blackwell Publishing.

Hylson-Smith, K. 2000. *Christianity in England from Roman Times to the Reformation, Volume II: 1066 to 1384*. London: SCM Press.

IOSH Rural Industries Group 2014. *Managing cattle safely*: https://www.iosh.co.uk/Membership/Our-membership-network/Our-Groups/Rural-Industries-Group/Group-news/Managing-Cattle-Safely-Workshop.aspx. Accessed 27th January 2015.

İşcan, M.Y., and Loth, S.R. 1986. ‘Estimation of age and determination of sex from the sternal rib.’ In Reichs, K.J. (ed.), *Forensic Osteology*. Springfield: Charles C. Thomas: 68-89.

Jantz, R.L., Hunt, D.R., and Meadows, L. 1994. ‘Maximum length of the tibia: how did Trotter measure it?’ *American Journal of Physical Anthropology* 93: 525-528.

Jay, M., and Richards, M.P. 2007. ‘British Iron Age Diet: Stable Isotopes and Other Evidence.’ *Proceedings of the Prehistoric Society* 73: 169-190.

Jillings, K. 2010. ‘Plague, pox and the physician in Aberdeen, 1495–1516.’ *Journal of the Royal College of Physicians of Edinburgh* 40: 70-6.

Jim, S., Ambrose, S.H., and Evershed, R.P. 2004. ‘Stable carbon isotope evidence for differences in the dietary origin of bone cholesterol, collagen, and apatite: Implications for their use in palaeodietary reconstruction.’ *Geochimica et Cosmochimica Acta* 68 (1): 61-72.

Jiménez-Brobeil, S., Roca-Rodríguez, M., Al Oumaoui, I., and du Souich, P. 2012. 'Vertebral Pathologies and Related Activity Patterns in two Mediaeval Populations from Spain.' *Collegium Antropologicum* 36 (2): 521-527.

Jones, A.K.G. 1995. 'The Fish Material.' In Morris, C.D., Batey, C.E., and Rackham, D.J. (eds.), *Freswick Links, Caithness. Excavation and Survey of a Norse Settlement. North Atlantic Biocultural Organisation Monograph Number 1*. Stroud, Gloucestershire: Sutton Publishing Ltd.: 154-191.

Jotischky, A. 2011. *A Hermits Cookbook. Monks, Food and Fasting in the Middle Ages*. London: Continuum.

Joyce, T. 1998. *Celtic Christianity: a sacred tradition, a vision of hope*. New York: Orbis Books.

Judd, M.A., and Roberts, C.A. 1998. Fracture patterns at the medieval leper hospital in Chichester. *American Journal of Physical Anthropology* 105: 43-55.

Judd, M.A., and Roberts, C.A. 1999. 'Fracture trauma in a medieval British farming village.' *American Journal of Physical Anthropology* 109: 229-43.

Jurmain, R. 1990. 'Paleoepidemiology of a Central California Prehistoric Population From CA-ALA-329: II. Degenerative Disease.' *American Journal of Physical Anthropology* 83: 83-94.

Karamanos, E.E., Voroney, R.P., and Rennie, D.A. 1981. 'Variation in natural ^{15}N abundance of central Saskatchewan soils.' *Soil Science Society of America Journal* 45: 826-828.

Kardong, T.G. 1996. *Benedict's Rule: A Translation and Commentary*. Minnesota: The Liturgical Press.

Katzenberg, M.A. 1989. 'Stable isotope analysis of archaeological faunal remains from southern Ontario.' *Journal of Archaeological Science* 16: 319-329.

Katzenberg, M.A. 2000. 'Stable Isotope Analysis: A Tool for Studying Past Diet, Demography, and Life History.' In Katzenberg, M.A., and Saunders, S.T. (eds.), *Biological Anthropology of the Human Skeleton*. New York: Wiley-Liss Inc.: 305-327.

Katzenberg, M.A., Saunders, S.R., and Fitzgerald, W.R. 1993. 'Age differences in stable carbon and nitrogen isotope ratios in a population of prehistoric maize horticulturalists.' *American Journal of Physical Anthropology* 90: 267-281.

Katzenberg, M.A., Schwarcz, H.P., Knyf, M., and Melbye, F.J. 1995. 'Stable Isotope evidence for maize horticulture and palaeodiet in southern Ontario, Canada.' *American Antiquity* 60: 335-350.

Katzenberg, M.A., Herring, D.A., and Saunders, S.R. 1996. 'Weaning and Infant Mortality: Evaluating the Skeletal Evidence.' *Yearbook of Physical Anthropology* 39: 177-199.

Katzenberg, M.A., and Lovell, N.C. 1999. 'Stable Isotope Variation in Pathological Bone.' *International Journal of Osteoarchaeology* 9: 316-324.

Keene, D. 2001. 'Issues of water in medieval London to c.1300.' *Urban History* 28 (2): 161-179.

Kilbride, W.G. 2000. 'Why I feel cheated by the term 'Christianisation.'' In Pluskowski, A. (ed.), *Early Medieval Religion*, Archaeological Review from Cambridge, Volume 17 (2): 1-17.

King, S.E. 2000. *The human remains from Tarbat Old Church, Portmahomack: The Specialist Report.* Unpublished report.

Knudson, K.J, O'Donnabhain, B., Carver., C., Cleland, R., and Douglas Price, T. 2012. 'Migration and Viking Dublin: paleomobility and paleodiet through isotopic analyses.' *Journal of Archaeological Science* 39: 308-320.

Knüsel, C.J. 1999. 'Orthopaedic Disability: Some Hard Evidence.' In Finlay, N. (ed.), *Disability and Archaeology*. Archaeological Review from Cambridge 15 (2): 31-53.

Knüsel, C.J. 2007. 'Activity-related skeletal change.' In Fiorato, V., Boylston, A., and Knüsel, C. (eds.), *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461*. Oxford: Oxbow Books: 103-118.

Knüsel, C.J., Chundun, Z.C., and Cardwell, P. 1992. 'Slipped proximal femoral epiphysis in a priest from the medieval period.' *International Journal of Osteoarchaeology* 2 (2): 109-119.

Knüsel, C.J., Göggel, S., and Lucy, D. 1997. 'Comparative Degenerative Joint Disease of the Vertebral Column in the Medieval Monastic Cemetery of the Gilbertine Priory of St. Andrew, Fishergate, York, England.' *American Journal of Physical Anthropology* 103: 481-495.

Kock, J. T. and Minard, A. 2012. *The Celts: History, Life, and Culture*. Santa Barbara: ABC-CLIO. LLC.

Kosiba, S.B., Tykot, R.H., and Carlsson, D. 2007. 'Stable isotopes as indicators of change in the food procurement and food preference of Viking Age and Early Christian populations on Gotland (Sweden).' *Journal of Anthropological Archaeology* 26: 394-411.

Krogman. W.M., and M.Y. İşcan. 1986. *The Human Skeleton in Forensic Medicine* (2nd edition). Springfield: Charles C. Thomas.

Krueger, H.W., and Sullivan, C.H. 1984. 'Models for carbon isotope fractionation between diet and bone.' In Turnlund, J.F., and Johnson, P.E. (eds.), *Stable isotopes in nutrition:* 205–22. ACS Symposium Series 258, Washington: American Chemical Society.

Kwiatkowska, B., Gawlikowska, A., Szczurowski, J., Nowakowski, D., and Dzięciołowska-Baran, E. 2011. 'A case of concha bullosa mucopyelocele in a Medieval human skull.' *International Journal of Osteoarchaeology* 21: 367-370.

Lambert, P.M. 2012. 'Ethics and Issues in the Use of Human Skeletal Remains in Paleopathology.' In Grauer, A.L. (ed.), *A Companion to Paleopathology*. Chichester: Wiley-Blackwell: 17-33.

Larsen, C.S. 1999. *Bioarchaeology: interpreting behaviour from the human skeleton*. Cambridge: Cambridge University Press.

Lawrence, C.H. 1989. *Medieval monasticism. Forms of religious life in western Europe in the Middle Ages* (2nd edition). London: Longman Group.

Lee, C., 2008. 'Forever Young: Child burial in Anglo-Saxon England.' In: Lewis-Simpson, S. (ed.), *Viking Age: Perspectives on Youth and Age in the Medieval North*. Leiden: Brill: 17-36.

Lee, F., and Magilton, J. 1989. 'The Cemetery of the Hospital of St James and St Mary Magdalene, Chichester - A Case Study.' *World Archaeology* (*Archaeology of Public Health*) 21 (2): 273-282.

Lee-Thorp, J.A. 2002. 'Two decades of progress towards understanding fossilisation processes and isotopic signals in calcified tissue minerals.' *Archaeometry* 44: 435-46.

Lee-Thorp, J.A. 2008. 'On Isotopes and Old Bones.' *Archaeometry* 50 (6): 925-950.

Lee-Thorp, J.A., Sealy J.C., and van der Merwe, N.J. 1989. 'Stable carbon isotope ratio differences between bone collagen and bone apatite, and their relationship to diet.' *Journal of Archaeological Science* 16: 585-99.

Lee-Thorp, J.A., and Sealy, J. 2008. 'Beyond documenting diagenesis: The fifth international bone diagenesis workshop.' *Palaeogeography, Palaeoclimatology, Palaeoecology* 266: 129-133.

Lee-Thorp, J.A., and Sponheimer, M. 2006. 'Contribution of Biogeochemistry to Understanding Hominin Dietary Ecology.' *Yearbook of Physical Anthropology* 49: 131-148.

Lee-Thorp, J.A., and Sponheimer, M. 2007. 'Contribution of Stable Light Isotopes to Paleoenvironmental Reconstruction.' In Henke, W., Tattersall, I., and Hardt, T. (eds.), *Handbook of Paleoanthropology*. Berlin Heidelberg: Springer Verlag: 289-310.

Lee-Thorp, J.A., and van der Merwe, N.J. 1987. 'Carbon isotope analysis of fossil bone apatite.' *South African Journal of Science* 83: 712-15.

Lehane, J., and Delaney, F. (eds.) 2010. *Archaeological excavation report E3770 – Owenbristy, Co Galway. Cashel and burial ground*. Eachtra Archaeology Report 8.

Le Huray, J.D., and Schutkowski, H. 2005. 'Diet and social status during the La Tène period in Bohemia: Carbon and nitrogen stable isotope analysis of bone collagen from Kutná Hora-Karlov and Radovesice.' *Journal of Anthropological Archaeology* 24: 135-147.

Lester, A.E. 2006. 'Cares Beyond the Walls: Cistercian Nuns and the Care of Lepers in Twelfth-Century Northern France.' In Jamroziak, E., and Burton, J. (eds.), *Religious and Laity in Western Europe, 1000-1400: Interaction, Negotiation, and Power*. Belgium: Brepols: 197-224.

Lever, J.H. 2002. 'Paget's disease of bone in Lancashire and arsenic pesticide in cotton mill wastewater: a speculative hypothesis.' *Bone* 31: 434-436.

Lewicka, P.B. 2014. 'Diet as Culture. On the Medical Context of Food Consumption in the Medieval Middle East.' *History Compass* 12 (7): 607-617.

Lewis, C.P., and Thacker, A.T. 2003. 'Later medieval Chester 1230-1550: City government, 1230-1350.' In Lewis, C.P., and Thacker, A.T. (eds.), *A History of the County of Chester: Volume 5 Part 1, the City of Chester: General History and Topography*. London: 38-44. Published online: http://www.british-history.ac.uk/vch/ches/vol5/pt1/pp38-44. Accessed 9th March 2015.

Lewis, M.E. 2007. *The Bioarchaeology of Children: Perspectives from Biological and Forensic Anthropology*. Cambridge: Cambridge University Press.

Lewis, M.E. 2008. 'The Children.' In Magilton, J., Lee, F., and Boylston, A. (eds.), *'Lepers outside the Gate': excavations at the cemetery of the hospital of St. James and St. Mary Magdalene, Chichester 1986-7 and 1993*. York: Council for British Archaeology: 174-187.

Lewis, M.E. 2014. 'Sticks and Stones: Exploring the nature and significance of child trauma in the past.' In Knüsel, C., and Smith, M.J., (eds.), *The Routledge Handbook of the Bioarchaeology of Human Conflict*. London: Routledge: 39-63.

Lewis, M.E., Roberts, C.A., and Manchester, K. 1995. 'Comparative Study of the Prevalence of Maxillary Sinusitis in Late Medieval Urban and Rural Populations in Northern England.' *American Journal of Physical Anthropology* 98: 497-506.

Libby, W.F., Berger, R., Mead, J., Alexander, G., and Ross, J. 1964. 'Replacement rates for human tissue from atmospheric radiocarbon.' *Science* 146: 1170-1172.

Lillie, M.C. 1998. 'Cranial surgery dates back to Mesolithic.' *Nature* 391: 854.

Linderholm, A., Jonson, C.H., Svensk, O., and Lidén, K. 2008, 'Diet and status in Birka: stable isotopes and grave goods compared.' *Antiquity* 82: 446-461.

Loe, L., and Robson-Brown, K. 2005. 'Summary report on the human skeletons.' In Holbrook, N., and Thomas, A. (eds.), 'An Early-medieval Monastic Cemetery at Llandough, Glamorgan: Excavations in 1994.' *Medieval Archaeology* 49: 1-92.

Longin, R. 1971. 'New Methods of Collagen Extraction for Radiocarbon Dating.' *Nature* 230: 241-242.

Lovejoy, C., Meindl, R.S., Pryzbeck, T.R., and Mensforth, R.P. 1985. 'Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age.' *American Journal of Physical Anthropology* 68: 15-28.

Lovell, N.C. 1994. 'Spinal Arthritis and Physical Stress at Bronze Age Harappa.' *American Journal of Physical Anthropology* 93: 149-164.

Lovell, N.C. 1997. 'Trauma Analysis in Paleopathology.' *Yearbook of Physical Anthropology* 40: 139-170.

Lovell, N.C., Nelson, D.E., and Schwarcz, H.P. 1986. 'Carbon isotope ratios in palaeodiet, lack of age or sex effect.' *Archaeometry* 28: 51-55.

Lucas, A.T. 1967. 'The Plundering and Burning of Churches in Ireland, 7^{th} to 16^{th} Century.' In Rynne, E. (ed.), *North Munster Studies: Essays in commemoration of Monsignor Michael Moloney*. Limerick: Thomond Archaeological Society: 172-229.

Lucock, M. 2004. 'Is folic acid the ultimate functional food component for disease prevention?' *British Medical Journal* 328: 211-214.

Lukacs. J.R. 1989. 'Dental paleopathology: methods for reconstructing dietary patterns.' In Iscan, M.Y., and Kennedy, K.A.R. (eds.): *Reconstruction of Life from the Skeleton*. New York: Alan R. Liss, Inc.: 261-286.

Lynn, C. 2003. *Navan Fort: Archaeology and Myth*. Co. Wicklow: Wordwell, Bray.

Lynn, C., McSparron, C., and Moore, P. 2003. *CAF Data Structure Report No. 13: Navan Fort, Co. Armagh.* Queen's University Belfast: Centre for Archaeological Fieldwork: School of Archaeology and Palaeoecology.

MacKenzie, F.T. 1998. *Our Changing Planet: An Introduction to Earth System Science and Global Environmental Change*. New Jersey: Prentice-Hall Inc.

McConnaughey, T., and McRoy, C.P. 1979. 'Food-web structure and the fractionation of carbon isotopes in the Bering sea.' *Marine Biology* 53: 257-262.

McKinley, J. 1993. *Inhumation burials from Tidworth, Salisbury Plain. Human bone report*. Unpublished report.

McLaughlan, T. 1865. *The Early Scottish Church: Ecclesiastical History of Scotland, from the First to the Twelfth Century*. Edinburgh: T. & T. Clark.

McNeill, P.G.B., and MacQueen, H.L. (eds.) 1996. *Atlas of Scottish History to 1707*. Edinburgh: The Scottish Medievalists and Department of Geography, University of Edinburgh.

Magilton, J. 2008a. 'Leprosy, lepers and their hospitals.' In Magilton, J., Lee, F., and Boylston, A. (eds.), *'Lepers outside the Gate': excavations at the cemetery of the hospital of St. James and St. Mary Magdalene, Chichester 1986-7 and 1993*. York: Council for British Archaeology: 9-26.

Magilton, J. 2008b. 'A history of the hospital.' In Magilton, J., Lee, F., and Boylston, A. (eds.), '*Lepers outside the Gate': excavations at the cemetery of the hospital of St. James and St. Mary Magdalene, Chichester 1986-7 and 1993*. York: Council for British Archaeology: 57-68.

Magnusson, R.J. 2001. *Water technology in the Middle Ages: cities, monasteries and waterworks after the Roman Empire*. Baltimore: The Johns Hopkins University Press.

Maldonado, A.D. 2011. *Christianity and burial in late Iron Age Scotland, AD 400-650*. Unpublished PhD thesis, University of Glasgow.

Malim, T., Hines, J., and Duhig, C. 1998. *The Anglo-Saxon Cemetery at Edix Hill (Barrington A), Cambridgeshire: Excavations, 1989-1991 and a Summary Catalogue of Material from 19th Century Interventions*. York: Council for British Archaeology.

Manchester, K., and Roberts, C.A. 1986. *Palaeopathological evidence of leprosy and tuberculosis in Britain*. Bradford: University of Bradford. Unpublished SERC report (Grant 337.367).

Maresh, M.M. 1970. 'Measurements from roentgenograms, heart size, long bone lengths, bone, muscles and fat widths, skeletal maturation.' In McCammon, R.W. (ed.), *Human growth and development*. Springfield: Charles C. Thomas: 155-200.

Mariotti,V., Facchini, F., and Giovanna Belcastro, M. 2004. 'Enthesopathies – Proposal of a Standardized Scoring Method and Applications.' *Collegium Antropologicum* 28 (1): 145-159.

Martin, D.L., Harrod, R.P., and Pérez, V.R. 2013. *Bioarchaeology: An Integrated Approach to Working with Human Remains. Manuals in Archaeological Method, Theory and Technique*. New York: Springer.

Mary Evans Picture Library. *Celtic monks farming*: http://www.maryevans.com/search.php?src=look&pic=10050277. Accessed 16th September 2014.

Marzke, M.W., and Marzke, R.F. 1987. 'The Third Metacarpal Styloid Process in Humans: Origin and Functions.' *American Journal of Physical Anthropology* 73: 415-431.

Mate, M.E. 2006. 'Work and leisure.' In Horrox, R., and Ormrod, W.M. (eds.), *A Social History of England, 1200-1500*. Cambridge: Cambridge University Press: 276-292.

Mays, S. 1989. *The Anglo-Saxon human bone report from School Street, Ipswich, Suffolk. English Heritage Ancient Monuments Laboratory Report 115/89*, Portsmouth: English Heritage, Centre for Archaeology. Unpublished report.

Mays, S. 1991. *The medieval burials from the Blackfriars friary, School Street, Ipswich, Suffolk. English Heritage Ancient Monuments Laboratory Report, 16/91, Part 1*. Portsmouth: English Heritage, Centre for Archaeology.

Mays, S. 1996. 'Healed Limb Amputations in Human Osteoarchaeology and their Causes: a Case Study from Ipswich, UK.' *International Journal of Osteoarchaeology* 6: 101-113.

Mays, S. 1997. 'Carbon Stable Isotope Ratios in Mediaeval and Later Human Skeletons From Northern England.' *Journal of Archaeological Science* 24: 561-567.

Mays, S. 2000. 'Biodistance Studies using Craniometric Variation in British Archaeological Skeletal Material.' In Cox, M., and Mays, S. (eds.), *Human Osteology in Archaeology and Forensic Science*. Cambridge: Cambridge University Press: 277-288.

Mays, S. 2006a. 'A Possible Case of Surgical Treatment of Cranial Blunt Force Injury from Medieval England.' *International Journal of Osteoarchaeology* 16: 95-103.

Mays, S. 2006b. 'The Osteology of Monasticism in Medieval England.' In Gowland R., and Knüsel, C.K. (eds.), *Social Archaeology of Funerary Remains*. Oxford, Oxbow: 179-189.

Mays, S. 2006c. ‘Spondylolysis, Spondylolisthesis, and Lumbo-Sacral Morphology in a Medieval English Skeletal Population.’ *American Journal of Physical Anthropology* 131: 352-362.

Mays, S., Crane-Kramer, G., and Bayliss, A. 2003. ‘Two Probable Cases of Treponemal Disease of Medieval Date From England.’ *American Journal of Physical Anthropology* 120: 133-143.

Mays, S., Fysh, E., and Taylor, G.M. 2002. ‘Investigation of the Link Between Visceral Surface Rib Lesions and Tuberculosis in a Medieval Skeletal Series From England Using Ancient DNA.’ *American Journal of Physical Anthropology* 119: 27-36.

Mays, S., Maat, G.J.R., and de Boer, H.H. 2013. ‘Scurvy as a factor in the loss of the 1845 Franklin expedition to the Arctic: a reconsideration.’ *International Journal of Osteoarchaeology* DOI: 10.1002/oa.2305.

Mays, S., Mavrogordato, M., Lambert, J., and Sofaer, J. 2014. ‘The Prevalence and Health Implications of Concha Bullosa in a Population from Mediaeval England.’ *International Journal of Osteoarchaeology* 24: 614-622.

Meindl, R.S., and Lovejoy, C.O. 1985. ‘Ectocranial suture closure: A revised method for the determination of skeletal age at death based on the lateral-anterior sutures.’ *American Journal of Physical Anthropology* 68: 57-66.

Meindl, R.S., Lovejoy, C.O., Mensforth, R.P., and Carlos, L.D. 1985. ‘Accuracy and determination of error in the sexing of the skeleton.’ *American Journal of Physical Anthropology* 68: 79-85.

Menzies, L. 2009. *St Columba of Iona*. Charleston: BiblioLife LLC.

Metzler, I. 2011. ‘Disability in the Middle Ages: Impairment at the Intersection of Historical Inquiry and Disability Studies.’ *History Compass* 9 (1): 45-60.

Milis, L.J.R. 1992. *Angelic Monks and Earthly Men. Monasticism and its meaning to medieval society*. Woodbridge: The Boydell Press.

Minagawa, M., and Wada, E. 1984. ‘Stepwise enrichment of ^{15}N along food chains: Further evidence and the relation between δ^{15}N and animal age.’ *Geochimica et Cosmochimica Acta 48*: 1135-1140.

Modzelewski, K. 2008. *Dietary Analysis of an Early Historical Southeastern Scottish Population*. Unpublished MA Thesis, The University of Reading.

Møller-Christensen, V. 1953. *Ten Lepers from Naevstead in Denmark*. Copenhagen: Danish Science Press.

Molleson, T., Cruse, K., and Mays, S. 1998. ‘Some Sexually Dimorphic Features of the Human Juvenile Skull and their Value in Sex Determination in Immature Remains.’ *Journal of Archaeological Science* 25: 719-728.

Montgomery, J., Müldner, G., and Cook, G. 2009. ‘Isotope Analysis of Bone Collagen and Tooth Enamel.’ In Lowe, C. (ed.), *Clothing for the Soul Devine: Burials at the Tomb of St Ninian, Excavations at Whithorn Priory, 1957-67*. Historic Scotland Archaeology Report no.3: 65-82.

Moorrees, C.F.A., Fanning, E.A., and Hunt, E.E. 1963a. ‘Formation and Resorption of Three Deciduous Teeth in Children.’ *American Journal of Physical Anthropology* 21: 205-213.

Moorrees, C.F.A., Fanning, E.A., and Hunt, E.E. 1963b. ‘Age Variation of Formation Stages for Ten Permanent Teeth.’ *Journal of Dental Research* 42 (6): 1490-1502.

Morton, R.S. 1962. ‘Some aspects of the early history of syphilis in Scotland.’ *British Journal of Venereal Diseases* 38: 175-180.

Müldner, G., Montgomery, J., Cook, G., Ellam, R., Gledhill, A., and Lowe, C. 2009. ‘Isotopes and individuals: diet and mobility among the medieval Bishops of Whithorn.’ *Antiquity* 83: 1-15.

Müldner, G., and Richards, M.P. 2005. ‘Fast or feast: reconstructing diet in later medieval England by stable isotope analysis.’ *Journal of Archaeological Science* 32: 39-48.

Müldner, G., and Richards, M.P. 2007a. ‘Stable Isotope Evidence for 1500 Years of Human Diet at the City of York, UK.’ *American Journal of Physical Anthropology* 133 (1): 682-697.

Müldner, G., and Richards, M.P. 2007b. ‘Diet and Diversity at Later Medieval Fishergate: The Isotopic Evidence.’ *American Journal of Physical Anthropology* 134 (2): 162-174.

Mulhern, D.M., and Jones, E.B. 2005. ‘Test of revised method of age estimation from the auricular surface of the ilium.’ *American Journal of Physical Anthropology* 126: 61-65.

Mulligan, M.E. 2000. ‘Myeloma and lymphoma.’ *Seminars in Musculoskeletal Radiology* 4 (1): 127-135.

Murray, M.L., and Schoeninger, M.J. 1988. ‘Diet, Status, and Complex Social Structure in Iron Age Central Europe: Some Contributions of Bone Chemistry.’ In Gibson, D.B., and Geselowitz, M.N. (eds.), *Tribe and Polity in Late Prehistoric Europe. Demography, Production, and Exchange in the Evolution of Complex Social Systems*. New York: Plenum Press: 155-176.

Myers, A.R. 1995. *English historical documents IV: 1327–1485* (2nd edition). London: Routledge.

Mytum, H. 1992. *The Origins of Early Christian Ireland*. London: Routledge.

Mytum, H. 2003. 'Surface and geophysical survey at Clonmacnoise: defining the extent of intensive monastic settlement.' In King, H. (ed.), *Clonmacnoise Studies 2*. Dublin: Duchás: 35-58.

Natural England. *National Character Area Profile: Mersey Valley*: http://publications.naturalengland.org.uk/file/5757459629080576. Accessed 13th January 2015.

Nelson, W. (ed.). 1956. *A Fifteenth Century Schoolbook*. Oxford: Clarendon.

Newhauser, R. 2013. 'John Gower's Sweet Tooth.' *The Review of English Studies, New Series*, 64 (267): 752-769.

Novak, S.A. 2007. 'Battle-Related Trauma.' In Fiorato, V., Boylston, A. and Knüsel, C. (eds.), *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* (2nd edition). Oxford: Oxbow Books: 90-102.

Novak, M., and Šlaus, M. 2011. 'Vertebral pathologies in two early modern period (16th-19th century) populations from Croatia.' *American Journal of Physical Anthropology* 145: 270-281.

O'Connell, T.C., and Hedges, R.E.M. 1999. 'Investigations into the effect of diet on modern human hair isotopic values.' *American Journal of Physical Anthropology* 108: 409-425.

O'Connor, T. 2000. *The archaeology of animal bones*. Stroud: Sutton Publishing Ltd.

Ó Cróinín, D. 2013. *Early Medieval Ireland* 400-1200. Oxon: Routledge.

O'Floinn, R. 1989. 'Secular Metalwork in the Eighth and Ninth Centuries.' In Young, S. (ed.), *The Work of Angels*. Austin: University of Texas Press: 72-124.

O'Sullivan, D. 2001. 'Space, Silence and Shortage on Lindisfarne. The Archaeology of Asceticism.' In Hamerow, H., and MacGregor, A. (eds.), *Image and Power in the Archaeology of Early Medieval Britain. Essays in honour of Rosemary Cramp*. Oxford: Oxbow Books: 33-52.

Ogden, A. 2008. 'Dental Health and Disease.' In Brown, F., and Howard-Davies, C. (eds.), *Norton Priory: Monastery to Museum, Excavations 1970-87*. Lancaster Imprints 16: 183-195.

Ogden, M.S. 1971. *The Cyrurgie of Guy de Chauliac*. Oxford: Oxford University Press. Early English Text Society 265.

Online Etymology Dictionary. *Monastery*: http://www.etymonline.com/index.php?search=monastery&searchmode=none. Accessed 29th April 2014.

Online Etymology Dictionary. *Disability*: http://www.etymonline.com/index.php?search=disability. Accessed 28th August 2014.

OR3D Scan: www.OR3D.co.uk. Accessed 12th January 2015.

Ortner, D.J. 2003. *Identification of Pathological Conditions in Human Skeletal Remains* (2nd edition). London: Academic Press.

Ortner, D.J., and Mays, S. 1989. 'Dry-bone manifestations of rickets in infancy and early childhood.' *International Journal of Osteoarchaeology* 8: 45-55.

Ortner, D.J., Butler, W., Cafarella, J., and Milligan, L. 2001. 'Evidence of Probably Scurvy in Subadults from Archaeological Sites in North America.' *American Journal of Physical Anthropology* 114: 343-351.

Oxford Archaeology North. *Furness Abbey, Cumbria*: http://oxfordarchaeology.com/featured-projects-by-name/226-furness-abbey-cumbria. Accessed 4th July 2014.

Oxford, Bodleian Library, Laud Misc. 482, fol. 26b: Frantzen, A.J., *The Anglo-Saxon Penitentials. A Cultural Database*: http://www.anglo-saxon.net/penance/index.php?p=index. Accessed 4th July 2014.

Pagnani, M., Mathis, C., and Solman, C. 2006. 'Painful os acromiale (or unfused acromial apophysis) in athletes.' *Journal of Shoulder and Elbow Surgery* 15: 432-435.

Patrick, P. 2014. *The 'Obese Medieval Monk': A multidisciplinary study of a stereotype*. BAR British Series 590. Oxford: Archaeopress.

Pearson, J.A. 2004. *Ancient diet in Neolithic Anatolia: Isotopic analyses of biological remains and their archaeological implications*. Unpublished PhD thesis, University of Oxford.

Pearson, J., Grove, M., Özbek, M., and Hongo, H. 2013. 'Food and social complexity at Çayönü Tepesi, southeastern Anatolia: Stable isotope evidence of differentiation in diet according to burial practice and sex in the early Neolithic.' *Journal of Anthropological Archaeology* 32: 180-189.

Pearson, J., Hillson, S., Haddow, S., Knüsel, C., Larsen, C.S., and Sadvari, J. Forthcoming. 'Stable carbon and nitrogen isotope analysis and dietary reconstruction through the life course at Neolithic Çatalhöyük, Turkey.' *Journal of Social Archaeology*.

Pearson, K. 1917-1919. 'A study of the long bones of the English skeleton I: The femur.' *University of London, University College, Department of Applied Statistics, Company research, Memoirs, Biometric Series X*, chapters 1-4.

Pearson, K.L. 1997. 'Nutrition and the Early-Medieval Diet.' *Speculum* 72 (1): 1-32.

Pfister, C., Schwarz-Zanetti, G., and Wegmann, M. 1996. 'Winter severity in Europe: the fourteenth century.' *Climatic Change* 34: 91-108.

Phenice, T.W. 1969. 'A newly developed visual method of sexing the os pubis.' *American Journal of Physical Anthropology* 30: 297-301.

Pickles, T. 2009. 'Church Organization and Pastoral Care.' In Stafford, P. (ed.), *A Companion to the Early Middle Ages: Britain and Ireland, c.500-1100,* Blackwell Companions to British History. Chichester: Wiley-Blackwell: 160-176.

Plomp, K.A., Roberts, C.A., and Viðarsdóttir, U.S. 2012. 'Vertebral Morphology Influences the Development of Schmorl's Nodes in the Lower Thoracic Vertebrae.' *American Journal of Physical Anthropology* 149: 572-582.

Polet, C., and Katzenberg, M.A. 2003. 'Reconstruction of the diet in a mediaeval monastic community from the coast of Belgium.' *Journal of Archaeological Science* 30: 525-533.

Porter, R. 1987. *Disease, Medicine and Society in England 1550-1860,* Studies in Economic and Social History. London: Macmillan Publishers Ltd.

Prendergast, T.J., and Ruoss, S.J. 2006. 'Pulmonary Disease.' In McPhee, S., and Ganong, W.F. (eds.), *Pathophysiology of Disease: An Introduction to Clinical Medicine* (5th edition). New York: McGraw-Hill: 218-258.

Prescher, A. 2001. 'Some remarks on the human accessory carpal bones.' In Vogel, R., Fanghänel, J., and Koppe, Th. (eds.), *Proceedings on the 10th Teratology Symposium: Greifswald, September 23-25, 1999.* Marburg: Tectum Verlag: 111-115.

Price, R., and Ponsford, M. 1998. *St Bartholomew's Hospital, Bristol: the excavation of a medieval hospital 1976-8*. York: Council for British Archaeology.

Privat, K.L., O'Connell, T.C., and Richards, M.P. 2002. 'Stable Isotope Analysis of Human and Faunal Remains from the Anglo-Saxon Cemetery at Berinsfield, Oxfordshire: Dietary and Social Implications.' *Journal of Archaeological Science* 29: 779-790.

Pryce, H. 2009. 'Conversions to Christianity.' In Stafford, P. (ed.), *A Companion to the Early Middle Ages: Britain and Ireland, c.500-1100,* Blackwell Companions to British History. Chichester: Wiley-Blackwell: 143-159.

Quintelier, K., Ervynck, A., Müldner, G., Van Neer, W., Richards, M.P., and Fuller, B.T. 2014. 'Isotopic Examination of Links Between Diet, Social Differentiation, and DISH at the Post-Medieval Carmelite Friary of Aalst, Belgium.' *American Journal of Physical Anthropology* 153: 203-213.

Ralston, I.B.M., and Armit, I. 1997. 'The Early Historic Period: An Archaeological Perspective.' In Edwards, K.J., and Ralston, I.B.M. (eds.), *Scotland: Environment and Archaeology, 8000 BC – AD 1000*. Edinburgh: Edinburgh University Press: 217-239.

Rawcliffe, C. 2002. ''Written in the Book of Life': Building the Libraries of Medieval English Hospitals and Almshouses.' *The Library* 7th series, 3: 127-162.

Rawcliffe, C. 2006. *Leprosy in Medieval England*. Woodbridge: The Boydell Press.

Rawcliffe, C. 2011. 'Medical Practice and Theory.' In Crick, J., and van Houts, E. (eds.), *A Social History of England, 900-1200*. Cambridge: Cambridge University Press: 391-401.

Resnick, D., and Niwayama, G. 1976. 'Radiographic and pathologic features of spinal involvement in diffuse idiopathic skeletal hyperostosis (DISH).' *Radiology* 119: 559–568.

Resnick, D., and Niwayama, G. 1988. *Diagnosis of Bone and Joint Disorders* (2nd edition). Philadelphia: W B Saunders Co.

Richards, M.P. 2000. 'Stable isotope analysis in archaeology: A short introduction.' *The Archaeologist* 38. Reading: Institute of Field Archaeologists (IFA).

Richards, M.P., Fuller, B.T., and Molleson, T.I. 2006. 'Stable isotope palaeodietary study of humans and fauna from the multi-period (Iron Age, Viking and Late Medieval) site of Newark Bay, Orkney.' *Journal of Archaeological Science* 33: 122-131.

Richards M.P., and Hedges, R.E.M. 1999. 'Stable Isotope Evidence for Similarities in the Types of Marine Foods Used by Late Mesolithic Humans at Sites Along the Atlantic Coast of Europe.' *Journal of Archaeological Science* 26: 717-722.

Richards, M.P., Mays, S.A., and Fuller, B.T. 2002. 'Stable Carbon and Nitrogen Isotope Values of Bone and Teeth Reflect Weaning Age at the Medieval Wharram Percy Site, Yorkshire, UK.' *American Journal of Physical Anthropology* 119: 205-210.

Rider, C. 2010. 'Lay religion and pastoral care in thirteenth century England: the evidence of a group of short confession manuals.' *Journal of Medieval History* 36: 327-340.

Rigby, S.H. 2003. *A companion to Britain in the later Middle Ages*. Oxford: Blackwell Publishers Ltd.

Ring, M.E. 1985. *Dentistry: an illustrated history*. New York: Abrams Mosby.

Ritchie, D., Shaver, J.C., Anderson, R.B., Lawrence, S.J., and Mair, S.D. 2011. 'Excision of Symptomatic Nonunions of Proximal Fifth Metatarsal Avulsion Fractures in Elite Athletes.' *American Journal of Sports Medicine* 39: 2466-2469.

Ritchie, G., and Ritchie, A. 1991. *Scotland: archaeology and early history*. Edinburgh: Edinburgh University Press.

Robb, J., Bigazzi, R., Lazzarini, L., Scarsini, C., and Sonego, F. 2001. 'Social ''status'' and biological ''status'': a comparison of grave goods and skeletal indicators from Pontecagnano.' *American Journal of Physical Anthropology* 115: 213-222.

Roberts, C.A. 1986 'Leprosy and Leprosaria in Medieval Britain.' *Museum for Applied Science Center for Archaeology Journal* 4: 15-21.

Roberts, C.A. 2000. 'Did they take sugar? The use of skeletal evidence in the study of disability in past populations.' In Hubert, J. (ed.), *Madness, Disability and Social Exclusion. The archaeology and anthropology of 'difference'*. One World Archaeology 40. Oxon: Routledge: 46-59.

Roberts, C.A. 2002. 'The antiquity of leprosy in Britain: The skeletal evidence.' In Roberts, C.A., Lewis, M.E., and Manchester, K. (eds.), British Archaeological Reports International Series 1054: *The past and present of leprosy. Archaeological, historical, palaeopathological and clinical approaches. International Congress on the Evolution and palaeoepidemiology of the infectious diseases 3 (ICEPID), 26th-31st July 1999*. Bradford University, Oxford: Archaeopress: 213-222.

Roberts, C.A. 2007. 'A bioarchaeological study of maxillary sinusitis.' *American Journal of Physical Anthropology* 133: 792-807.

Roberts, C.A. 2009. 'Health and welfare in medieval England: the human skeletal remains contextualised.' In Gilchrist, R., and Reynolds, A. (eds.), *Reflections: 50 years of medieval archaeology, 1957-2007*. Leeds: Maney: 307-325.

Roberts, C.A. 2011. 'The bioarchaeology of leprosy and tuberculosis: a comparative study of perceptions, stigma, diagnosis and treatment.' In Agarwal, S.C., and Glencross, B.A. (eds.), *Social bioarchaeology*. Chichester: Wiley-Blackwell: 252-281.

Roberts, C.A., Boylston, A., Buckley, L., Chamberlain, A.C., and Murphy, E.M. 1998. 'Rib lesions and tuberculosis: the palaeopathological evidence.' *Tubercle and Lung Disease* 79 (1): 55-60.

Roberts, C.A., and Buikstra, J.E. 2003. '*The bioarchaeology of tuberculosis: a global perspective on a re-emerging disease*.' Gainesville: University Press of Florida.

Roberts, C., and Connell, B. 2004. 'Guidance on recording palaeopathology.' In Brickley, M., and McKinley, J.I. (eds.), *Guidelines to the Standards for Recording Human Remains*. IFA Paper No. 7. BABAO and the Institute of Field Archaeologists: 34-39.

Roberts, C.A., and Cox, M. 2003. *Health and Disease in Britain: From Prehistory to the Present Day*. Stroud: Sutton Publishing Ltd.

Roberts, C.A., Knüsel, C.J., and Race, L. 2004. 'A Foot Deformity from a Romano-British Cemetery at Gloucester, England, and the Current Evidence for *Talipes* in Palaeopathology.' *International Journal of Osteoarchaeology* 14: 389-403.

Roberts, C.A., Lucy, D., and Manchester, K. 1994. 'Inflammatory Lesions of Ribs: An Analysis of the Terry Collection.' *American Journal of Physical Anthropology* 95: 169-182.

Roberts, C.A., and McKinley, J. 2003. 'Review of trepanations in British antiquity focusing on funerary context to explain their occurrence.' In Arnott, R., Finger, S., and Smith, C.U.M. (eds.), *Trepanation. History, discovery, theory*. Lisse: Swets and Zeitlinger: 56-78.

Roberts C.A., and Manchester, K. 2005. *The Archaeology of Disease* (3rd edition). New York: Cornell University Press.

Roberts, J. 2000. 'Human skeletal remains.' In Atkinson, J.A. (ed.), 'Excavation of 10th-century burials at Chapelhall, Innellan, Argyll, 1994.' Edinburgh: *Society of Antiquaries of Scotland* 130: 651-676.

Rogers, J., and Waldron, T. 1995. *A Field Guide to Joint Disease in Archaeology*. Chichester: John Wiley & Sons Ltd.

Rogers, J., and Waldron, T. 2001. 'DISH and the Monastic Way of Life.' *International Journal of Osteoarchaeology* 11: 357-365.

Rogers, J., Jeffrey, D.R., and Watt, I. 2002. 'Paget's Disease in an Archaeological Population.' *Journal of Bone and Mineral Research* 17 (6): 1127-1134.

Rosen, G. 1993. *A History of Public Health* (expanded edition). Baltimore, Maryland: The Johns Hopkins University Press.

Rutherford, A., and Ritchie, J.N.G. 1974 'The Catstane.' *Proceedings of the Society of Antiquaries of Scotland*, 105: 183-8.

Sager, P. 1969. *Spondylosis cervicalis. Årsberetn, Københavns Univs Medic.-Hist. Inst. Mus*., 1968-69: [185]-24. Thesis summary in English and Danish.

Saunders, S.R. 1989. 'Non-metric variation.' In Işcan, M.Y., and Kennedy, K.A.R. (eds.), *Reconstruction of Life from the Skeleton*. New York: 95-108.

Saunders, S.R. 2008. 'Juvenile Skeletons and Growth-Related Studies.' In: Saunders, S.R., and Katzenberg, A.M. (eds.), *Biological Anthropology of the Human Skeleton* (2nd edition). New Jersey: Wiley-Liss: 117-147.

Schaefer, M., Black, S.M., and Scheuer, L. 2009. *Juvenile Osteology: A Laboratory and Field Manual*. Elsevier, London.

Scheuer, L. 2002. 'Brief Communication: A Blind Test of Mandibular Morphology for Sexing Mandibles in the First Years of Life.' *American Journal of Physical Anthropology* 119: 189-191.

Scheuer, J.L., Musgrave, J.H., and Evans, S.P. 1980. 'The estimation of late fetal and perinatal age from limb bone length by linear and logarithmic regression.' *Annals of Human Biology* 7 (3): 257-265.

Scheuer, J.L., and MacLaughlin-Black, S. 1994. 'Age estimation from the Pars Basilaris of the fetal and juvenile occipital bone.' *International Journal of Osteoarchaeology* 4: 377-380.

Scheuer, L., and Black, S. 2000. *Developmental Juvenile Osteology*. London: Academic Press.

Schoeller, D.A. 1999. 'Isotope fractionation: Why aren't we what we eat?' *Journal of Archaeological Science* 26: 667-673.

Schoeninger, M.J. 1985. 'Trophic Level Effects on $^{15}N/^{14}N$ and $^{13}C/^{12}C$ Ratios in Bone Collagen and Strontium Levels in Bone Mineral.' *Journal of Human Evolution* 14: 515-525.

Schoeninger, M.J. and DeNiro, M.J. 1984. 'Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals.' *Geochimica et Cosmochimica Acta* 48: 625-539.

Schoeninger, M.J., DeNiro, M.J., and Tauber, H. 1983. 'Stable Nitrogen Isotope Ratios of Bone Collagen Reflect Marine and Terrestrial Components of Prehistoric Human Diet.' *Science* 220: 1381-1383.

Schultz, R.M., and Liebmann, L.M. 1997. 'Proteins I: composition and structure.' In Devlin, T.M. (ed.), *Textbook of Biochemistry with Clinical Corrections*. New York: Wiley Liss: 23-83.

Schurr, M.R., and Schoeninger, M.J. 1995. 'Associations between agricultural intensification and social complexity: an example from the prehistoric Ohio Valley.' *Journal of Anthropological Archaeology* 14: 315-339.

Schutkowski, H. 1993. 'Sex Determination of Infant and Juvenile Skeletons: I. Morphognostic Features.' *American Journal of Physical Anthropology* 90: 199-205.

Schutkowski, H. 2008. 'Thoughts for food: evidence and meaning of past dietary habits.' In Schutkowski, H. (ed.), *Between Biology and Culture*. Cambridge: Cambridge University Press: 141-164.

Schutkowski, H., Herrmann, B., Wiedemann, F., Bocherens, H., and Grupe, G. 1999. 'Diet, status and decomposition at Weingarten: Trace element and isotope analyses on early medieval skeletal material.' *Journal of Archaeological Science* 26: 629-636.

Schwarcz, H.P. 2000. 'Some Biochemical Aspects of Carbon Isotopic Paleodiet Studies.' In Ambrose, S.H., and Katzenberg, M.A. (eds.), *Biogeochemical Approaches to Paleodietary Analysis.* Advances in Archaeological and Museum Science, Volume 5. New York: Kluwer Academic/Plenum Publishers: 189-209.

Schwarcz, H.P., and Schoeninger, M.J. 1991. 'Stable Isotope Analyses in Human Nutritional Ecology.' *Yearbook of Physical Anthropology* 34: 283-321.

Sealy, J. 2001. 'Body tissue chemistry and palaeodiets.' In: Brothwell, D.R., and Pollard, A.M. (eds.), *Handbook of Archaeological Sciences*. Chichester: Wiley and Sons: 269-279.

Sealy, J., van der Merwe, N.J., Lee-Thorp, J.A., and Lanham, J.L. 1987. 'Nitrogen isotopic ecology in southern Africa: Implications for environmental and dietary tracing.' *Geochimica et Cosmochimica Acta* 51: 2707-2717.

Seetah, K. 2011. *Assessment of Animal Bones from Tarbat, Portmahomack, Ross-Shire*. Faunal report prepared for the Tarbat Discovery Programme. York: FAS Heritage. Unpublished report.

Sellen, D.W., and Smay, D.B. 2001. 'Relationship Between Subsistence and Age at Weaning in "Preindustrial" Societies.' *Human Nature* 12 (1): 47-87.

Serjeantson, D., and Woolgar, C.M. 2006. 'Fish Consumption in Medieval England.' In Woolgar, C.M., Serjeantson, D., and Waldron, T. (eds), *Food in Medieval England: Diet and Nutrition*. Oxford: Oxford University Press: 102-130.

Sharpe, R. 1995. *Adomnán of Iona. Life of St Columba* (translation with notes). London: Penguin Books.

Sharp, Z. 2007. *Principles of Stable Isotope Geochemistry*. New Jersey: Pearson Prentice Hall.

Sheppard, F.H.W. (ed.). 1957. 'The Priory of St. Mary Spital', In *Survey of London: Volume 27, Spitalfields and Mile End New Town*: 21-23. Published online: http://www.british-history.ac.uk/survey-london/vol27/pp21-23. Accessed 20th February 2015.

Sherley-Price, L., (trans). 1990. *Bede: Ecclesiastical History of the English People, with Bede's letter to Egbert and Cuthbert's letter on the death of Bede*. Revised by Latham, R.E. Translation of the minor works, new introduction and notes by Farmer, D.H. London: Penguin Books.

Sillen, A., Sealy, J.C. and van der Merwe, N.J. 1989. 'Chemistry and Paleodietary Research: No More East Answers.' *American Antiquity* 54 (3): 504-512.

Sinclair, J. 1791-9. *The [Old] Statistical Account of Scotland*, 21 volumes. Edinburgh.

Singman, J.L. 1999. *Daily Life in Medieval Europe*. Westport, Connecticut: The Greenwood Press.

Smith, B.H. 1984. 'Patterns of molar wear in hunter-gatherers and agriculturalists.' *American Journal of Physical Anthropology* 63: 39-56.

Smith, H.B. 1991. 'Standards of Human Tooth Formation and Dental Age Assessment.' In Kelley, M.A., and Larsen, C.S. (eds.), *Advances in Dental Anthropology*. New York: Wiley-Liss: 143-168.

Smith, L.B. 2012. *Henry VIII*. Stroud, Gloucestershire: Amberley Publishing.

Smyth, A.P. 1984. *Warlords and holy men, Scotland 80-1000*. Edinburgh: Edinburgh University Press.

Sofaer Derevenski, J. 2000. 'Sex Differences in Activity-Related Osseous Change in the Spine and the Gendered Division of Labor at Ensay and Wharram Percy, UK.' *American Journal of Physical Anthropology* 111: 333-354.

Sofaer, J. 2011. 'Towards a Social Bioarchaeology of Age.' In Agarwal, S.C., and Glencross, B.A. (eds.), *Social Bioarchaeology,* Blackwell Studies in Global Archaeology. Chichester: Wiley-Blackwell: 285-311.

Spencer, C. 2000. 'Food and Drink around the World: The British Isles.' In Kiple, K.F., and Ornelas, K.C. (eds.), *The Cambridge World History of Food,* Volume 2. Cambridge: Cambridge University Press: 1218-1223.

Spencer, R. 2008. *Testing hypotheses about diffuse idiopathic skeletal hyperostosis (DISH) using stable isotope and aDNA analysis of late medieval British populations.* Unpublished PhD thesis, Durham University.

Spencer, R. 2009. 'Stable Isotope Analysis of DISH and Diet.' In Baker, S., Gray, A., Lakin, K., Madgwick, R., Poole, K., and Sandias, M. (eds.), *Food and Drink in Archaeology 2*. University of Nottingham Postgraduate Conference 2008. Devon: Prospect Books: 90-97.

Sponheimer, M., and Lee-Thorp, J.A. 1999. 'Alteration of Enamel Carbonate Environments during Fossilization.' *Journal of Archaeological Science* 26: 143-150.

Sponheimer, M., Robinson, T., Ayliffe, L., Roeder, B., Hammer, J., Passey, B., West, A., Cerling, T., Dearing, D., and Ehleringer, J. 2003. 'Nitrogen Isotopes in Mammalian Herbivores: Hair $\delta^{15}N$ Values from a Controlled Feeding Study.' *International Journal of Osteoarchaeology* 13: 80-87.

Stavely, K., and Fitzgerald, K. 2004. *America's founding food: the story of New England cooking*. North Carolina: The University of North Carolina Press.

Steinbock, R.T. 1976. *Paleopathological Diagnosis and Interpretation*. Springfield: Charles C. Thomas.

Stenhouse, M.J., and Baxter, M.S. 1979. 'The uptake of bomb ^{14}C in humans.' In Berger, R., and Suess, H. (eds.), *Radiocarbon Dating*. Berkeley: University of California Press: 324-341.

Stewart, T.D. 1979. *Essentials of forensic anthropology*. Springfield: Charles C. Thomas.

Stirland, A.J. 1991. 'Diagnosis of occupationally related palaeopathology: can it be done?' In Ortner, D.J., and Aufderheide, A.C. (eds.), *Human paleopathology: current syntheses and future options*. Washington: Smithsonian Institution Press: 40-47.

Stirland, A.J. 1993. *Asymmetry and Activity-related Change in Selected Bones of the Human Male Skeleton*. Unpublished PhD Thesis, University College London.

Stirland, A.J. 1994. 'Evidence for pre-Columbian treponematosis in medieval Europe.' In Dutour, O., Pálfi, G., Berato, J., and Brun, J.-P. (eds.), *The origins of syphilis in Europe, before or after 1493?*' Toulon, Centre Archéologique du Var, Paris, France: 109-115.

Stirland, A. 2000. *Raising the dead: the skeleton crew of Henry VIII's great ship, the Mary Rose*. Chichester: John Wiley.

Stöber, K., 2006. 'Bequests and Burials: Changing Attitudes of the Laity as Patrons of English and Welsh Monasteries.' In Jamroziak, E., and Burton, J. (eds.), *Religious and Laity in Western Europe, 1000-1400: Interaction, Negotiation, and Power.* Belgium: Brepols: 131-146.

Stroud, G. 1993. 'The Human Bones.' In Stroud, G., and Kemp, R.L. (eds.), *Cemeteries of the Church and Priory of St Andrew, Fishergate*. York: Council for British Archaeology: 160-241.

Stuart-Macadam, P. 1985. 'Porotic hyperostosis: representative of a childhood condition.' *American Journal of Physical Anthropology* 66: 391-398.

Sugar Nutrition UK. 2011. *The history of sugar*: http://www.sugarnutrition.org.uk/history-of-sugar.aspx. Accessed 10th September 2014.

Tan, A., and Ralston, S.H. 2014. 'Paget's disease of bone.' *QJM: An International Journal of Medicine*. Oxford: Oxford University Press: 1-5.

Tan, S.Y., and Brown, J. 2006. 'Rudolph Virchow (1821-1902): "pope of pathology"' *Singapore Medical Journal* 47 (7): 567-568.

Tanner, N., and Watson, S. 2006. 'Least of the laity: the minimum requirements for a medieval Christian.' *Journal of Medieval History* 32: 395-423.

Tauber, H. 1981. '^{13}C evidence for dietary habits of prehistoric man in Denmark.' *Nature* 292: 332-333.

The Joint Nature Conservation Committee (JNCC), 2009: http://www.jncc.gov.uk/ProtectedSites/SACselection/sac.asp?EUCode=UK0019806. Accessed 20th December 2014.

Thomas, C. 1981. *Christianity in Roman Britain to AD 500*. Los Angeles: University of California Press.

Thomas, C. 1991-2. 'The Early Christian Inscriptions of Southern Scotland.' *Glasgow Archaeological Journal* 17: 1-10.

Thomas, R.M. 2007. 'Food and the Maintenance of Social Boundaries in Medieval England.' In Twiss, K. (ed.), *The Archaeology of Food and Identity*. Southern Illinois University: Centre for Archaeological Investigations Carbondale, Occasional Paper No. 34: 130-151.

Threlfall-Holmes, M. 2005. *Monks and Markets: Durham Cathedral Priory 1460-1520*. Oxford: Oxford University Press.

Tieszen, L.L., Boutton, T.W., Tesdahl, K.G., and Slade, N.A. 1983. 'Fractionation and turnover of stable carbon isotopes in animal tissues: Implications for δ^{13}C analysis of diet.' *Oecologia* 57: 32-37.

Tieszen, L.L., and Fagre, T. 1993. 'Effect of diet Quality and Composition on the Isotopic Composition of Respiratory CO_2, Bone Collagen, Bioapitite and Soft Tissues.' In Lambert, J., and Grupe, G. (eds.), *Prehistoric Human Bone: Archaeology at the Molecular Level*. New York: Springer-Verlag: 121-155.

Trotter, M. 1970. 'Estimation of stature from intact limb bones.' In Stewart, T.D. (ed.), *Personal identification in mass disasters*. Washington: National Museum of Natural History, Smithsonian Institution: 71-83.

Trotter, M., and Gleser, G.C. 1952. 'Estimation of stature from long bones of American whites and Negroes.' *American Journal of Physical Anthropology* 10: 463-514.

Trotter, M., and Gleser, G.C. 1958. 'A re-evaluation of estimation of stature taken during life and of long bones after death.' *American Journal of Physical Anthropology* 16: 79-123.

Turkel, S. 1989. 'Congenital abnormalities in skeletal populations.' In İşcan, M.Y., and Kennedy, K.A.R. (eds.), *Reconstruction of life from the skeleton*. New York: Alan Liss: 109-127.

Tuross, N. 2003. 'Recent Advances in Bone, Dentin, and Enamel Biochemistry.' In Ortner, D.J. (ed.), *Identification of Pathological Conditions in Human Skeletal Remains*. London: Academic Press: 65-72.

Ubelaker, D.H. 1989. *Human Skeletal Remains: excavation, analysis, interpretation*. Manuals on Archaeology 2 (2nd edition). Washington: Taraxacum.

Ubelaker, D.H. 2008. *Human Skeletal Remains: excavation, analysis, interpretation* (paperback edition). New Brunswick, New Jersey: Aldine Transaction.

Ubelaker, D.H., and Volk, C.G. 2001. 'A test of the Phenice method for the estimation of sex.' *Journal of Forensic Sciences* 47 (1): 19-24.

UK map of Scotland, 2008: http://commons.wikimedia.org/wiki/File:Uk_map_scotland.png. Accessed 6th February 2015.

Urbanczyk, P. 1998. 'Christianization of Early Medieval Societies: an Anthropological Perspective.' In Crawford, B.E. (ed.), *Conversion and Christianity in the North Sea World*. Fife: University of St Andrews: 129-133.

Valentin, J. (ed.). 2003. *Basic anatomical and physiological data for use in radiological protection: reference values*. ICRP publication 89: International Commission on Radiological Protection. Oxford: Pergamon.

van der Merwe, N.J. 1982. 'Carbon Isotope Photosynthesis and Archaeology.' *American Scientist* 70: 596-606.

van der Merwe, N.J., and Vogel, J.C. 1978. '^{13}C content of human collagen as a measure of prehistoric diet in Woodland North America.' *Nature* 276: 815-16.

van Klinken, G.J. 1999. 'Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements.' *Journal of Archaeological Science* 26: 687-695.

van Klinken, G.J., and Hedges, R.E.M. 1995. 'Experiments on Collagen–Humic Interactions: Speed of Humic Uptake, and Effects of Diverse Chemical Treatments.' *Journal of Archaeological Science* 22: 263-270.

van Klinken, G.J., Richards, M.P., and Hedges, R.E.M. 2000. 'An Overview of Causes for Stable Isotopic Variations in Past European Human Populations: Environmental, Ecophysiological, and Cultural Effects.' In Ambrose, S.H., and Katzenberg, M.A. (eds.), *Biogeochemical Approaches to Paleodietary Analysis*. New York: Kluwer Academic/Plenum Publishers: 39-63.

Veitch, K. 1997. 'The Columban Church in northern Britain, 664-717: a reassessment.' *Proceedings of the Society of Antiquities Scotland* 127: 627-647.

Villotte, S., Castex, D., Couallier, V., Dutour, O., Knüsel, C.J., and Henry-Gambier, D. 2010. 'Enthesopathies as Occupational Stress Markers: Evidence From the Upper Limb.' *American Journal of Physical Anthropology* 142: 224-234.

Vincent, S., and Mays, S. 2009. *Huntingdon Castle Mound, Cambridgeshire: Osteological Analysis of the Huntingdon Castle Population*. Research Department Report Series (unpublished) No. 8-2009. Portsmouth: English Heritage: 1-79.

Visconti, M.R., Langston, A.L., Alonso, N., Goodman, K., Selby, P.L., Fraser, W.D., and Ralston, R.H. 2010 'Mutations of SQSTM1 Are Associated With Severity and Clinical Outcome in Paget Disease of Bone.' *Journal of Bone and Mineral Research* 25 (11): 2368-2373.

Vitousek, P.M., Aber, J., Howarth, R.W., Likens, G.E., Matson, P.A., Schindler, D.W., Schlesinger, W.H., and Tilman, G.D. 1997. 'Human Alteration of the Global Nitrogen Cycle: Causes and Consequences.' *Issues in Ecology* 1: 2-16.

Vogel, J.C., and van der Merwe, N.J. 1977. 'Isotopic evidence for early maize cultivation in New York State.' *American Antiquity* 42: 238–42.

Wada, E., and Hattori, A. 1976. 'Natural abundance of ^{15}N in particulate organic matter in the North Pacific Ocean.' *Geochimica et Cosmochimica Acta* 12: 97-102.

Wakely, J., Strouhal, E., Vyhnánek, L., and Němečková, A. 1998. 'Case of a Malignant Tumour from Abingdon, Oxfordshire, England.' *Journal of Archaeological Science* 25: 949-955.

Waldron, T. 1985. 'DISH at Merton Priory: evidence for a "new" occupational disease?' *British Medical Journal* 291: 1762-1763.

Waldron, T. 1993. *The Human Remains from the Royal Mint Site (MIN86).* London: MoLAS archival report HUM/REP/07/93. Unpublished report.

Waldron, T. 1994. *Counting the Dead: The Epidemiology of Skeletal Populations*. Chichester: Wiley & Sons.

Waldron, T. 2000. 'Hidden or overlooked? Where are the disadvantaged in the skeletal record?' In Hubert, J. (ed.), *Madness, Disability and Social Exclusion. The archaeology and anthropology of 'difference'*. One World Archaeology 40. Oxon: Routledge: 29-45.

Waldron, T. 2007. *St Peter's, Barton-upon-Humber, Lincolnshire, Volume 2. The Human Remains*. Oxford: Oxbow Books.

Waldron, T. 2009. *Palaeopathology*. Cambridge Manuals in Archaeology. Cambridge University Press.

Waldron, T. 2012. 'Joint Disease.' In Grauer, A.L. (ed.), *A Companion to Paleopathology*. Chichester: Wiley-Blackwell: 513-530.

Walker, P.L., Bathurst, R.R., Richman, R., Gjerdrum, T., and Andrushko, V.A. 2009. 'The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis.' *American Journal of Physical Anthropology* 139: 109-125.

Wang, Y., and Cerling, T.E. 1994. 'A model of fossil tooth and bone diagenesis: implications for paleodiet reconstruction from stable isotopes.' *Palaeogeography, Palaeoclimatology, Palaeoecology* 107: 281-9.

Ward, S.W. 2000. *Chester Cathedral Song School*. Chester Archaeology evaluation. Unpublished report.

Warner, R.B. 1990. 'The 'prehistoric' Irish annals: fable or history.' *Archaeology Ireland* 4 (1): 30-33.

Washburn, S.L. 1951. 'The new physical anthropology.' *Transactions of the New York Academy of Sciences* 13: 298-304.

Waterman, D.W., and Lynn, C.J. 1997. *Excavations at Navan Fort 1961–71*. Belfast: The Stationery Office.

Watkins, C. 2011. 'Religion and Belief.' In Crick, J., and van Houts, E. (eds.), *A Social History of England, 900-1200*. Cambridge: Cambridge University Press: 265-289.

Watson, W.J. 1904. *Place Names of Ross and Cromarty*. Inverness: The Northern Counties Printing and Publishing Company Limited.

Weiss, E., and Jurmain, R. 2007. 'Osteoarthritis Revisited: A Contemporary Review of Aetiology.' *International Journal of Osteoarchaeology* 17: 437-450.

Wellcome Images: http://wellcomeimages.org/indexplus/page/Home.html. Accessed 30th August 2014 and 27th February 2015.

Welle, S. 1999. *Human Protein Metabolism*. New York: Springer-Verlag.

Wells, C. 1964. *Bones, bodies, and disease: Evidence of disease and abnormality in early man*. London: Thames and Hudson.

Wells, C. 1967. 'A leper cemetery at South Acre, Norfolk.' *Medieval Archaeology* 11: 242-248.

Weston, D.A. 2012. 'Nonspecific Infection in Paleopathology: Interpreting Periosteal Reactions.' In Grauer, A.L. (ed.), *A Companion to Paleopathology*. Chichester: Wiley-Blackwell: 492-512.

White, T.D., and Folkens, P.A. 2005. *The Human Bone Manual*. London: Elsevier Academic Press.

WHO. 2006. *Constitution of the World Health Organization*: http://www.who.int/governance/eb/who_constitution_en.pdf. Accessed 3rd September 2014.

Wiggins, R., Boylston, A., and Roberts, C. 1993. *The human skeletal remains from Blackfriars, Gloucester*. The University of Bradford. Unpublished report.

Williams, J. 1860. *Annales Cambriae*. London: Longman and Roberts.

Williams, D.H. 2001. *The Welsh Cistercians: Written to Commemorate the Centenary of the Death of Stephen William Williams (1837-1899), the Father of Cistercian Archaeology in Wales* (3rd edition), Herefordshire: Gracewing.

Wishart, A.W. 2009. *A Concise History of Monks and Monasteries*. Haines City: Revelation Insight.

Wood, I. 1994. 'The Mission of Augustine of Canterbury to the English.' *Speculum* 69: 1-17.

Wood, J., George, W., Milner, R., Harpending, H.C., and Weiss, K.M. 1992. 'The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples.' *Current Anthropology* 33: 343-370.

Woolf, A. 2007. *From Pictland to Alba: 789-1070*. The New Edinburgh History of Scotland Volume 2. Edinburgh: Edinburgh University Press.

Woolf, A. 2009. 'Scotland.' In Stafford, P. (ed.), *A Companion to the Early Middle Ages: Britain and Ireland, c.500-c.1100*. Chichester: Wiley-Blackwell: 251-267.

Woolgar, C.M. 1999. *The Great Household in Late Medieval England*. New Haven: Yale University Press.

Woolgar, C.M. 2000. 'Take this penance now, and afterwards the fare will improve: seafood and late medieval diet.' In Starkey, D.J., Reid, C., and Ashcroft, N., (eds.), *England's Sea Fisheries: the Commercial Sea Fisheries of England and Wales since 1300*. Chatham, London: 36-44.

Woolgar, C.M. (ed.), 2006. *Food in Medieval England: Diet and Nutrition*. Oxford: Oxford University Press.

Woolgar, C.M. 2006. 'Meat and Dairy Products in Late Medieval England.' In Woolgar, C.M. (ed.), *Food in Medieval England: Diet and Nutrition*. Oxford: Oxford University Press: 88-101.

Woolgar, C.M. 2010. 'Food and the Middle Ages.' *Journal of Medieval History* 36: 1-19.

Wormald, J.M. 1980. 'Bloodfeud, Kindred and Government in Early Modern Scotland.' *Past and Present* 87: 54-97.

Wormald, P. 2006. 'Bede and the 'Church of the English'.' In Baxter, S. (ed.), *The Times of Bede*. Oxford: Blackwell Publishing: 207-28.

Wright, D. 2011. *Geoffrey Chaucer: The Canterbury Tales* (new verse translation). Introduction and notes by Cannon, C. Oxford World's Classics. Oxford: Oxford University Press.

Yeoman, P. 1995. *Medieval Scotland*. London: B.T. Batsford Ltd/Historic Scotland.

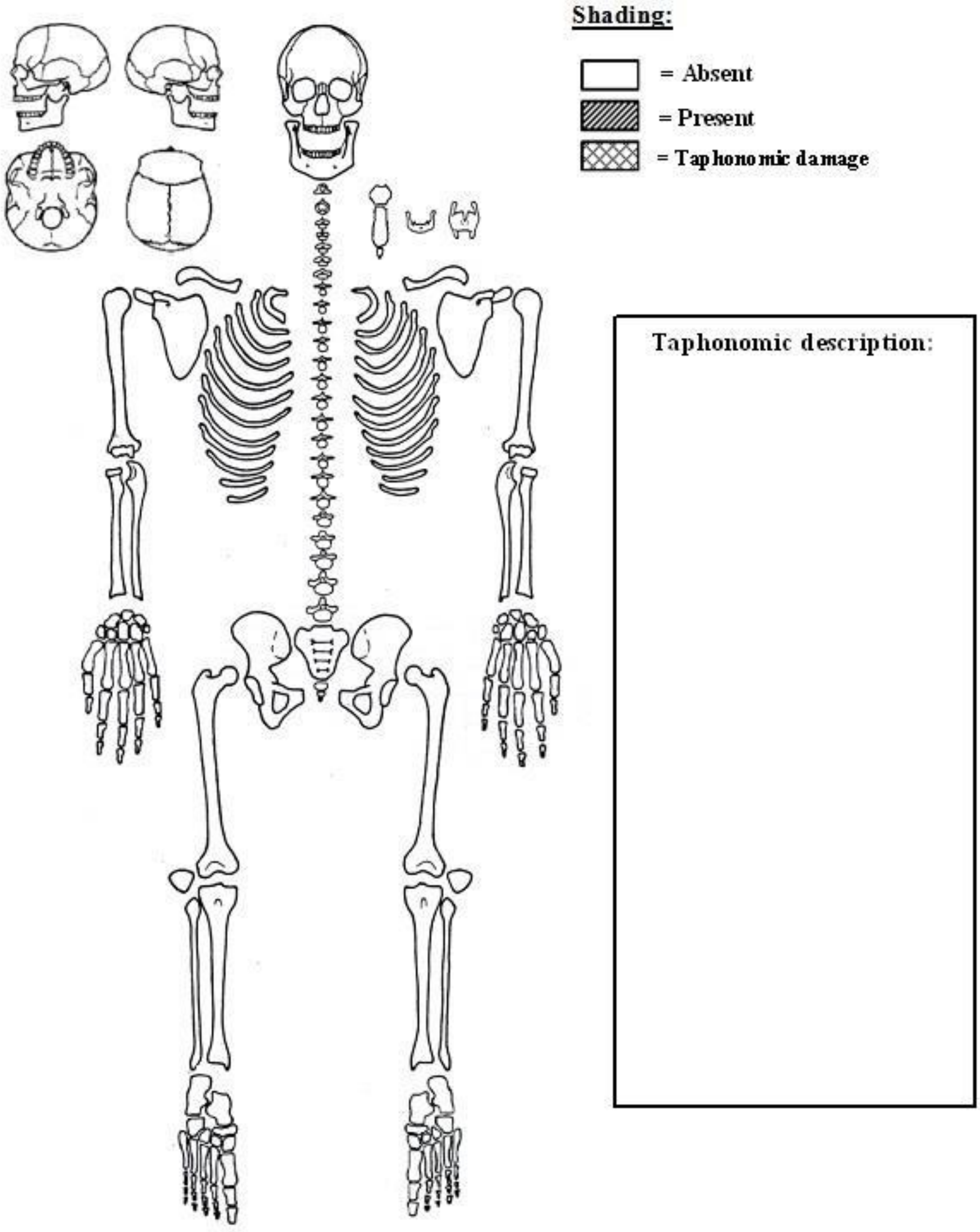
Yorke, B. 2006. *The conversion of Britain: Religion, politics, and society in Britain, c.600-800*. Harlow: Pearson Education Ltd.

Zakrzewski, S.R. 2003. 'Variation in Ancient Egyptian Stature and Body Proportions.' *American Journal of Physical Anthropology* 121: 219-229.

Zakrzewski, S.R. 2011. 'Population migration, variation and identity: an Islamic population in Iberia.' In Agarwal, S.C., and Glencross, B.A. (eds.), *Social Bioarchaeology,* Blackwell Studies in Global Archaeology. Chichester: Wiley-Blackwell, 183-211.

APPENDICES

Appendix 1a: Adult skeleton schematic inventory



Appendix 1b: Skeleton inventory form

Bone	L	R	Bone	L	R
SKULL:					
Frontal			Sphenoid		
Parietal			Lacrimal		
Occipital			Zygomatic		
Temporal			Palatine		
Nasal			Maxilla		
Ethmoid			Mandible		
No. unidentified fragments =					
POSTCRANIAL:					
Clavicle			**OS COXAE**		
Scapula Body			Ilium		
Glenoid Fossa			Ischium		
Patella			Pubis		
Sacrum			Acetabulum		
Coccyx			Auricular Surface		
Sternum					
No. unidentified fragments:					

Completeness scoring:

0 = Absent
1 = > 75% present = complete
2 = 50-75% present = partial
3 = 25-50% present = partial
4 = < 25% present = poor

HANDS	L	R	Unsided
Carpals			
Metacarpals			
Phalanges			
FEET	**L**	**R**	**Unsided**
Tarsals			
Metatarsals			
Phalanges			

VERTEBRAE:

Vertebra	Centrum	Neural Arch	Vertebra	Centrum	Neural Arch
C1			L1		
C2			L2		
C7			L3		
T1			L4		
T10			L5		
T11			**No. unidentified fragments:**		
T12					

RIBS	L	R	Unsided
1st			
2nd			
11th			
12th			
No. Head fragments			
No. Shaft fragments			
No. Unidentified fragments:			

LONG BONES	Proximal Epiphysis	Proximal Third	Middle Third	Distal Third	Distal Epiphysis
Humerus (L)					
Humerus (R)					
Radius (L)					
Radius (R)					
Ulna (L)					
Ulna (R)					
Femur (L)					
Femur (R)					
Tibia (L)					
Tibia (R)					
Fibula (L)					
Fibula (R)					
No. unidentified fragments:					

Comments:

Appendix 1c: Adult sex, age and stature estimation

SEX ESTIMATION: OS COXAE	Score
Sub-pubic concavity	
Ventral arc	
Ischiopubic ramus	
Greater sciatic notch	
Preauricular sulcus	
Sub-pubic angle	
ESTIMATED SEX:	

SEX ESTIMATION: SKULL	Score
Nuchal crest/occipital protuberance	
Mastoid process	
Supra-orbital margin	
Supra-orbital ridge/glabella	
Mental eminence	
Gonial flare	
ESTIMATED SEX:	

Sex estimation scores (After Buikstra & Ubelaker 1994)

U = unobservable
1 = female
2 = probable female
3 = ambiguous sex
4 = probable male
5 = male

SEX ESTIMATION: *OSTEOMETRICS*	Measurement (mm)	M/F
Formula:		
Max clavicle length (m = > 150mm, f = <138mm)		
Glenoid cavity width (m = > 29mm, f = < 26mm)		
Humeral vertical head diameter (m = > 47mm, f = < 44.9mm)		
Humerus epicondylar breadth (m = > 60.1mm, f = < 60.1mm)		
Femoral head diameter (m = > 48mm, f = <43mm)		
Femoral epicondylar breadth (m = > 76mm, f = <74mm)		
ESTIMATED SEX:		

Comments:

OVERALL SEX: ____________________

ADULT AGE ESTIMATION

ADULT AGEING METHODS	Element/ side used	Score/ Phase	Mean age (or range)
Dental attrition			
Pubic symphysis			
Auricular surface			
Sternal rib ends			

Adult age categories:

Adult	= 18+
Young adult	= 18-25
Young middle adult	= 26-35
Old middle adult	= 36-45
Mature adult	= 46-59
Old adult	= 60+

AGE CATEGORY: ____________________

STATURE ESTIMATE: ____________________ BONE(S)/SIDE USED: ____________________

Appendix 1d: Post-cranial measurements

Bone	Measurement	R (mm)	L (mm)
Clavicle			
Pc1	Max/Diaphyseal Length		
Pc2	AP Diameter at Midshaft		
Pc3	SI Diameter at Midshaft		
Scapula			
Pc4	Height		
Pc5	Breadth		
Pc6	Glenoid Cavity Width		
Humerus			
Pc7	Max/Diaphyseal Length		
Pc8	Epicondylar Breadth		
Pc9	Vertical Head Diameter		
Pc10	Max Diameter at Midshaft		
Pc11	Min Diameter at Midshaft		
Pc12	Least Circumference of Shaft		
Radius			
Pc13	Max/Diaphyseal Length		
Pc14	AP Diameter at Midshaft		
Pc15	ML Diameter at Midshaft		
Pc16	Max Head Diameter		
Ulna			
Pc17	Max/Diaphyseal Length		
Pc18	AP Diameter		
Pc19	ML Diameter		
Pc20	Physiological Length		
Pc21	Minimum Circumference		
Sacrum			
Pc22	Anterior Length		
Pc23	Anterior Superior Breadth		
Pc24	Max Transverse Diameter of Base		
Os Coxae			
Pc25	Height		
Pc26	Iliac Breadth		
Pc27	Pubis Length		
Pc28	Ischium Length		

Bone	Measurement	R (mm)	L (mm)
Femur			
Pc29	Max/Diaphyseal Length		
Pc30	Bicondylar Length		
Pc31	Epicondylar Breadth		
Pc32	Max Head Diameter		
Pc33	Subtroch AP Diameter		
Pc34	Subtroch ML Diameter		
Pc35	Midshaft AP Diameter		
Pc36	Midshaft ML Diameter		
Pc37	Midshaft Circumference		
Tibia			
Pc38	Max/Diaphyseal Length		
Pc39	Max Prox Epiphyseal Breadth		
Pc40	Max Distal Epipyseal Breadth		
Pc41	AP Diameter at Nutrient Foramen		
Pc42	ML Diameter at Nutrient Foramen		
Pc43	Circumference at Nutrient Foramen		
Fibula			
Pc44	Max/Diaphyseal Length		
Pc45	Max Diameter at Midshaft		
Patella			
Pc46	Max Width		
Pc47	Max Length		
Calcaneus			
Pc48	Max Length		
Pc49	Middle Breadth		
Pc50	Body height		
Talus			
Pc51	Max Length		
Pc52	Max Width		
Pc53	Max Height		

Appendix 1e: Cranial measurements

No.	Measurement (code)	mm		No.	Measurement (code)	mm	
C1	Maximum Length (g-op)			C18	Biorbital Breadth (ec-ec)		
C2	Maximum Breadth (eu-eu)			C19	Interorbital Breadth (d-d)		
C3	Bizygomatic Diameter (zy-zy)			C20	Frontal Chord (n-b)		
C4	Basion-Bregma Height (ba-b)			C21	Parietal Chord (b-l)		
C5	Cranial Base Length (ba-n)			C22	Occipital Chord (l-o)		
C6	Basion-Prosthion Length (ba-pr)			C23a	Foramen Magnum Length (ba-o)		
C7	Maxilloalveolar Breadth (ecm-ecm)			C23b	Foramen Magnum Breadth (-)		
C8	Maxilloalveolar Length (pr-alv)			C24	Mastoid Length (-)	**R:**	**L:**
C9	Biauricular Breadth (au-au)			C25	Symphysis (Chin) Height (id-gn)		
C10	Total Facial Height (n-gn)			C26	Height of Mandibular Body (-)		
C11	Upper Facial Height (n-pr)			C27	Breadth of Mandibular Body (-)		
C12	Minimum Frontal Breadth (ft-ft)			C28	Bigonial Width (go-go)		
C13	Upper Facial Breadth (fmt-fmt)			C29	Bicondylar Breadth (cdl-cdl)		
C14	Nasal Height (n-ns)			C30	Minimum Ramus Breadth (-)		
C15	Nasal Breadth (al-al)			C31	Maximum Ramus Breadth (-)		
C16	Orbital Breadth (d-ec)	**R:**	**L:**	C32	Maximum Ramus Height (-)		
C17	Orbital Height (-)	**R:**	**L:**				

Appendix 1f: Non-metric traits

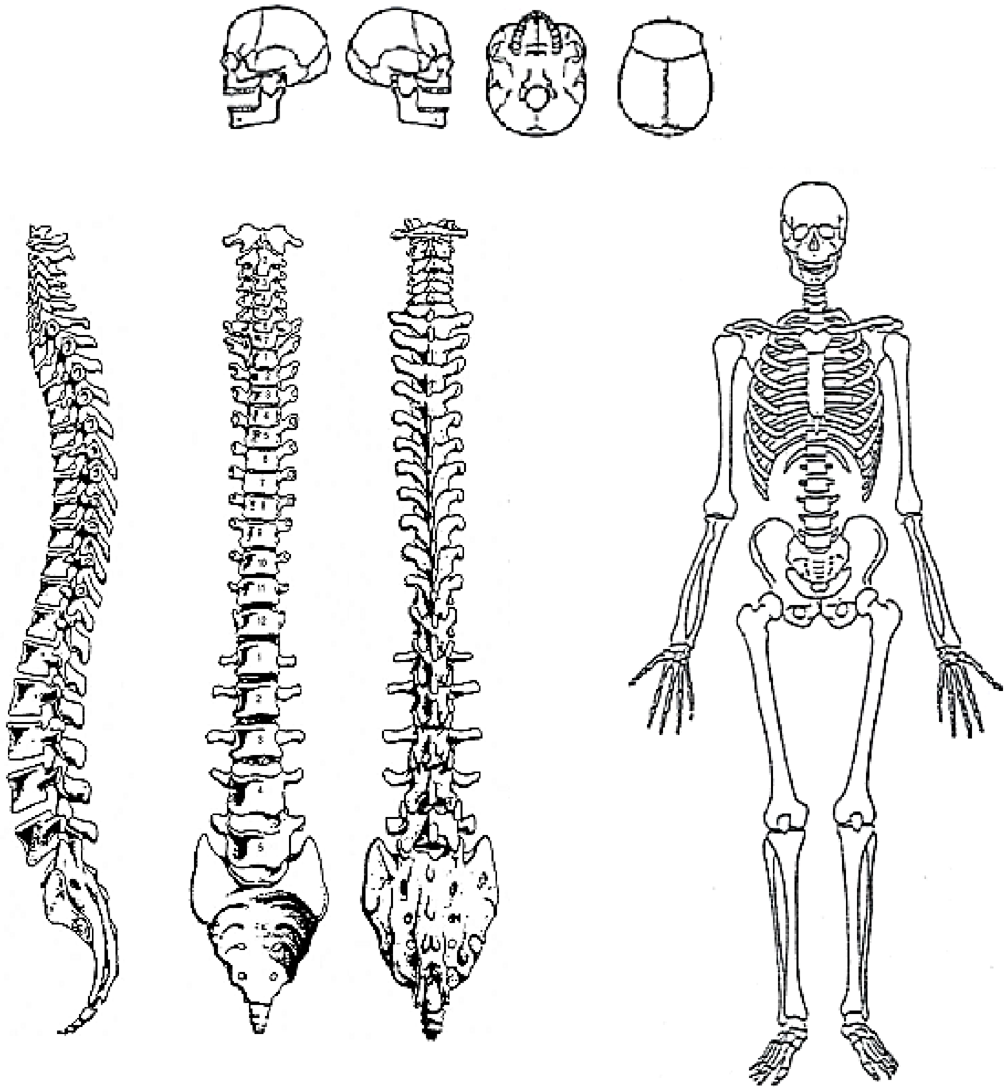
Scoring: A = absent, P = present, U = unobservable, / = Bone absent					
Cranial trait	**R**	**L**	**Post-cranial trait**	**R**	**L**
Ossicle at lambda			Allen's fossa		
Bregmatic bone			Poirier's facet		
Metopism			Hypotrochanteric fossa		
Lambdoid ossicles			Exostosis: trochanteric fossa		
Parietal foramen			Third trochanter		
Coronal ossicle			Medial tibial squatting facet		
Epipteric bone			Lateral tibial squatting facet		
Parietal notch bone			Supracondyloid process		
Ossicle at asterion			Septal aperture		
Foramen of Huschke			Double anterior calcaneal facet		
Posterior condylar canal			Anterior calcaneal facet absent		
Condylar facet double			**Comments:**		
Precondylar tubercle					
Foramen ovale incomplete					
Accessory lesser palatine foramen					
Zygomatico-facial foramen					
Supraorbital foramen					
Frontal foramen					
Accessory infra-orbital foramen					

Appendix 1g: Skeletal pathology recording sheet

Pathology	**Score**	**Affected area(s)**	**Descriptive sheets used? (✓)**
Circulatory disorders			
Compression fractures			
Congenital abnormality			
Developmental abnormality			
Exostosis			
Infectious diseases			
Metabolic disorders			
Neoplastic disease			
Osteoarthritis (M)			
Joint diseases			
Paget's			
Periostitis			
Rib periostitis			
Sinusitis			
Trauma			
Other			

***Scoring: P** = present, **A** = Absent, **U** = Unobservable.*

Appendix 1h: Pathological distribution



Appendix 1i: Vertebral joint disease recording – Cervical

		1			2			3			4		
		R	**L**	**B**	**R**	**L**	**B**	**R**	**L**	**B**	**R**	**L**	**B**
C1	**OP**												
	PO												
	EB												
C2	**OP**												
	PO												
	EB												
C3	**OP**												
	PO												
	EB												
C4	**OP**												
	PO												
	EB												
C5	**OP**												
	PO												
	EB												
C6	**OP**												
	PO												
	EB												
C7	**OP**												
	PO												
	EB												

1,2,3,4 = area. **R, L, B =** siding. **OP, PO, EB =** pathologies (see scoring box below).

Vertebral OA Scoring

Area:		**Pathologies:**		**Siding:**		**Grading:**	
1	Upper body	OP	Osteophytes	R	Right side	A	Absent
2	Lower body	PO	Porosity	L	Left side	S	Slight
3	Upper facets	EB	Eburnation	B	Both sides	M	Moderate
4	Lower facets	SN	Schmorl's Nodes			C	Considerable
5	Transverse processes						
6	Costal facets						

Appendix 1j: Vertebral joint disease recording - Thoracic
(See cervical sheet for scoring codes)

		1			2			3			4			5			6		
		R	L	B	R	L	B	R	L	B	R	L	B	R	L	B	R	L	B
T1	OP																		
	PO																		
	EB																		
	SN																		
T2	OP																		
	PO																		
	EB																		
	SN																		
T3	OP																		
	PO																		
	EB																		
	SN																		
T4	OP																		
	PO																		
	EB																		
	SN																		
T5	OP																		
	PO																		
	EB																		
	SN																		
T6	OP																		
	PO																		
	EB																		
	SN																		
T7	OP																		
	PO																		
	EB																		
	SN																		
T8	OP																		
	PO																		
	EB																		
	SN																		
T9	OP																		
	PO																		
	EB																		
	SN																		
T10	OP																		
	PO																		
	EB																		
	SN																		
T11	OP																		
	PO																		
	EB																		
	SN																		
T12	OP																		
	PO																		
	EB																		
	SN																		

Appendix 1k: Vertebral joint disease recording - Lumbar
(See cervical sheet for scoring codes)

		1			2			3			4		
		R	L	B	R	L	B	R	L	B	R	L	B
L1	OP												
	PO												
	EB												
	SN												
L2	OP												
	PO												
	EB												
	SN												
L3	OP												
	PO												
	EB												
	SN												
L4	OP												
	PO												
	EB												
	SN												
L5	OP												
	PO												
	EB												
	SN												

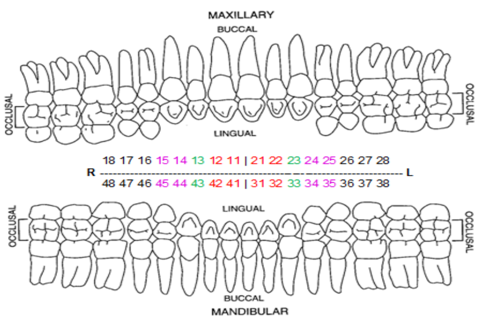
Appendix 1l: Extra-vertebral osteoarthritis (EVOA) recording

Site	Joint	R	L
Skull	TMJ		
	Mandibular condyles		
	Occipital condyles		
Acromioclavicular			
Sternoclavicular			
Shoulder	Humerus		
	Glenoid		
Elbow	Humerus		
	Ulna		
	Radius		
Wrist	Radius		
	Ulna		
Hand	Carpus		
	Carpometacarpal		
	Metacarpophalangeal		
	Prox. interphalangeal		
	Distal interphalangeal		
Hip	Femur		
	Pelvis		
Knee	Femur/Patella		
	Medial		
	Lateral		
Ankle			
Foot	Tarsus		
	Tarsometatarsal		
	Metatarsophalangeal		
	Prox. interphalangeal		
	Distal interphalangeal		
Sacro-iliac joint			

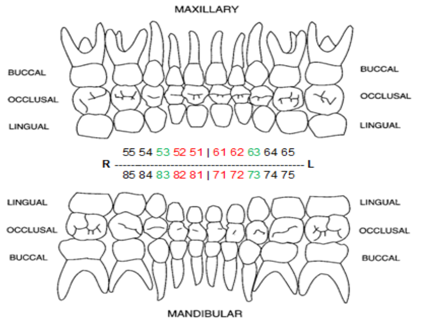
Extra-vertebral scoring:
A = normal articular surface
B = appearance of small deposits of bone on articular margins
C = small pits
D = polishing/eburnation
E = other (describe below):

Appendix 1m: Adult/Sub-adult dental inventory/pathologies

Permanent Teeth



Deciduous Teeth



Inventory scoring:

O Present
X Lost ante-mortem
UE Unerupted
UD Undeveloped
/ Lost post-mortem
=== Alveolus/tooth absent
PE Partial eruption

Comments:

MAXILLA Right Left

Permanent Teeth	**18**	**17**	**16**	**15**	**14**	**13**	**12**	**11**		**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Deciduous Teeth				**55**	**54**	**53**	**52**	**51**		**61**	**62**	**63**	**64**	**65**			
Calculus																	
DEH																	
Caries																	
Abscess																	
Granuloma/Cyst																	
Periodontal																	
Occlusal wear																	

MANDIBLE Right Left

Permanent Teeth	**48**	**47**	**46**	**45**	**44**	**43**	**42**	**41**		**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
Deciduous Teeth				**85**	**84**	**83**	**82**	**81**		**71**	**72**	**73**	**74**	**75**			
Calculus																	
DEH																	
Caries																	
Abscess																	
Granuloma/Cyst																	
Periodontal																	
Occlusal wear																	

Dental pathology scoring:

Position
B = buccal/labial
L = lingual
M = mesial
D = distal
O = occlusal
B + L = E (external)
M + D = I (interproximal)
A = all sides

Calculus
P = present
O = occlusal
R = root
0 = unable to score

DEH
1 = pit
2 = line
3 = groove

Granuloma/Cyst
1 = buccal/labial
2 = lingual

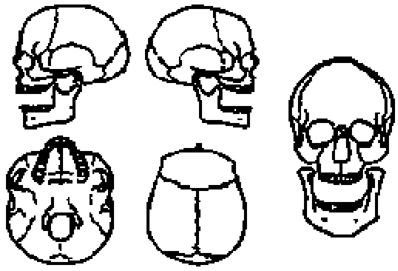
Carious lesions
1 = occlusal surface
2 = interproximal surfaces
3 = smooth surfaces
4 = cervical caries
5 = root caries
6 = large caries
7 = non-carious pulp exposure

Abscess
1 = buccal/labial
2 = lingual

Periodontal Disease
1 = no disease
2 = mild periodontitis
3 = moderate periodontitis
4 = severe periodontitis

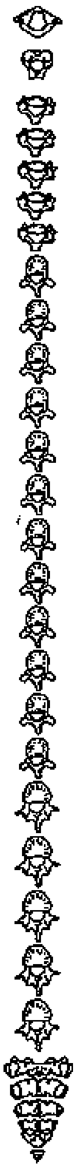
Occlusal Wear
1 = slight wear
2 = moderate wear
3 = severe wear
U = unable to score

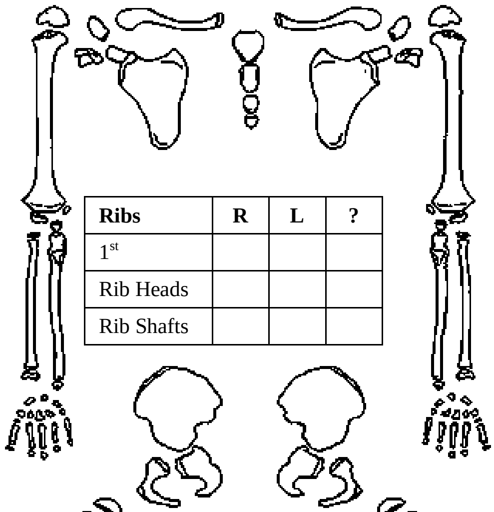
Appendix 1n: Sub-adult skeleton schematic inventory



Shading:

- = Absent
- = Present
- = Post-mortem damage



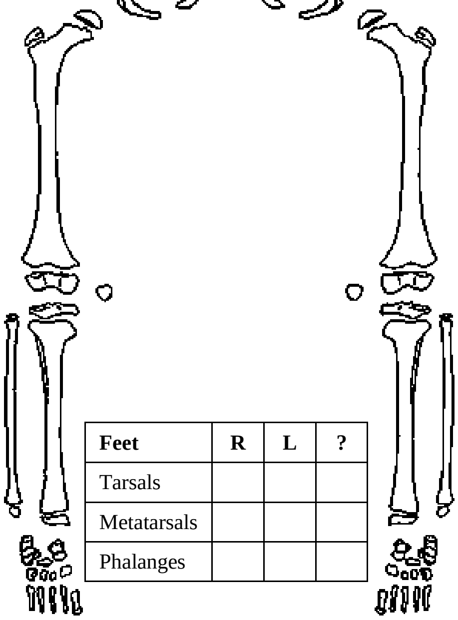


Ribs	**R**	**L**	**?**
1st			
Rib Heads			
Rib Shafts			

Completeness:

0 = Absent
1 = > 75% present = complete
2 = 50-75% present = partial
3 = 25-50% present = **partial**
4 = < 25% present = **poor**

Hands	**R**	**L**	**?**
Carpals			
Metacarpals			
Phalanges			



Feet	**R**	**L**	**?**
Tarsals			
Metatarsals			
Phalanges			

Taphonomic description:

Condition: ____________

Verts	**Arch**	**Body**
C1-2		
C3-7		
T1-12		
L1-5		
S1-5		
?		

Appendix 1o: Sub-adult ageing

LBM - Long-bone measurements (Scheuer *et al.* 1980; Scheuer and Black 2000)			
Bone	**Right (mm)**	**Left (mm)**	**Age**
Humerus			
Radius			
Ulna			
Femur			
Tibia			
Fibula			
Mean age:			

PB - Pars Basilaris dimensions (Scheuer and MacLaughlin-Black 1994)		
Area	**Measurement (mm)**	**Age**
Max Width		
Max Length		
Sagittal Length		
Mean age:		

TFD - Tooth formation/development (Moorrees *et al*. 1963a, 1963b; Smith 1991)			
Tooth	**Development stage**	**Age**	**Macro/ Radio**
Mean age:			

TDE - Tooth development/eruption (Ubelaker 1989)		
Tooth	**Age**	**Macro/ Radio**
Mean age:		

Overall sub-adult age assessment	
Age	**Method(s) used**

Appendix 1p: Perinatal to adolescent ageing from epiphyseal fusion

PAF - Perinatal to Adolescent ageing: fusion of primary elements (after Schaefer *et al*. 2009)					
Bone	**Primary element**	**Open (✓)**	**Partial (✓)**	**Complete (✓)**	**Age**
Sphenoid	Lesser wings to sphenoid body				
	Pre sphenoid to post sphenoid				
	Greater wings to sphenoid body				
	Foramen Ovale (greater wing)				
Temporal	Tympanic ring to temporal squamous				
	Petromastoid to squamotympanic				
Occipital	Supra-occipital to interparietal squama				
	Superior median fissure				
	Sutura mendosa				
	Partes laterals to squama				
	Hypoglossal canal (Pars Basilaris)				
	Partes laterals to Pars Basilaris				
Mandible	Mandibular symphysis				
Frontal	Fusion of 2 halves of frontal bone				
	Obliteration of metopic suture (generally)				
Vertebrae	Intradental union (C2)				
	Neural arches of C3 – L5				
	Neural arches of C2				
	Neural arches of C1				
	Neural arches to centrum (C3 – L5)				
	Dens to neural arch (C2)				
	Centrum to neural arch (C2)				
	Neural arch to anterior bar (C1)				
	Ossiculum terminale of dens				
Sacrum	Lateral element to neural arch				
	Wing (Lat element & NA) to centra				
Pelvis	Ischiopubic ramus				
Humerus	Greater and lesser tubercles to head				

Age based on fusion: __________________

Appendix 1q: Adolescent to post-adolescent ageing from epiphyseal fusion

APF - Adolescent to post-adolescent ageing: epiphyseal fusion (after Schaefer *et al*. 2009)					
Bone	**Epiphyses**	**Open (✓)**	**Partial (✓)**	**Complete (✓)**	**Age**
Humerus	Proximal				
	Medial				
	Distal				
Radius	Proximal				
	Distal				
Ulna	Proximal				
	Distal				
Hand	MCs & Phalanges				
Femur	Head				
	Greater trochanter				
	Lesser trochanter				
	Distal				
Tibia	Proximal				
	Distal				
Fibula	Proximal				
	Distal				
Foot	Calcaneus				
	MTs & Phalanges				
Scapula	Coraco-glenoid/complex				
	Acromion				
	Inferior angle				
	Medial border				
Pelvis	Tri-radiate complex				
	Anterior inferior iliac spine				
	Ischial tuberosity				
	Iliac crest				
Sacrum	Auricular surface				
	S1 – S2 bodies				
	S1 – S2 Alae				
	S2 – S5 bodies				
	S2 – S5 alae				
Vertebrae	Annular rings/bodies				
Ribs	Heads				
Clavicle	Medial				
Manubrium	1st costal notch				

Age based on fusion: __________________

Appendix 2a: Pathology abbreviation list

Abbreviation	Pathology
LL	Lepromatous leprosy
TB	Tuberculosis
PNB	Periosteal new bone
CO	Cribra orbitalia
IFH	Internal frontal hyperostosis
PH	Porotic hyperostosis
IVO	Intervertebral osteochondrosis
SFCE	Slipped femoral capital epiphysis
SBO	Spina bifida occulta
AS	Ankylosing spondylitis
DISH	Diffuse idiopathic skeletal hyperostosis
MOT	Myositis ossificans traumatica
NCB	Nasal concha bullosa
VJD	Vertebral joint disease
EVOA	Extra-vertebral osteoarthritis
SN	Schmorl's nodes
DEH	Dental enamel hypoplasia
AMTL	Ante-mortem tooth loss

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[3]
1	4	?M	Adult	25-50	169	EVOA/PNB/Fracture
2	4		1.1-2.5	>75		CO/Rickets/Calculus
3	4		10.6-14.5	25-50		
4	5		0-1	50-75		
5	4	F	46-59	50-75	147	EVOA/VJD/Fracture/AMTL/Calculus//Caries/Periodontal
6	5		0-1	50-75		Rickets/Scurvy
7	4		2.6-6.5	25-50		
8	4	?M	18-25	<25	175	Osgood-Schlatter's
9	4	?M	46-59	25-50	172	
10	4		6.6-10.5	<25		
11	4		2.6-6.5	25-50		
12	5		0-1	>75		Scurvy
13	5		0-1	>75		Scurvy
14	4		1.1-2.5	50-75		
15	5		1.1-2.5	<25		
16	4		6.6-10.5	>75		
17	5	M	36-45	>75	168	AMTL/Calculus/Caries/AMTL/DEH
18	4	M	36-45	50-75	171	DISH
20	4	?F	46-59	<25	150	
21	4		2.6-6.5	>75		CO
22	5		0-1	25-50		PNB
23	5	F	46-59	>75	165	VJD/EVOA/ Rib_PNB/Vert_compression/Calculus/Caries/AMTL/DEH/Abscess/Granuloma
24	4		14.6-17	25-50		
25	4	M	46-59	>75	163	VJD/EVOA//Sacralisation/AMTL/Calculus/DEH/Granuloma/Periodontal
26	4		0-1	50-75		Scurvy
27	4		10.6-14.5	>75		

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[3]
28	4	F	46-59	25-50	160	
29	5		1.1-2.5	25-50		
30	4	M	36-45	>75	176	Craniosynostosis/EVOA/AMTL/Calculus/DEH
31	4	M	36-45	>75	160	EVOA/Vertebral-border-shifting
32	4	M	60+	25-50	170	
33	5		0-1	>75		Scurvy
34	4	M	46-59	50-75	168	EVOA/SN/VJD
35	4	M	18-25	>75	176	Nasopalatine cyst
36	4	M	46-59	>75	180	EVOA/VJD/Blade_injury/Calculus/DEH/Periodontitis
37	4	M	26-35	>75	158	DEH/Calculus/Caries
38	2	M	46-59	>75	170	Neoplasm/VJD/PNB/Calculus/Caries
39	2	?M	Adult	<25	168	Fracture
40	2	M	46-59	>75	174	VJD/EVOA/AMTL/Calculus/DEH/Granuloma
41	4	M	18-25	50-75		VJD/NCB/Vert_compression/Calculus/Periodontal
42	2	M	46-59	25-50	178	Fracture/EVOA/VJD/SBO/AMTL/Calculus/Caries/Abscess/Granuloma/Periodontal
43	4	M	46-59	50-75	173	VJD/DEH/Caries/Periodontal
44	2	M	46-59	<40		VJD/AMTL/Calculus/Caries/Abscess
45	2	M	46-59	25-50	171	VJD/AMTL/Calculus/Abscess/Granuloma/Periodontal
46	1	M	Adult	25-50	172	
47	2	M	26-35	25-50	174	Calculus/DEH
48	2	?M	36-45	25-50	166	
49	4	?F	Adult	<25	166	
50	2	?M	Adult	<25	164	
51	2	M	36-45	50-75	164	Fracture/EVOA/VJD
52	2	M	46-59	25-50	166	PNB
53	2	M	46-59	50-75		SN/Calculus/Caries/Abscess
54	2	M	18-25	50-75	173	?TB/Calculus/DEH/Dental_anomaly

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Complete ness (%)	Stature (cm)	Pathology[3]
55	4	?F	18-25	>75	166	Caries/Calculus
56	4	M	46-59	50-75	169	AMTL/Calculus/DEH/Caries/Abscess/Granuloma/Periodontal
57	5		0-1	25-50		
58	4		0-1	<25		
59	5		2.6-6.5	>75		Calculus
60	5		1.1-2.5	25-50		
61	5		0-1	25-50		PNB
62	4	F	46-59	50-75	161	
63	4		2.6-6.5	>75		Rickets
64	4	M	46-59	>75	164	EVOA/VJD/DISH/Fracture
65	4		6.6-10.5	>75		Blade_wound/CO
66	4	M	26-35	50-75	156	EVOA/VJD/Sinusitis/NCB/Rib_PNB/AMTL/Calculus/DEH/Caries/Abscess/Granuloma/Periodontal
67	4	F	26-35	50-75	158	VJD/SN
68	4		Perinate	50-75		CO
69	4	F	46-59	50-75	157	VJD/EVOA
70	5		1.1-2.5	50-75		
71	4		2.6-6.5	50-75		
72	4	?	18-25	<25		
73	5		0-1	50-75		Scurvy
74	4	M	46-59	25-50	164	Fracture/VJD
75	4	?M	Adult	25-50	160	EVOA
76	4	F	Adult	<25		Periodontitis/Caries/Calculus/Fistula(?)
77	4	M	36-45	50-75	170	EVOA/VJD
78	4	F	26-35	25-50	152	
80	4	M	36-45	25-50		EVOA/SN/Fractures
81	4		10.6-14.5	>75		PNB

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Complete ness (%)	Stature (cm)	Pathology[3]
82	4	F	36-45	25-50		VJD
83	4	F	36-45	50-75	158	SN
84	4	M	46-59	25-50	175	Sacralisation/VJD/EVOA/Avulsion
85	4	?M	18-25	>75	170	Calculus/Dental_anomaly/Sacralisation
86	4		6.6-10.5	>75		CO/Scurvy
88	4	F	36-45	>75	148	EVOA/VJD/SN/Calculus/DEH/Caries/Granuloma/Periodontal
89	4		1.1-2.5	>75		Congenital
90	4	M	60+	>75	173	EVOA/VJD/SN/AMTL/Calculus/DEH/Periodontal
91	4	F	26-35	>75	149	Calculus/Periodontal
92	4	F	26-35	<25	149	PNB
93	4	M	26-35	>75	166	EVOA/VJD/Neoplasm/PNB
95	4	F	46-59	>75	150	EVOA/VJD/Osteoporosis/AMTL/Calculus/DEH/Caries/Abscess
96	4	?M	Adult	<25	173	
97	4	?F	46-59	25-50		Circulatory/SN/Developmental
98	4	M	26-35	>75	175	EVOA/VJD
99	4	F	60+	<25	150	EVOA
100	4	F	26-35	<25	157	VJD/Calculus/Caries/Periodontal
101	4	F	46-59	<40	159	EVOA/VJD
102	4	F	36-45	50-75	156	EVOA/VJD
103	4	M	26-35	>75	166	Developmental/Congenital/Calculus/DEH/Caries
104	4	M	Adult	<25	174	PNB
105	4	F	46-59	25-50	154	EVOA/VJD/Fracture/PNB
106	4	F	60+	50-75	156	EVOA/VJD
107	4		14-17	<40	166	PNB
108	4	M	36-45	>75	172	EVOA/VJD/PNB/Calculus/Granuloma/Periodontal
109	4	M	46-59	>75	166	Dental_anomaly/Caries/Fracture

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Complete-ness (%)	Stature (cm)	Pathology[3]
110	4		10.6-14.5	50-75		CO/?TB/Calculus
111	3	M	26-35	50-75	168	VJD/Calculus/Abscess/Granuloma
112	4	M	46-59	>75	173	VJD/Calculus/DEH/Caries/Granuloma
113	4	M	36-45	>75	165	EVOA/VJD/Blade_wound/Fracture/MOT/Os.acromiale/AMTL/Calculus/DEH/Caries/Abscess/Granuloma/Periodontal
114	4	F	18-25	>75	157	EVOA/PNB/Trauma
115	4	F	Adult	25-50	160	EVOA/VJD
116	2	M	46-59	25-50		EVOA/VJD
117	4	M	18-25	50-75	163	Fracture/Blade_wounds/SN
118	2	M	18-25	25-50		Fracture
119	4		10.6-14.5	25-50		Granuloma/Calculus
120	4	M	36-45	50-75	161	SN
121	2	M	26-35	>75	167	Vert_compression/Spondylolysis/SN/Os_Acromiale/EVOA
122	2	M	46-59	>75	174	EVOA/VJD/Vert_compression/Fractures/AMTL/Calculus/DEH/Granuloma/Periodontal
123	2	M	60+	25-50	175	Fracture/EVOA
124	2	M	18-25	25-50	177	?Scurvy/Congenital/SN
125	2	M	60+	>75	173	Fracture/EVOA/VJD
126	2	M	46-59	50-75	170	EVOA/SN/VJD/Abscesses/Calculus
127	2	?M	36-45	50-75	161	VJD/Dental_anomaly/AMTL/Calculus/DEH/Abscess
128	2	?M	46-59	<40		VJD/AMTL/Calculus
129	2	?M	18-25	>75	165	Calculus
130	2	?M	46-59	>75	170	EVOA/VJD/AMTL/Abscess/Granuloma
131	1	F	46-59	<25		
133	2	M	60+	25-50	169	EVOA/VJD/Os_acromiale
134	4	M	18-25	25-50	172	PNB/Fracture
135	2	?M	46-59	25-50		VJD/SN/?Scheuermann’s
136	3	M	36-45	50-75	174	VJD/Calculus/DEH

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[3]
137	2	?M	36-45	25-50	174	AMTL/Calculus/DEH/Granuloma
138	2	?	Adult	<25		
139	2	M	46-59	25-50	164	Scurvy/VJD/SN
140	2	M	18-25	>75	166	SN/Os_acromiale
141	2	M	36-45	>75	169	SN/Spondylolysis/Sacralisation/Fracture
142	2	M	46-59	25-50	174	EVOA/Fracture/O_Dissecans
143	2	M	60+	>75	168	SN/PNB/EVOA/VJD
144	2	M	46-59	50-75	161	VJD/SN/EVOA/AMTL/Calculus/Caries/Abscess/Granuloma/Periodontal
145	3	M	Adult	25-50		VJD/Fracture/Caries
146	1	F	26-35	25-50	160	
147	3	M	26-35	50-75	172	VJD/Granulomas/Abscesses/Calculus
148	2	M	60+	25-50	178	EVOA/VJD/PNB/SN
149	1	M	60+	50-75		Fracture/?Neoplasm/EVOA/VJD/SN/Sinusitis/CO/AMTL/Calculus/Abscess/Granuloma/Periodontal
150	4	M	Adult	25-50	172	EVOA/PNB
151	2	M	46-59	50-75	172	EVOA/VJD/Fracture
152	2	M	26-35	50-75	174	Blade_wounds/Sinusitis/Calculus/DEH/Periodontal
153	2	M	36-45	50-75	171	SN/Scheuermanns/Vert_compression/Calculus/DEH/Abscess/Granuloma/Periodontal
154	2	M	46-59	50-75	170	VJD/EVOA/PNB/AMTL/Calculus/Caries/Periodontal
155	2	F	46-59	50-75	165	VJD
156	3	M	36-45	50-75	171	VJD/DEH
157	2	M	46-59	50-75	173	VJD/AMTL
158	2	M	46-59	50-75	173	Blade_wound/Fractures/EVOA/VJD/SN/AMTL/Calculus/Caries/Abscess/Periodontal
159	2		10.6-14.5	50-75		
160	2	?M	Adult	25-50	166	EVOA/VJD
161	4	M	36-45	>75	170	EVOA/VJD/SN/Calculus/Granuloma
162	1	M	Adult	25-50	168	

Appendix 2b: Portmahomack osteology catalogue

SK no.	Period[1]	Sex[2]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[3]
163	1	M	36-45	25-50	174	
164	2	M	46-59	>75	166	Neoplasm?/Sacralisation/Fractures/EVOA/VJD/AMTL/Calculus/Caries
165	2	?	Adult	<25		
166	1	?F	Adult	<25	154	
167	2	M	Adult	<40	167	
168	2	?M	36-45	25-50	-	
169	1	M	26-35	50-75	176	
170	1	M	26-35	>75	177	Calculus/Fracture/SN
171	2	M	36-45	>75	175	EVOA/VJD/Spondylolysis/O_dissecans
172	1	F	46-59	50-75	159	EVOA/VJD/Granuloma
173	2	M	46-59	25-50		VJD/Scheuermann's/SN/Sinusitis/AS/AMTL/Abscess/Granuloma
174	2	?F	Adult	25-50		
175	4		6.6-10.5	50-75		Calculus
176	2	M	46-59	>75	162	EVOA/VJD/Fracture/Sinusitis/CO/Spondylolysis/AMTL/Calculus/Abscess/Granuloma/Periodontal
177	5		0-1	25-50		
186	1	M	26-35	>75	169	Spondylolisis/Os_acromiale/Calculus
187	1	?M	36-45	50-75	172	SBO/Fracture/PNB
188	1	?M	Adult	<25		VJD
189	2	M	26-35	25-50		Calculus/DEH
190	4		2.6-6.5	<25		PNB
192	4?	M	36-45	>75	171	EVOA/SFCE

[1] **Burial periods (AD): Period 1** = c.550-c.700, **Period 2** = c.700-c.800, **Period 3** = c.900-c.1100, **Period 4** = c.1100-c.1600, **Period 5** = c.1600-c.1700.
[2] **M** = Male, **F** = Female, **?M** = Probable male, **?F** Probable female, **?** = unknown sex. **Shaded areas** = not applicable.
[3] See Appendix 2a for pathology abbreviation list.

Appendix 2c: Norton Priory osteology catalogue

Sk No.	Period (AD)	Sex[1]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[2]
1	12th c	?M	18-25	25-50		CO/Sinusitis/Calculus/Tooth_anomaly
2	?	M	18-25	25-50	170	CP/PO/Osteitis/Calculus/Caries
3	14th c	M	26-35	25-50	174	EVOA/Impingement/Rickets/Calculus
4	?	M	46-59	25-50		
5	12th c	M	46-59	50-75	171	EVOA/VJD/SN/Caries/Abscess/Granuloma
6	?	M	46-59	<25		VJD/Craniosynostosis/Calculus
7	14th c	?M	46-59	50-75		EVOA/VJD/PNB/Calculus/Abscess/Granuloma
8	12th c	M	36-45	25-50		EVOA/VJD/Calculus/Abscess/Granuloma/Caries/Fistula
9	14th c	M	26-35	50-75	172	VJD/SN/SBO/PNB/Calculus/Caries
10	14th c	?M	46-59	25-50	168	PNB/Calculus
11	14th c	F	18-25	<25		Calculus
12	15th c	M	36-45	50-75	176	PNB/SN/VJD/EVOA
13	15th c	?M	36-45	50-75	168	VJD/SN/EVOA/PNB/Calculus/Caries/Abscesses
14	15th c	M	46-59	50-75	173	EVOA/SN/VJD/PNB/IFH/PO/Caries/Calculus/Granuloma
15	15th c	M	26-35	50-75		EVOA/VJD/SN/Caries/Calculus
16	15th c	F	26-35	25-50		Rib_anomaly/VJD/SN/Dislocation/Caries/Calculus
17	15th c	F	Adult	25-50		SJD/SN/Caries/Calculus/DEH
18	15th c	F	36-45	25-50		Osteoma/VJD/Calculus/Periodontitis
19	15th c	M	36-45	25-50		Fracture/PNB/EVOA
20	15th c	M	36-45	50-75		VJD/SN/Rickets/Neoplasm/PNB/Caries/Abscess/Calculus
21	15th c	M	46-59	50-75	173	EVOA/VJD/SN/Calculus/DEH
22	13th c	M	46-59	>75	175	Pagets/SpondylolysisVJD/EVOA/SN/Blade_wounds/Calculus
23	15th c		14.6-17	>75		Scheuermann's/Calculus
24	14th c		2.6-6.5	>75		CO
25	15th c	?M	26-35	50-75	170	Fracture/Rickets/VJD/EVOA/PNB

Appendix 2c: Norton Priory osteology catalogue

Sk No.	Period (AD)	Sex[1]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[2]
26	15th c		2.6-6.5	25-50		
27	14th c	M	26-35	>75	171	PH/VJD/SN/Abscess/Caries/Calculus
28	15th c	M	46-59	>75	175	EVOA/VJD/Calculus
29	14th c	M	46-59	>75	178	DISH/Pagets/EVOA/VJD/SN/PNB/CO/Calculus/Granuloma/Caries
30	15th c	M	18-25	50-75	168	Fracture/SBO/Sacralisation/PNB/SN
31	14th c		2.6-6.5	>75		CO/Caries
32	13th c	M	46-59	50-75		EVOA/VJD/SN/?Pagets/Calculus/AMTL
33	15th c	M	60+	>75	176	EVOA/VJD/SN/SBO/Sacralisation/PNB
34	14th c	M	26-35	50-75	172	CO/SN/Vert_compression/Calculus
35	14th c	M	46-59	50-75	180	Pagets/PNB
36	14th c	F	18-25	25-50		IFH/SN/VJD/Calculus
37	14th c	M	46-59	>75	176	TB/EVOA/VJD/SN/PNB/Caries/Tooth_anomaly/DEH
38	14th c	M	26-35	>75	170	TB/PNB/SN/Abscess/Caries/Calculus
39	13th c	F	46-59	25-50		Granuloma
40	13th c	?F	36-45	>75		VJD/SN/Granuloma/Calculus/Tooth-anomaly
41	14th c	M	26-35	50-75		VJ/SN
42	13th c	M	36-45	>75	176	Neoplasm/Osteochondroma/Congenital/EVOA/VJD/SN/Periodontitis/Calculus
43	14th c	F	26-35	>75	162	EVOA/VJD/SN/PNB/Fistula
44	15th c	M	26-35	50-75		VJD/SN/Tooth_anomaly/Calculus
45	13th c	M	26-35	>75		EVOA/VJD/SN/Calculus/DEH
46	14th c	F	46-59	50-75		EVOA/Caries
47	14th c	M	26-35	50-75	171	?LL/PNB
48	14th c	M	26-35	>75	172	PNB/EVOA/SN
49	?	M	46-59	>75	173	EVOA/VJD/DEH
50	14th c	M	26-35	>75	177	LL/Impingement/IVO/EVOA/VJD/Granuloma

Appendix 2c: Norton Priory osteology catalogue

Sk No.	Period (AD)	Sex[1]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[2]
51	14th c		2.6-6.5	50-75		
52	14th c	M	36-45	>75	172	Pagets/EVOA/VJD/SN/IVO/SBO/PNB/Fractures/Caries/Calculus/Periodontitis
53	14th c		1.1-2.5	>75		Scurvy/CO
54	14th c		0-1	25-50		?Rickets/CO
55	14th c	M	46-59	50-75	177	Pagets/VJD/EVOA/PNB
56	14th c	?M	14.6-17	>75		PH/Calculus
57	13th c	M	46-59	<25		NCB/Craniosynostosis
58	15th c	M	26-35	>75	171	Treponemal/EVOA/SN/Calculus
59	?	M	26-35	>75	177	PNB/VJD/EVOA/Calculus
60	?		6.6-10.5	50-75		
61	15th c	M	36-45	50-75		IFH/PH/VJD/SN/EVOA/PNB/Calculus
62	13th c	F	46-59	50-75		IFH/?Pagets/EVOA/PNB/VJD/SN/Periodontitis/Calculus
63	13th c	?M	26-35	25-50		Sacralisation/SN/VJD/Caries
64	13th c	?F	26-35	25-50		
65	13th c	?F	26-35	25-50		VJD/PNB/SBO
66	14th c	?F	Adult	25-50		VJD/PNB/Calculus/DEH
67	14th c	M	36-45	25-50		EVOA/VJD/PNB/S_Spondyloarthropathy/Calculus/Caries/Granuloma/AMTL
68	15th c	M	36-45	50-75		EVOA/VJD/DISH/Calculus
69	14th c	M	26-35	>75	162	Sternal_foramen/3rd_MC_styloid_absence/SBO/SN/CO/EVOA/Calculus
70	15th c	M	60+	>75	173	EVOA/VJD/Neoplasm/Fracture/Psoriatic_arthritis/Developmental/Caries/Calculus/Dental_anomaly
71	15th c	M	46-59	50-75	174	EVOA/VJD/Fractures/Impingement/Abscess/Caries/Calculus
72	14th c	F	18-25	>75	154	SBO/EVOA/SN/Hypodontia/DEH/Calculus/Caries
73	14th c	M	36-45	50-75		EVOA/VJD/PNB/Abscess/Exostosis/Calculus
74	?	M	46-59	50-75	177	?AS
75	14th c	M	36-45	>75	175	Absence_R.3rd MC styloid/EVOA/VJD/SN/IVO/Dental_anomaly/Granuuloma/Calculus

Appendix 2c: Norton Priory osteology catalogue

Sk No.	Period (AD)	Sex[1]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[2]
76	14th c	M	36-45	50-75	174	DISH/PNB/VJD/EVOA/Impingement/CO/PO/Caries
77	13th c	F	46-59	50-75	156	EVOA/VJD/PNB
78	13th c	F	46-59	>75	161	IFH/EVOA/VJD/PNB/Sinusitis/Dislocation/Caries/Calculus/Cyst
79	15th c	?	Adult	25-50		Fractures/PNB/EVOA
80	15th c	M	26-35	50-75	175	PH/Calculus/Dental_anomaly
81	15th c	M	26-35	>75	174	EVOA/VJD/Calculus
82	15th c	M	Adult	25-50	183	PNB/EVOA/SN
83	13th c	M	26-35	>75	169	CO/EVOA/VJD/SN/PNB/Spondylolysis/Cyst/Calculus
84	?		Sub-adult	<25		
85	14th c	M	26-35	50-75		IVO/VJD/SN
86	15th c	M	36-45	>75	175	?TB/PNB/EVOA/VJD/SN/Fracture/Hypodontia/Taurodontism/Calculus
87	15th c	F	60+	50-75		?TB/PNB/VJD/EVOA/SN/?Pagets/Granuloma
88	15th c	M	26-35	>75	171	CO/PH/PNB/Caries/DEH/Calculus
89	13th c	M	26-35	50-75		PNB/SN/Calculus/Caries
90	14th c	M	36-45	50-75		Gout/IVO/SN/EVOA/VJD/PNB/Calculus
91	14th c	M	26-35	25-50	175	PNB/Caries
92	16th c	M	36-45	50-75	167	VJD
93	15th c	M	26-35	>75	177	SBO/PNB/TB/VJD/OP/Calculus/Caries/Granuloma
94	14th c	M	26-35	>75		EVOA/SN/VJD/Calculus/Caries
95	14th c	M	36-45	>75	166	Nasal_infection/EVOA/VJD/Calculus/Periodontitis
96	15th c	M	36-45	>75	178	DISH/VJD/EVOA/SN/PNB/Calculus/Caries
97	14th c	M	46-59	>75	171	Rib_PNB/SN/Neoplasm/EVOA/VJD/Fracture/Calculus/Imbrication
98	14th c	F	26-35	50-75		IFH/VJD/EVOA/PNB/Sinusitis/Caries/Calculus
99	15th c	M	36-45	>75	172	EVOA/VJD/SN/DISH/PNB/Impingement/Calculus/DEH
100	15th c	M	46-59	50-75	170	EVOA/VJD/SN/Amputation
101	15th c	M	46-59	>75	168	Pagets/EVOA/VJD/Dislocation/Fracture/Calculus

Appendix 2c: Norton Priory osteology catalogue

Sk No.	Period (AD)	Sex[1]	Age (yrs)	Completeness (%)	Stature (cm)	Pathology[2]
102	13th c	M	26-35	>75	173	VJD/SN/PNB/Calculus/DEH
103	15th c	M	36-45	>75	175	SN/VJD/PNB/Calculus/Caries
104	14th c	M	26-35	>75	170	SN/VJD/PNB/Calculus
105	14th c	M	46-59	50-75	173	EVOA/VJD/Fractures
106	14th c	M	60+	>75	168	EVOA/VJD/SN/PNB/MOT/Fracture/Spondylolysis/Caries/Calculus/Abscess
107	?		6.6-10.5	>75		Caries
108	14th c	?	46-59	25-50		EVOA
109	14th c	M	26-35	50-75	174	VJD/EVOA
110	14th c	M	36-45	>75	173	Neoplasm/EVOA/VJD/SN/PNB/Sacralisation/Caries/Calculus/Impaction
111	15th c	M	36-45	>75	179	EVOA/VJD/SN/Absence_R.3rd_MC_styloid/Dental_anomaly/Calculus/Hypercementosis
112	15th c	F	18-25	>75	153	C1_cleft/Rib_PNB/SBO/Caries
113	?	?M	36-45	50-75		VJD/Caries
114	15th c	F	26-35	50-75	149	SN/Calculus/Caries
115	?	F	36-45	50-75		Sternal_aperture/VJD/SN/Septic_arthritis/PNB/Caries/Granuloma
116	?	M	26-35	50-75		VJD/Calculus
117	?	M	26-35	50-75		PNB/Calculus
118	15th c	F	26-35	>75	157	PNB/SN/VJD/L1_Cleft/Calculus
119	15th c		Perinate	50-75		
120	15th c	F	26-35	>75	152	EVOA/VJD/SN/PNB/Caries/Cyst
121	15th c	M	26-35	50-75		
122	?		6.6-10.5	>75		
123	?	M	46-59	50-75	168	Rickets/SN/EVOA/PNB
124	?	F	26-35	25-50		
125	?	F	26-35	25-50		
126	?	F	26-35	50-75		PNB/VJD
127	?	F	46-59	50-75		IFH/Neoplasm/VJD
128	15th c	?	Adult	25-50		PNB/EVOA

[1]**M** = Male, **F** = Female, **?M** = Probable male, **?F** Probable female, **?** = unknown sex. **Shaded areas** = not applicable. [2] See Appendix 2a for pathology abbreviation list.

Appendix 3a: Period-specific prevalence of cranial non-metric traits at Portmahomack

Trait*	Period 1 (N=6)		Period 2 (N=32)		Period 3 (N=2)		Period 4 (N=27)		Period 5 (N=2)	
	n	PSP%	n	PSP%	n	PSP%	n	PSP%	n	PSP%
1	1	16.7%	7	21.9%	1	100.0%	4	18.8%	0	0.0%
2	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
3	0	0.0%	4	12.5%	0	0.0%	2	7.4%	0	0.0%
	PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)	
	R	L	R	L	R	L	R	L	R	L
4	33.3% (2)	0.0% (0)	31.3% (10)	46.9% (15)	0.0% (0)	0.0% (0)	22.2% (6)	29.6% (8)	50.0% (1)	50.0% (1)
5	33.3% (2)	16.7% (1)	34.4% (11)	31.3% (10)	0.0% (0)	100.0% (1)	55.6% (15)	44.4% (12)	50.0% (1)	50.0% (1)
6	0.0% (0)	0.0% (0)	0.0% (0)	3.1% (1)	0.0% (0)	0.0% (0)	0.0% (0)	3.7% (1)	0.0% (0)	0.0% (0)
7	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	3.7% (1)	0.0% (0)	0.0% (0)	0.0% (0)
8	0.0% (0)	0.0% (0)	6.3% (2)	6.3% (2)	0.0% (0)	0.0% (0)	3.7% (1)	11.1% (3)	0.0% (0)	0.0% (0)
9	16.7% (1)	16.7% (1)	9.4% (3)	9.4% (3)	0.0% (0)	0.0% (0)	11.1% (3)	22.2% (6)	0.0% (0)	50.0% (1)
10	0.0% (0)	0.0% (0)	3.1% (1)	3.1% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
11	33.3% (2)	33.3% (2)	37.5% (12)	28.1% (9)	0.0% (0)	100.0% (1)	29.6% (8)	44.4% (12)	50.0% (1)	50.0% (1)
12	0.0% (0)	0.0% (0)	3.1% (1)	6.3% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
13	0.0% (0)	16.7% (1)	25.0% (8)	25.0% (8)	0.0% (0)	0.0% (0)	14.8% (4)	14.8% (4)	0.0% (0)	0.0% (0)
14	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	11.1% (3)	3.7% (1)	0.0% (0)	0.0% (0)
15	33.3% (2)	16.7% (1)	9.4% (3)	18.8% (6)	0.0% (0)	0.0% (0)	22.2% (6)	7.4% (2)	0.0% (0)	0.0% (0)
16	50.0% (3)	50.0% (3)	65.6% (21)	62.5% (20)	100.0% (1)	100.0% (1)	81.5% (22)	66.7% (18)	100.0% (2)	100.0% (2)
17	33.3% (2)	50.0% (3)	59.4% (19)	53.1% (17)	100.0% (1)	100.0% (1)	51.9% (14)	59.3% (16)	50.0% (1)	100.0% (2)
18	0.0% (0)	0.0% (0)	9.4% (3)	6.3% (2)	100.0% (1)	100.0% (1)	18.5% (5)	18.5% (5)	0.0% (0)	0.0% (0)
19	0.0% (0)	16.7% (1)	9.4% (3)	12.5% (4)	0.0% (0)	0.0% (0)	18.5% (5)	18.5% (5)	0.0% (0)	0.0% (0)

*** Cranial non-metric traits:** 1 (Ossicle at lambda), 2 (Bregmatic bone), 3 (Metopism), 4 (Lambdoid ossicles), 5 (Parietal foramen), 6 (Coronal ossicle), 7 (Epipteric bone), 8 (Parietal notch bone), 9 (Ossicle at asterion), 10 (Foramen of Huschke), 11 (Posterior condylar canal), 12 (Condylar facet double), 13 (Precondylar tubercle), 14 (Foramen ovale incomplete), 15 (Accessory lesser palatine foramen), 16 (Zygomaticofacial foramen), 17 (Supraorbital foramen), 18 (Frontal foramen), 19 (Accessory infra-orbital foramen).

Appendix 3b: Period-specific prevalence of postcranial non-metric traits at Portmahomack

Trait*	Period 1 (N=13)		Period 2 (N=56)		Period 3 (N=3)		Period 4 (N=64)		Period 5 (N=2)	
	PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)	
	R	L	R	L	R	L	R	L	R	L
1	0.0% (0)	0.0% (0)	1.8% (1)	0.0% (0)	0.0% (0)	0.0% (0)	3.1% (2)	1.6% (1)	0.0% (0)	0.0% (0)
2	7.7% (1)	0.0% (0)	5.4% (3)	5.4% (3)	1.3% (1)	1.3% (1)	21.9% (14)	26.6% (17)	0.0% (0)	0.0% (0)
3	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
4	23.1% (3)	38.5% (5)	30.4% (17)	32.1% (18)	0.0% (0)	1.3% (1)	40.6% (26)	35.9% (23)	50.0% (1)	50.0% (1)
5	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
6	7.7% (1)	7.7% (1)	1.8% (1)	3.6% (2)	0.0% (0)	0.0% (0)	3.1% (2)	1.6% (1)	0.0% (0)	0.0% (0)
7	30.8% (4)	38.5% (5)	19.6% (11)	23.2% (13)	0.0% (0)	1.3% (1)	28.1% (18)	32.8% (21)	50.0% (1)	50.0% (1)
8	0.0% (0)	0.0% (0)	0.0% (0)	1.8% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
9	0.0% (0)	0.0% (0)	1.8% (1)	3.6% (2)	0.0% (0)	0.0% (0)	3.1% (2)	7.8% (5)	0.0% (0)	0.0% (0)
10	30.8% (4)	38.5% (5)	8.9% (5)	14.3% (8)	0.0% (0)	0.0% (0)	20.3% (13)	21.9% (14)	50.0% (1)	50.0% (1)
11	0.0% (0)	0.0% (0)	1.8% (1)	1.8% (1)	0.0% (0)	0.0% (0)	1.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)

***Postcranial non-metric traits:** 1 (Allen's fossa), 2 (Poirier's facet), 3 (Hypotrochanteric fossa), 4 (Exostosis: trochanteric fossa), 5 (Third trochanter), 6 (Medial tibial squatting facet), 7 (Lateral tibial squatting facet), 8 (Supracondyloid process), 9 (Septal aperture),10 (Double anterior calcaneal facet), 11 (Anterior calcaneal facet absent).

Appendix 3c: Period-specific prevalence for cranial non-metric traits at Norton

Trait*	12th (N=3)		13th (N=13)		14th (N=34)		15th (N=28)		16th (N=1)		? (N=14)	
	n	**PSP%**	**n**	**PSP%**	**n**	**PSP%**	**n**	**PSP%**	**n**	**PSP%**	**n**	**PSP%**
1	2	66.7%	0	0.0%	5	14.7%	5	17.9%	0	0.0%	0	0.0%
2	0	0.0%	0	0.0%	1	2.9%	1	3.6%	0	0.0%	0	0.0%
3	0	0.0%	0	0.0%	5	14.7%	2	7.1%	0	0.0%	0	0.0%
	PSP% (n)		**PSP% (n)**		**PSP% (n)**		**PSP% (n)**		**PSP% (n)**		**PSP% (n)**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
4	66.7% (2)	66.7% (2)	0.0% (0)	15.4% (2)	52.9% (18)	44.1% (15)	32.1% (9)	25.0% (7)	0.0% (0)	0.0% (0)	0.0% (0)	7.1% (1)
5	66.7% (2)	33.3% (1)	23.1% (3)	30.8% (4)	38.2% (15)	44.1% (15)	42.9% (12)	42.9% (12)	0.0% (0)	0.0% (0)	28.6% (4)	35.7% (5)
6	33.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	5.9% (2)	8.8% (3)	3.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
7	0.0% (0)	33.3% (1)	0.0% (0)	0.0% (0)	2.9% (1)	8.8% (3)	3.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	7.1% (1)
8	0.0% (0)	33.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	3.6% (1)	7.1% (2)	0.0% (0)	0.0% (0)	0.0% (0)	7.1% (1)
9	33.3% (1)	66.7% (2)	7.7% (1)	15.4% (2)	11.8% (4)	8.8% (3)	14.3% (4)	7.1% (2)	0.0% (0)	0.0% (0)	0.0% (0)	7.1% (1)
10	0.0% (0)	0.0% (0)	15.4% (2)	15.4% (2)	11.8% (4)	14.7% (5)	7.1% (2)	7.1% (2)	0.0% (0)	0.0% (0)	14.3% (2)	14.3% (2)
11	0.0% (0)	0.0% (0)	23.1% (3)	23.1% (3)	17.6% (6)	20.6% (7)	17.9% (5)	10.7% (3)	0.0% (0)	0.0% (0)	0.0% (0)	7.1% (1)
12	33.3% (1)	33.3% (1)	7.7% (1)	7.7% (1)	11.8% (4)	8.8% (3)	3.6% (1)	0.0% (0)	0.0% (0)	0.0% (0)	7.1% (1)	0.0% (0)
13	0.0% (0)	0.0% (0)	38.5% (5)	38.5% (5)	23.5% (8)	20.6% (7)	17.9% (5)	14.3% (4)	0.0% (0)	0.0% (0)	21.4% (3)	28.6% (4)
14	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	5.9% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	14.3% (2)	0.0% (0)
15	0.0% (0)	33.3% (1)	15.4% (2)	23.1% (3)	8.8% (3)	5.9% (2)	7.1% (2)	14.3% (4)	0.0% (0)	0.0% (0)	7.1% (1)	7.1% (1)
16	66.7% (2)	66.7% (2)	46.2% (6)	38.5% (5)	55.9% (19)	52.9% (18)	60.7% (17)	46.4% (13)	0.0% (0)	0.0% (0)	42.9% (6)	21.4% (3)
17	100.0% (3)	100.0% (3)	46.2% (6)	53.8% (7)	50.0% (17)	38.2% (13)	57.1% (16)	39.3% (11)	0.0% (0)	0.0% (0)	37.5% (5)	37.5% (5)
18	66.7% (2)	33.3% (1)	7.7% (1)	0.0% (0)	11.8% (4)	14.7% (5)	7.1% (2)	10.7% (3)	0.0% (0)	0.0% (0)	14.3% (2)	7.1% (1)
19	0.0% (0)	33.3% (1)	7.7% (1)	0.0% (0)	2.9% (1)	2.9% (1)	3.6% (1)	7.1% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)

***Cranial non-metric traits:** 1 (Ossicle at lambda), 2 (Bregmatic bone), 3 (Metopism), 4 (Lambdoid ossicles), 5 (Parietal foramen), 6 (Coronal ossicle), 7 (Epipteric bone), 8 (Parietal notch bone), 9 (Ossicle at asterion), 10 (Foramen of Huschke), 11 (Posterior condylar canal), 12 (Condylar facet double), 13 (Precondylar tubercle), 14 (Foramen ovale incomplete), 15 (Accessory lesser palatine foramen), 16 (Zygomaticofacial foramen), 17 (Supraorbital foramen), 18 (Frontal foramen), 19 (Accessory infra-orbital foramen).

Appendix 3d: Period-specific prevalence for postcranial non-metric traits at Norton

Trait*	12th (N=1)		13th (N=15)		14th (N=38)		15th (N=40)		16th (N=1)		? (N=13)	
	PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)		PSP% (n)	
	R	L	R	L	R	L	R	L	R	L	R	L
1	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	2.6% (1)	5.3% (2)	2.5% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
2	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	10.5% (4)	10.5% (4)	22.5% (9)	15.0% (6)	0.0% (0)	0.0% (0)	15.4% (2)	0.0% (0)
3	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
4	0.0% (0)	0.0% (0)	13.3% (2)	20.0% (3)	18.4% (7)	21.1% (8)	12.5% (5)	25.0% (10)	0.0% (0)	0.0% (0)	15.4% (2)	0.0% (0)
5	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	2.6% (1)	5.3% (2)	7.5% (3)	5.0% (2)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
6	0.0% (0)	0.0% (0)	6.7% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
7	0.0% (0)	0.0% (0)	0.0% (0)	13.3% (2)	5.3% (2)	13.2% (5)	10.0% (4)	10.0% (4)	0.0% (0)	0.0% (0)	7.7% (1)	7.7% (1)
8	0.0% (0)	0.0% (0)	6.7% (1)	6.7% (1)	0.0% (0)	0.0% (0)	2.5% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)
9	0.0% (0)	0.0% (0)	6.7% (1)	6.7% (1)	2.6% (1)	5.3% (2)	5.0% (2)	5.0% (2)	0.0% (0)	0.0% (0)	15.4% (2)	7.7% (1)
10	0.0% (0)	0.0% (0)	6.7% (1)	20.0% (3)	26.3% (10)	34.2% (13)	27.5% (11)	30.0% (12)	100.0% (1)	100.0% (1)	15.4% (2)	15.4% (2)
11	0.0% (0)	0.0% (0)	0.0% (0)	6.7% (1)	10.5% (4)	10.5% (4)	7.5% (3)	2.5% (1)	0.0% (0)	0.0% (0)	15.4% (2)	7.7% (1)

* **Postcranial non-metric traits:** 1 (Allen's fossa), 2 (Poirier's facet), 3 (Hypotrochanteric fossa), 4 (Exostosis: trochanteric fossa), 5 (Third trochanter), 6 (Medial tibial squatting facet), 7 (Lateral tibial squatting facet), 8 (Supracondyloid process), 9 (Septal aperture),10 (Double anterior calcaneal facet), 11 (Anterior calcaneal facet absent).

Appendix 4a: Age-specific prevalence of extra-vertebral osteoarthritis (EVOA) for Portmahomack adults

Age	Males affected	Male ASP%	Females affected	Female ASP%
18-25	0		1	50.0
26-35	4	28.6	0	
36-45	10	43.5	1	25.0
46-59	20	58.8	9	69.2
60+	8	100.0	2	100.0
Adult	6	46.2	1	20.0

Shaded areas = not applicable.

Appendix 4b: Period-specific prevalence of EVOA for Portmahomack adults

Period	Males affected	Male PSP%	Females affected	Female PSP%
1	3	33.3	1	25.0
2	26	51.0	0	
3	0		0	
4	19	48.7	13	52.0
5	0		0	

Shaded areas = not applicable.

Appendix 4c: EVOA summary scores for Portmahomack adults

		1R	1L	1B	2R	2L	2B	3R	3L	3B	4R	4L	4B	Total affected
Skull	TMJ	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Mand Condyles	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Occipital Condyles	0	0	0	0	0	0	0	0	0	0	0	0	**0**
	Acromioclavicular	0	0	1	9	0	8	0	0	0	1	3	7	**29**
	Sternoclavicular	0	0	0	2	1	5	0	0	0	2	0	1	**11**
	Manubriosternum	0	0	1	0	0	4	0	0	0	0	0	0	**5**
Shoulder	Humerus	1	1	1	9	0	3	0	2	0	0	1	0	**18**
	Glenoid	5	5	2	2	0	1	1	0	0	1	1	0	**18**
Elbow	Humerus	3	3	3	2	1	0	0	0	0	1	0	0	**13**
	Ulna	7	7	2	1	2	0	0	0	0	0	0	0	**19**
	Radius	1	1	0	0	0	0	0	0	0	1	0	0	**3**
Wrist	Ulna	1	1	0	0	0	1	0	0	0	0	0	0	**3**
	Radius	0	0	0	0	1	0	0	0	0	0	0	2	**3**
Hand	Carpus	1	1	0	1	0	0	4	2	0	1	0	1	**11**
	CarpoMC	1	1	0	0	0	0	1	0	0	0	1	0	**4**
	MCPhal	2	2	1	1	0	0	1	0	1	0	0	0	**8**
	Prox IntPhal	2	2	1	0	1	0	0	0	0	1	0	0	**7**
	Dist IntPhal	1	1	2	0	0	0	0	0	0	1	1	0	**6**
Hip	Femur	0	0	1	0	1	6	2	1	1	2	1	1	**16**
	Pelvis	0	0	2	3	2	3	0	0	2	2	1	1	**16**
	Sac-iliac	0	0	3	0	0	1	0	0	0	1	0	0	**5**
Knee	Femur/Patella	0	0	7	0	0	4	0	2	0	0	1	0	**14**
	Tibia Medial	2	2	2	0	0	0	0	1	0	0	0	0	**7**
	Tibia Lateral	0	0	2	0	0	0	0	1	0	0	0	0	**3**
Ankle	Tibia/Fibula	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Foot	Tarsus	0	0	0	1	0	0	1	0	0	1	0	0	**3**
	TarsoMT	0	0	0	0	0	0	1	0	1	0	0	0	**2**
	MTPhal	0	0	0	1	1	0	0	1	1	1	0	1	**6**
	Prox IntPhal	0	0	0	0	1	0	0	0	0	2	0	0	**3**
	Dist IntPhal	1	1	0	1	0	0	0	0	0	0	1	0	**4**

Grades: 1 = osteophytes (OP), 2 = porosity (PO)/possible osteophytes, 3 = eburnation (EB)/possible OP & PO, 4 = Joint contour change/possible OP, PO & EB.
Positions: L = Left, R = Right, B = Both.

Appendix 4d: Age-specific prevalence of EVOA for Norton adults

Age	Males affected	Male ASP%	Females affected	Female ASP%
18-25	0		1	25.0%
26-35	12	37.5%	3	27.3%
36-45	20	87.0%	1	33.3%
46-59	16	69.6%	4	66.7%
60+	3	100.0%	1	100.0%
Adult	1	100.0%	1	50.0%

Shaded area = not applicable.

Appendix 4e: Period-specific prevalence of EVOA for Norton adults

Period	Males affected	Male PSP%	Females affected	Female PSP%	?Sex affected	?Sex PSP%
12th	2	66.7	0		0	
13th	4	44.4	3	42.9	0	
14th	19	59.4	4	57.1	1	100.0
15th	24	80.0	3	37.5	2	100.0
16th	1	100.0	0		0	
?	2	20.0	1	20.0	0	

Shaded areas = not applicable.

Appendix 4f: EVOA summary scores for Norton adults

		1R	1L	1B	2R	2L	2B	3R	3L	3B	4R	4L	4B	Total affected
SKULL	TMJ	0	0	0	1	0	1	0	0	1	0	0	0	3
	Mand Condyles	1	1	1	0	1	0	0	0	0	0	0	1	5
	Occipital Condyles	2	0	1	0	0	0	0	0	0	0	0	0	3
	Acromioclavicular	0	0	0	7	4	4	3	2	2	2	0	2	26
	Sternoclavicular	1	0	1	5	4	14	0	0	0	0	0	0	25
	Manubriosternum	0	0	1	0	0	7	0	0	0	0	0	0	8
SHOULDER	Humerus	2	1	2	0	0	1	0	0	1	0	0	0	7
	Glenoid	7	1	7	1	0	1	0	0	0	1	0	0	18
ELBOW	Humerus	0	0	5	1	0	0	1	1	1	0	0	0	9
	Ulna	2	2	9	1	1	0	0	0	0	0	0	0	15
	Radius	1	1	3	0	0	0	1	0	1	0	0	0	7
WRIST	Ulna	1	1	0	0	0	1	1	1	2	0	0	0	7
	Radius	0	0	0	0	1	0	2	0	2	1	0	0	6
HAND	Carpus	2	0	2	0	0	0	3	3	0	0	0	0	10
	CarpoMC	0	1	2	0	0	0	1	2	0	0	0	0	6
	MCPhal	2	2	2	0	0	0	0	0	1	0	2	0	9
	Prox IntPhal	0	0	2	0	0	0	1	1	1	0	0	0	5
	Dist IntPhal	0	1	1	0	1	0	0	1	0	0	2	0	6
HIP	Femur	1	0	1	0	0	1	1	0	0	0	0	0	4
	Pelvis	0	2	4	2	0	4	1	0	0	1	0	0	14
	Sac-iliac	4	0	1	0	0	0	1	0	0	0	0	0	6
KNEE	Femur/Patella	2	1	9	0	0	0	0	0	2	0	0	0	14
	Tibia Medial	1	1	6	0	0	0	0	0	0	0	0	0	8
	Tibia Lateral	2	2	6	0	0	0	0	0	0	0	0	0	10
ANKLE	Tibia/Fibula	0	0	1	0	0	0	0	0	0	0	0	0	1
FOOT	Tarsus	1	1	1	0	0	0	0	0	1	0	0	0	4
	TarsoMT	0	0	0	0	0	0	0	0	0	0	0	0	0
	MTPhal	3	2	1	0	1	0	0	1	1	0	0	0	9
	Prox IntPhal	2	0	0	0	0	0	0	0	0	1	0	0	3
	Dist IntPhal	0	1	0	0	0	0	0	0	1	0	0	0	2

Grades: 1 = osteophytes (OP), 2 = porosity (PO)/possible osteophytes, 3 = eburnation (EB)/possible OP & PO, 4 = Joint contour change/possible OP, PO & EB.
Positions: L = Left, R = Right, B = Both.

Appendix 5a: Portmahomack adult Schmorl's nodes summary scores

	n= scored	n= affected	SSP%	CERVICAL				THORACIC				LUMBAR				Verts scored	Verts affected
				Cervical verts scored	Mild nodes	Moderate nodes	Severe nodes	Thoracic verts scored	Mild nodes	Moderate nodes	Severe nodes	Lumbar verts scored	Mild nodes	Moderate nodes	Severe nodes		
Male	83	44	53.0%	170	0	0	0	452	98	94	29	199	41	28	15	821	305
Female	24	9	37.5%	33	0	0	0	81	21	6	2	38	9	2	1	152	41
Total	**107**	**53**		**203**	**0**	**0**	**0**	**533**	**119**	**100**	**31**	**237**	**50**	**30**	**16**	**973**	**346**

Appendix 5b: Norton adult Schmorl's nodes summary scores

	n= scored	n= affected	SSP%	CERVICAL				THORACIC				LUMBAR				Verts scored	Verts affected
				Cervical verts scored	Mild nodes	Moderate nodes	Severe nodes	Thoracic verts scored	Mild nodes	Moderate nodes	Severe nodes	Lumbar verts scored	Mild nodes	Moderate nodes	Severe nodes		
Male	77	51	66.2%	242	3	2	1	515	94	81	46	214	45	26	7	971	305
Female	24	12	50.0%	68	0	0	0	114	19	19	10	35	10	1	1	217	60
Total	**101**	**63**		**310**	**3**	**2**	**1**	**629**	**113**	**100**	**56**	**249**	**55**	**27**	**8**	**1188**	**365**

Appendix 6a: Sex-specific prevalence of trauma on Portmahomack adults

Sex-specific prevalence		Fractures/ Trauma	Spondylolysis	Myositis ossificans traumatica	Vertebral compression	Osteochondritis dissecans	Blade injuries
M	SSP% (n)	25.2 (26)	4.9 (5)	1.0 (1)	3.9 (4)	1.9 (2)	4.9 (5)
F	SSP% (n)	9.4 (3)			3.1 (1)		

Shaded areas = no trauma observed.

Appendix 6b: Age-specific prevalence of trauma on Portmahomack adults

Age-specific prevalence		Fractures/ Trauma	Spondylolysis	Myositis ossificans traumatica	Vertebral compression	Osteochondritis dissecans	Blade injuries
18-25	ASP% (n)	30.8 (4)			7.7 (1)		7.7 (1)
26-35	ASP% (n)	5.0 (1)	10.0 (2)		5.0 (1)		5.0 (1)
36-45	ASP% (n)	18.5 (5)	7.4 (2)	3.7 (1)	3.7 (1)	3.7 (1)	3.7 (1)
46-59	ASP% (n)	27.7 (13)	2.1 (1)		4.3 (2)	2.1 (1)	4.3 (2)
60+	ASP% (n)	30.0 (3)					
Adult	ASP% (n)	16.7 (3)					

Shaded areas = no trauma observed.

Appendix 6c: Period-specific prevalence of trauma on Portmahomack adults

Period-specific prevalence		Fractures/ Trauma	Spondylolysis	Myositis ossificans traumatica	Vertebral compression	Osteochondritis dissecans	Blade injuries
Period 1	PSP% (n)	23.1 (3)	7.7 (1)				
Period 2	PSP% (n)	25.0 (14)	7.1 (4)		5.4 (3)	3.6 (2)	3.6 (2)
Period 3	PSP% (n)						
Period 4	PSP% (n)	18.5 (12)		1.5 (1)	1.5 (1)		4.6 (3)
Period 5	PSP% (n)				50.0 (1)		

Shaded areas = no trauma observed.

Appendix 6d: Sex-specific prevalence of trauma on Norton adults

Sex-specific prevalence		Fractures	Dislocation	Spondylolysis	Myositis ossificans traumatica	Vertebral compression	Amputation	Blade injuries
M	SSP% (n)	12.9 (11)	8.2 (7)	3.5 (3)	1.2 (1)	1.2 (1)	1.2 (1)	1.2 (1)
F	SSP% (n)		11.1 (3)					
?Sex	SSP% (n)	33.3 (1)						

Shaded areas = no trauma observed.

Appendix 6e: Age-specific prevalence of trauma on Norton adults

Age-specific prevalence		Fractures	Dislocation	Spondylolysis	Myositis ossificans traumatica	Vertebral compression	Amputation	Blade injuries
18-25	ASP% (n)	14.3 (1)						
26-35	ASP% (n)	2.3 (1)	7.0 (3)	2.3 (1)		2.3 (1)		
36-45	ASP% (n)	11.5 (3)	11.5 (3)					
46-59	ASP% (n)	13.8 (4)	13.8 (4)	3.4 (1)			3.4 (1)	3.4 (1)
60+	ASP% (n)	50.0 (2)		25.0 (1)	25.0 (1)			
Adult	ASP% (n)	33.3 (1)						

Shaded areas = no trauma observed.

Appendix 6f: Period-specific prevalence of trauma on Norton adults

Period-specific prevalence		Fractures	Dislocation	Spondylolysis	Myositis ossificans traumatica	Vertebral compression	Amputation	Blade injuries
13th C	PSP% (n)		6.3 (1)	12.5 (2)				6.3 (1)
14th C	PSP% (n)	10.3 (4)	12.8 (5)	2.6 (1)	2.6 (1)	2.6 (1)		
15th C	PSP% (n)	21.1 (8)	10.5 (4)				2.6 (1)	

Shaded areas = no trauma observed.
NB: no trauma observed from 12th or 16th century groups.

Appendix 7a: Isotope data for Portmahomack adult human bone collagen. Data in bold from Curtis-Summers *et al.* (2014)

Lab no.	Sex	Age	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
PMK1	?M	Adult	-18.5	15.4	46.8	16.7	3.3	21.4
PMK5	F	46-59	-16.9	15.9	41.4	14.7	3.3	12.9
PMK8	?M	18-25	-18.2	14.6	43.1	15.4	3.3	25.1
PMK9	?M	46-59	-18.0	15.2	44.7	15.9	3.3	23.5
PMK17	M	36-45	-19.6	14.4	46.8	16.2	3.4	19.8
PMK18	M	36-45	-18.4	15.4	45.2	15.8	3.4	18.7
PMK20	?F	46-59	-18.1	16.3	42.2	14.9	3.3	17.6
PMK23	F	46-59	-19.2	13.6	45.5	16.0	3.3	22.0
PMK25	M	46-59	-19.1	14.3	41.9	15.0	3.3	14.5
PMK28	F	46-59	-17.7	15.5	40.7	14.5	3.3	19.9
PMK30	M	36-45	-19.1	13.7	47.4	16.8	3.3	21.9
PMK31	M	36-45	-15.5	17.6	38.6	13.8	3.3	15.7
PMK32	M	60+	-17.4	15.4	45.4	16.3	3.3	21.5
PMK34	M	46-59	-16.8	16.7	39.9	14.2	3.3	11.8
PMK35	**M**	**18-25**	**-17.4**	**15.4**	**42.1**	**15.4**	**3.2**	**2.4**
PMK36	M	46-59	-19.0	13.9	45.4	16.1	3.3	19.2
PMK37	M	26-35	-16.1	17.2	45.8	16.5	3.3	12.6
PMK38	M	46-59	-20.6	12.5	27.6	9.6	3.4	3.0
PMK39	?M	Adult	-20.1	11.4	39.4	13.9	3.3	6.6
PMK40	M	46-59	-20.3	12.3	42.6	15.0	3.3	11.1
PMK41	M	18-25	-20.3	11.7	46.6	16.6	3.3	18.7
PMK42	M	46-59	-19.7	12.9	45.8	15.9	3.4	19.5
PMK43	M	46-59	-19.2	14.4	42.2	14.7	3.4	9.1
PMK44	M	46-59	-20.4	12.1	45.2	15.9	3.3	22.6
PMK45	M	46-59	-20.3	12.8	43.0	15.2	3.3	8.3
PMK46	M	Adult	-20.0	13.1	43.9	15.3	3.4	9.6
PMK47	M	26-35	-20.0	12.4	42.5	15.1	3.3	10.9
PMK48	?M	36-45	-20.7	13.2	37.6	12.8	3.4	6.2
PMK49	?F	Adult	-20.8	11.1	45.8	16.2	3.3	22.8
PMK50	?M	Adult	-20.2	11.4	40.5	14.0	3.4	6.3
PMK51	M	36-45	-20.3	12.1	44.6	15.7	3.3	24.0
PMK52	M	46-59	-20.3	12.1	45.3	15.7	3.4	8.0
PMK53	M	46-59	-20.2	11.8	41.6	14.8	3.3	9.4
PMK54	M	18-25	-20.5	12.1	46.7	16.4	3.3	21.6
PMK55	?F	18-25	-19.1	13.6	44.8	16.1	3.3	16.3
PMK56	M	46-59	-17.5	15.7	50.5	18.0	3.3	21.7
PMK62	F	46-59	-19.0	14.2	45.2	16.2	3.3	22.7
PMK64	**M**	**46-59**	**-19.3**	**13.9**	**42.1**	**15.5**	**3.2**	**7.8**
PMK66	M	26-35	-18.3	14.9	43.5	15.7	3.2	23.6
PMK67	F	26-35	-18.8	15.0	46.4	16.7	3.3	19.8
PMK69	**F**	**46-59**	**-19.7**	**14.4**	**41.8**	**13.5**	**3.6**	**1.2**
PMK72	?	18-25	-18.4	15.3	45.1	16.1	3.3	12.9
PMK74	M	46-59	-19.3	14.5	47.0	16.9	3.2	17.3
PMK75	?M	Adult	-19.6	14.4	45.8	16.2	3.3	26.0
PMK76	F	Adult	-21.0	11.8	44.5	15.8	3.3	22.0

Appendix 7a: Isotope data for Portmahomack adult human bone collagen

Lab no.	Sex	Age	δ^{13}C	δ^{15}N	%C	%N	C/N	% Collagen
PMK77	M	36-45	-15.9	17.1	43.4	15.5	3.3	13.8
PMK78	F	26-35	-17.4	15.8	46.6	16.9	3.2	25.2
PMK80	M	36-45	-17.6	16.3	45.9	16.5	3.3	13.8
PMK82	F	36-45	-20.3	12.4	45.3	16.4	3.2	24.7
PMK83	**F**	**36-45**	**-19.4**	**14.9**	**43.5**	**15.9**	**3.2**	**6.4**
PMK84	M	46-59	-19.5	13.1	44.3	16.3	3.2	11.6
PMK85	**?M**	**18-25**	**-18.0**	**15.1**	**43.3**	**15.9**	**3.2**	**5.2**
PMK88	**F**	**36-45**	**-18.4**	**15.0**	**44.1**	**16.2**	**3.2**	**3.5**
PMK90	**M**	**60+**	**-18.0**	**15.1**	**43.4**	**15.8**	**3.2**	**3.7**
PMK91	**F**	**26-35**	**-19.8**	**14.0**	**43.2**	**15.7**	**3.2**	**3.5**
PMK93	**M**	**26-35**	**-17.1**	**16.6**	**43.1**	**15.6**	**3.2**	**8.7**
PMK95	F	46-59	-18.6	14.7	43.7	15.7	3.3	22.7
PMK96	?M	Adult	-19.0	14.1	44.0	15.8	3.3	13.5
PMK97	**?F**	**46-59**	**-18.3**	**15.0**	**44.2**	**16.2**	**3.2**	**5.2**
PMK98	**M**	**26-35**	**-17.9**	**15.8**	**43.9**	**16.1**	**3.2**	**7.7**
PMK99	F	60+	-17.1	16.2	44.5	15.8	3.3	22.0
PMK100	**F**	**26-35**	**-19.4**	**15.0**	**42.4**	**15.4**	**3.2**	**3.8**
PMK101	F	46-59	-18.5	14.8	47.0	16.6	3.3	24.8
PMK102	**F**	**36-45**	**-17.8**	**16.1**	**43.0**	**15.9**	**3.2**	**7.5**
PMK103	**M**	**26-35**	**-18.0**	**15.6**	**43.6**	**16.1**	**3.2**	**7.0**
PMK104	M	Adult	-18.3	14.9	44.1	15.9	3.2	13.7
PMK105	**F**	**46-59**	**-20.4**	**12.7**	**43.6**	**16.0**	**3.2**	**6.8**
PMK106	**F**	**60+**	**-18.7**	**15.5**	**43.9**	**15.9**	**3.2**	**3.4**
PMK108	**M**	**36-45**	**-19.5**	**14.7**	**45.6**	**16.8**	**3.2**	**6.8**
PMK109	**M**	**46-59**	**-18.2**	**14.4**	**43.2**	**15.8**	**3.2**	**11.5**
PMK111	M	26-35	-20.7	12.0	42.2	14.8	3.3	6.6
PMK112	**M**	**46-59**	**-18.9**	**14.4**	**43.0**	**15.8**	**3.2**	**7.1**
PMK113	**M**	**36-45**	**-19.1**	**13.8**	**44.6**	**16.4**	**3.2**	**5.8**
PMK114	F	18-25	-17.5	15.2	38.2	13.6	3.3	9.2
PMK115	F	Adult	-18.8	15.4	45.3	15.4	3.4	9.8
PMK116	**M**	**46-59**	**-20.3**	**13.0**	**42.2**	**15.3**	**3.2**	**11.0**
PMK117	M	18-25	-20.5	11.5	43.4	15.6	3.3	15.9
PMK118	M	18-25	-19.7	11.9	44.9	16.3	3.2	22.8
PMK120	M	36-45	-19.5	14.3	44.4	15.8	3.3	11.7
PMK121	M	26-35	-20.2	12.8	46.0	16.2	3.3	7.8
PMK122	M	46-59	-20.3	12.4	42.1	15.6	3.2	9.2
PMK123	M	60+	-20.4	12.6	44.2	15.6	3.3	24.6
PMK124	**M**	**18-25**	**-20.8**	**11.4**	**41.8**	**15.1**	**3.2**	**5.1**
PMK125	M	60+	-20.3	12.9	43.7	15.1	3.4	5.7
PMK126	M	46-59	-20.9	10.8	38.5	13.6	3.3	5.9
PMK127	**?M**	**36-45**	**-20.4**	**11.8**	**41.2**	**15.1**	**3.2**	**10.6**
PMK128	**?M**	**46-59**	**-20.5**	**11.7**	**42.0**	**14.9**	**3.3**	**4.4**
PMK129	?M	18-25	-20.6	11.3	44.0	15.4	3.4	10.3
PMK130	?M	46-59	-20.7	12.1	43.6	15.0	3.4	7.5
PMK131	F	46-59	-20.9	10.4	43.9	15.4	3.3	22.8
PMK133	M	60+	-20.3	12.2	44.3	15.4	3.4	20.3
PMK134	M	18-25	-17.6	14.9	48.3	16.8	3.4	19.8
PMK135	?M	46-59	-20.8	11.6	43.4	15.1	3.4	11.0

Appendix 7a: Isotope data for Portmahomack adult human bone collagen

Lab no.	Sex	Age	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
PMK136	**M**	**36-45**	**-21.1**	**11.9**	**40.3**	**14.2**	**3.3**	**1.3**
PMK137	?M	36-45	-20.5	11.8	43.3	14.8	3.4	8.9
PMK138	?	Adult	-20.9	11.4	27.4	9.7	3.3	4.7
PMK139	M	46-59	-19.8	12.6	43.6	15.2	3.4	21.5
PMK140	**M**	**18-25**	**-20.3**	**12.6**	**40.5**	**14.6**	**3.2**	**2.0**
PMK141	M	36-45	-20.1	12.3	44.8	15.5	3.4	20.3
PMK142	M	46-59	-20.4	11.8	40.1	14.2	3.3	8.2
PMK143	M	60+	-20.0	12.4	39.8	13.7	3.4	7.2
PMK144	**M**	**46-59**	**-19.1**	**14.6**	**40.7**	**14.7**	**3.2**	**2.4**
PMK145	M	Adult	-20.5	12.3	42.7	14.7	3.4	9.9
PMK146	F	26-35	-20.6	11.0	42.9	15.4	3.3	23.6
PMK147	**M**	**26-35**	**-20.4**	**11.2**	**39.9**	**14.6**	**3.2**	**5.4**
PMK148	M	60+	-20.7	12.4	41.5	14.2	3.4	7.4
PMK149	M	60+	-20.4	12.3	41.3	14.3	3.4	12.8
PMK150	M	Adult	-19.3	14.4	42.1	15.0	3.3	23.8
PMK151	**M**	**46-59**	**-20.6**	**12.6**	**40.0**	**14.5**	**3.2**	**6.6**
PMK152	**M**	**26-35**	**-20.5**	**11.7**	**40.9**	**15.0**	**3.2**	**6.0**
PMK153	M	36-45	-20.3	12.0	42.5	14.7	3.4	16.1
PMK154	**M**	**46-59**	**-20.5**	**11.8**	**41.2**	**14.8**	**3.2**	**9.3**
PMK155	F	46-59	-20.7	12.0	43.5	15.6	3.3	22.2
PMK156	M	36-45	-20.9	12.0	41.4	14.2	3.4	5.0
PMK157	M	46-59	-20.7	12.1	40.2	14.1	3.3	7.4
PMK158	**M**	**46-59**	**-20.3**	**12.4**	**40.8**	**14.9**	**3.2**	**8.6**
PMK160	**?M**	**Adult**	**-20.7**	**11.1**	**40.7**	**14.9**	**3.2**	**7.7**
PMK161	M	36-45	-18.0	14.4	43.8	15.7	3.3	22.5
PMK162	M	Adult	-21.2	10.9	44.0	15.4	3.3	23.6
PMK163	M	36-45	-21.0	10.9	42.9	15.2	3.3	9.2
PMK164	**M**	**46-59**	**-20.2**	**12.8**	**40.5**	**14.8**	**3.2**	**8.3**
PMK165	?	Adult	-21.1	11.1	43.2	14.9	3.4	18.4
PMK166	**?F**	**Adult**	**-21.0**	**10.8**	**49.5**	**18.0**	**3.2**	**10.4**
PMK167	M	Adult	-21.1	11.1	45.3	16.0	3.3	20.1
PMK168	**?M**	**36-45**	**-20.0**	**12.3**	**42.1**	**15.4**	**3.2**	**3.8**
PMK169	**M**	**26-35**	**-20.7**	**10.0**	**46.2**	**17.0**	**3.2**	**8.8**
PMK170	M	26-35	-20.6	11.9	41.8	14.6	3.3	14.3
PMK171	**M**	**36-45**	**-19.7**	**12.2**	**43.3**	**15.9**	**3.2**	**2.9**
PMK172	**F**	**46-59**	**-20.8**	**10.8**	**41.3**	**15.2**	**3.2**	**10.1**
PMK173	M	46-59	-20.3	13.1	42.9	15.0	3.3	10.5
PMK174	**?F**	**Adult**	**-21.1**	**11.4**	**40.7**	**15.0**	**3.2**	**12.4**
PMK176	M	46-59	-20.1	12.8	41.2	14.4	3.3	10.9
PMK186	M	26-35	-20.7	11.2	44.2	15.7	3.3	21.1
PMK187	?M	36-45	-20.4	11.3	42.2	14.5	3.4	4.8
PMK188	?M	Adult	-21.1	11.9	42.9	15.3	3.3	20.9
PMK189	M	26-35	-21.1	11.7	37.2	12.9	3.4	4.6
PMK192	M	36-45	-18.3	15.6	44.0	15.7	3.3	19.9

Appendix 7b: Isotope data for Portmahomack sub-adult human bone collagen

Lab no.	Age	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
PMK3	10.6-14.5	-18.7	14.4	44.9	16.3	3.2	4.5
PMK24	14.6-17.0	-18.1	14.9	45.0	16.2	3.3	8.7
PMK27	10.6-14.5	-18.2	15.0	44.6	16.3	3.2	10.4
PMK81	10.6-14.5	-18.6	13.4	44.6	16.2	3.2	14.7
PMK107	14.6-17.0	-15.6	17.4	46.6	16.9	3.2	15.3
PMK110	10.6-14.5	-20.1	13.7	46.2	16.9	3.2	17.4
PMK119	10.6-14.5	-19.2	13.6	45.2	16.5	3.2	21.1
PMK159	10.6-14.5	-20.4	12.5	44.8	16.1	3.3	11.4

Appendix 7c: Isotope data for Portmahomack faunal bone collagen. Data in bold from Curtis-Summers *et al*. (2014)

Lab no.	Species	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
C3122/4	**Cattle**	**-22.3**	**6.8**	**41.9**	**15.2**	**3.2**	**5.6**
C3122/5	**Cattle**	**-22.4**	**6.4**	**42.1**	**15.3**	**3.2**	**6.8**
C3122/6	**Cattle**	**-22.2**	**6.4**	**41.6**	**15.2**	**3.2**	**5.3**
C3122/7	**Cattle**	**-21.8**	**6.6**	**42.5**	**15.2**	**3.2**	**6.2**
C3122/8	**Cattle**	**-22.4**	**5.9**	**42.2**	**15.3**	**3.3**	**7.1**
C3122/9	**Cattle**	**-21.8**	**6.2**	**42.1**	**15.2**	**3.2**	**4.3**
C3122/10	**Cattle**	**-22.0**	**3.4**	**42.0**	**15.0**	**3.2**	**6.4**
C1280/2	**Cattle**	**-22.0**	**10.0**	**42.2**	**15.4**	**3.3**	**6.8**
PK/A/1179	Cattle	-22.2	7.2	42.4	15.2	3.3	6.0
PK/A/3470	Cattle	-21.5	7.2	42.4	15.5	3.2	15.2
PK/A/3535B	Cattle	-22.5	4.7	42.1	15.2	3.3	11.7
PK/A/2117	Cattle	-22.4	6.1	39.5	13.5	3.4	2.2
PK/A/1733	Cattle	-21.9	6.5	42.5	15.0	3.3	2.2
PK/A/1734	Cattle	-22.6	5.0	44.3	15.7	3.3	13.6
PK/A/3545A	Cattle	-21.7	5.4	44.4	15.8	3.3	19.2
PK/A/3545B	Cattle	-22.4	6.1	42.7	14.9	3.3	10.0
PK/A/3562D	Cattle	-22.0	5.8	43.4	15.5	3.3	13.6
PK/A/1250B	Cattle	-22.0	5.5	42.3	15.2	3.3	6.1
PK/A/1823A	Cattle	-21.9	5.9	41.5	14.8	3.3	0.8
PK/A/1823B	Cattle	-21.3	5.7	41.9	14.9	3.3	8.8
PK/A/3233B	Red deer	-21.8	6.9	40.6	14.6	3.2	8.5
PK/A/3455B	Red deer	-22.0	7.1	41.5	14.9	3.2	11.1
PK/A/3562C	Red deer	-21.6	6.6	43.1	15.6	3.2	14.8
PK/A/1877B	Red deer	-22.1	4.3	42.7	14.9	3.4	10.1
PK/A/1250C	Red deer	-22.3	5.2	42.1	14.8	3.3	11.1
PK/A/3324	Roe deer	-21.6	3.8	42.0	15.0	3.3	13.6
PK/A/3562A	Roe deer	-22.1	3.9	41.9	14.2	3.5	5.6
PK/A/1544	S/G	-22.0	9.1	27.8	10.0	3.3	0.2
PK/A/2491	S/G	-21.8	7.8	42.3	15.2	3.3	8.1
PK/A/1284B	S/G	-21.7	8.5	41.7	14.7	3.3	5.2
PK/A/3562E	S/G	-22.2	9.6	43.2	15.1	3.3	0.5
PK/A/3562F	S/G	-22.0	7.4	43.2	14.6	3.5	13.9
PK/A/1427	S/G	-22.0	9.5	41.1	14.9	3.2	8.7
PK/A/1877C	S/G	-22.2	4.7	42.7	15.2	3.3	13.9
PK/A/1250A	S/G	-22.0	8.1	41.0	14.7	3.3	9.7
C1280/1	**S/G**	**-22.0**	**8.8**	**41.7**	**14.7**	**3.3**	**2.2**
PK/A/3535A	Pig	-22.4	7.9	41.8	15.0	3.3	7.8
PK/A/2448	Pig	-22.2	7.6	42.1	15.0	3.3	9.8
PK/A/3233A	Pig	-21.8	7.3	37.7	13.3	3.3	3.9
PK/A/3455A	Pig	-22.0	7.8	44.2	15.7	3.3	1.9
PK/A/1284A	Pig	-21.4	9.4	42.5	15.1	3.3	11.0
PK/A/1918	Pig	-21.6	8.5	42.1	15.2	3.2	13.5
PK/A/3562B	Pig	-22.5	9.2	42.7	14.7	3.4	8.5
PK/A/1575	Pig	-21.7	8.9	41.1	14.6	3.3	10.6
C3122/1	**Pig**	**-21.4**	**8.8**	**42.7**	**15.4**	**3.2**	**3.2**
C3122/2	**Pig**	**-21.5**	**8.1**	**40.8**	**14.8**	**3.2**	**1.5**
C3122/3	**Pig**	**-21.4**	**8.3**	**41.0**	**15.0**	**3.2**	**3.6**
C1280/4	**Pig**	**-21.1**	**12.0**	**41.5**	**14.8**	**3.2**	**3.4**

Appendix 7c: Isotope data for Portmahomack faunal bone collagen

Lab no.	Species	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
C1280/5	**Pig**	**-21.7**	**11.8**	**41.8**	**15.0**	**3.3**	**3.9**
PK/A/3297	Dog	-19.3	10.3	41.9	15.1	3.3	5.5
C1280/3	**Dog**	**-16.8**	**15.3**	**41.5**	**14.9**	**3.2**	**2.9**
PK/A/2004A	Dog	-19.5	11.3	42.1	14.8	3.3	9.7
PK/A/2004B	?Otter	-12.1	17.6	41.7	14.6	3.3	2.2
PK/F/3193	Char	-14.4	9.7	36.1	13.2	3.2	2.9
PK/F/3446	Char	-15.0	10.0	39.9	14.8	3.2	1.8
PK/F/2568	Char	-14.9	10.9	41.9	14.4	3.4	0.2
C1303/1	**Cod**	**-12.4**	**14.3**	**41.1**	**14.6**	**3.2**	**1.3**
PK/F/1678	Cod	-12.3	14.9	41.6	14.6	3.3	0.3
PK/F/1270A	Cod	-11.5	14.5	41.5	15.2	3.2	0.2
PK/F/2061	Cod	-12.8	15.1	41.0	14.0	3.4	1.2
PK/F/1346	Cod	-12.7	15.0	39.2	13.4	3.4	2.2
PK/F/1882	Cod	-12.8	13.0	41.3	14.7	3.3	5.6
PK/F/3168	Gadid	-12.5	14.3	42.5	14.5	3.4	0.2
PK/F/1283	Gadid	-14.6	13.0	42.5	13.7	3.6	0.3
PK/F/1293	Haddock	-14.3	14.4	42.7	14.4	3.5	0.8
PK/F/2534	H.mackerel	-13.8	13.2	41.9	15.1	3.2	0.4
PK/F/1270B	Pollack	-13.1	15.2	41.4	14.1	3.4	2.3
PK/F/1374	Pollack	-13.1	15.5	41.1	14.5	3.3	4.4
PK/F/1387	Pollack	-13.0	14.7	41.3	13.8	3.5	0.4
PK/F/1004	Saithe	-13.7	13.0	43.5	15.1	3.4	4.1
PK/F/1348	Conger eel	-14.0	14.5	37.7	13.4	3.3	0.5

Appendix 7d: Isotope data for Norton Priory adult human bone collagen

Lab no.	**Sex**	**Age**	**$\delta^{13}C$**	**$\delta^{15}N$**	**%C**	**%N**	**C/N**	**% Collagen**
NP1	M?	18-25	-19.0	14.2	43.1	14.8	3.4	6.97
NP2	M	18-25	-18.8	13.6	44.8	15.6	3.4	15.86
NP3	M	26-35	-19.1	14.2	37.4	12.9	3.4	4.99
NP4	M	46-59	-19.2	13.9	28.9	10.2	3.3	1.22
NP5	M	46-59	-19.6	12.5	36.2	12.6	3.4	3.70
NP6	M	46-59	-19.6	13.0	38.8	13.4	3.4	4.20
NP7	M?	46-59	-19.6	13.6	40.8	14.7	3.3	8.66
NP8	M	36-45	-19.1	12.9	45.4	16.1	3.3	13.88
NP9	M	26-35	-19.8	13.7	42.5	15.0	3.3	11.33
NP10	M?	46-59	-20.1	13.3	45.2	16.0	3.3	16.47
NP11	F	18-25	-20.6	13.4	24.7	8.6	3.4	0.80
NP12	M	36-45	-19.0	14.1	43.2	14.7	3.4	7.28
NP13	M?	36-45	-18.5	14.4	42.3	14.8	3.3	11.40
NP14	M	46-59	-19.3	13.0	43.7	15.2	3.4	7.90
NP15	M	26-35	-18.9	13.8	39.2	13.8	3.3	7.57
NP16	F	26-35	-19.5	13.1	39.6	13.9	3.3	4.78
NP17	F	Adult	-19.7	13.4	41.4	14.8	3.3	2.93
NP18	F	36-45	-19.1	12.3	40.5	14.3	3.3	14.31
NP19	M	36-45	-18.8	14.0	42.8	15.1	3.3	11.15
NP20	M	36-45	-20.3	11.9	41.4	14.6	3.3	9.76
NP21	M	46-59	-18.5	14.8	45.2	15.8	3.3	15.54
NP22	M	46-59	-19.1	13.8	45.8	16.1	3.3	10.10
NP25	M?	26-35	-19.3	12.7	45.6	16.2	3.3	23.39
NP28	M	46-59	-18.6	14.7	46.5	16.4	3.3	20.15
NP29	M	46-59	-19.1	14.2	43.6	15.1	3.4	10.62
NP30	M	18-25	-18.9	14.4	44.2	15.5	3.3	12.72
NP32	M	46-59	-19.0	13.2	43.2	14.8	3.4	4.46
NP33	M	60+	-19.9	13.7	43.1	15.2	3.3	15.46
NP35	M	46-59	-18.9	13.9	45.3	16.0	3.3	14.48
NP37	M	46-59	-18.8	14.7	43.9	14.6	3.5	6.66
NP38	M	26-35	-19.4	13.1	28.9	9.9	3.4	0.24
NP39	F	46-59	-19.6	13.6	44.2	15.5	3.3	12.01
NP43	F	26-35	-19.4	12.8	41.5	14.9	3.3	6.31
NP44	M	26-35	-19.9	13.2	44.8	16.0	3.3	21.41
NP45	M	26-35	-18.5	13.8	43.7	15.4	3.3	16.14
NP46	F	46-59	-20.0	12.8	43.8	14.8	3.5	8.13
NP49	M	46-59	-18.4	14.4	44.0	15.5	3.3	18.46
NP50	M	26-35	-18.6	14.6	44.9	16.1	3.3	18.50
NP52	M	36-45	-19.1	13.7	41.2	13.8	3.5	5.00
NP58	M	26-35	-19.0	14.1	43.4	14.8	3.4	4.78
NP59	M	26-35	-19.0	14.0	33.6	11.3	3.5	1.06
NP63	M?	26-35	-18.9	13.7	45.0	15.8	3.3	17.90
NP65	F?	26-35	-18.8	13.2	41.6	14.3	3.4	6.41
NP67	M	36-45	-19.7	12.4	44.5	15.4	3.4	10.95
NP68	M	36-45	-19.1	13.2	45.3	16.0	3.3	21.07
NP69	M	26-35	-19.3	12.8	44.3	15.4	3.4	11.89

Appendix 7d: Isotope data for Norton Priory adult human bone

Lab no.	Sex	Age	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
NP70	M	60+	-18.4	14.2	44.8	15.5	3.4	10.57
NP71	M	46-59	-19.3	12.1	45.9	16.2	3.3	16.72
NP72	F	18-25	-19.2	13.6	44.3	15.4	3.4	11.28
NP74	M	46-59	-19.1	12.7	44.3	15.4	3.4	6.43
NP75	M	36-45	-19.1	13.7	44.7	15.8	3.3	10.68
NP76	M	36-45	-19.3	13.6	31.1	10.6	3.4	4.10
NP78	F	46-59	-19.5	14.1	37.4	12.5	3.5	0.33
NP79	?	Adult	-19.6	12.6	44.6	15.6	3.3	4.74
NP82	M	Adult	-19.3	13.8	43.8	14.6	3.5	0.35
NP85	M	26-35	-19.1	12.8	42.8	15.1	3.3	3.85
NP86	M	36-45	-19.3	13.8	43.9	14.7	3.5	0.67
NP87	F	60+	-20.0	12.2	42.6	14.8	3.4	0.64
NP88	M	26-35	-19.8	13.2	42.8	15.2	3.3	8.67
NP89	M	26-35	-18.9	12.6	43.8	15.2	3.4	3.01
NP90	M	36-45	-19.7	12.7	42.4	15.0	3.3	3.15
NP91	M	26-35	-19.5	13.7	44.4	15.7	3.3	7.40
NP92	M	36-45	-19.0	13.7	36.7	12.3	3.5	1.23
NP93	M	26-35	-19.6	12.8	42.6	15.2	3.3	10.42
NP94	M	26-35	-19.8	13.3	42.4	14.9	3.3	2.29
NP95	M	36-45	-19.5	13.5	41.2	13.7	3.5	0.17
NP96	M	36-45	-19.0	13.9	42.1	15.0	3.3	17.52
NP98	F	26-35	-19.2	13.3	42.0	14.4	3.4	5.11
NP100	M	46-59	-19.3	13.6	42.7	14.8	3.4	10.80
NP101	M	46-59	-19.5	13.2	42.7	14.8	3.4	3.71
NP102	M	26-35	-19.4	13.0	43.1	15.3	3.3	18.01
NP104	M	26-35	-19.6	13.2	17.8	6.0	3.5	1.94
NP105	M	46-59	-19.6	12.6	41.1	14.1	3.4	1.02
NP106	M	60+	-19.6	12.6	25.4	8.6	3.5	8.70
NP108	?	46-59	-19.8	12.6	41.6	14.4	3.4	3.08
NP109	M	26-35	-19.9	12.8	42.8	15.0	3.3	1.97
NP110	M	36-45	-19.2	14.8	38.6	12.9	3.5	1.30
NP111	M	36-45	-18.8	13.5	43.4	15.7	3.2	17.81
NP112	F	18-25	-20.5	11.6	44.6	15.9	3.3	9.85
NP114	F	26-35	-19.7	13.7	38.9	13.1	3.5	1.12
NP118	F	26-35	-19.1	13.0	45.8	16.2	3.3	13.09
NP120	F	26-35	-20.1	12.3	42.1	15.0	3.3	7.57
NP121	M	26-35	-19.9	13.0	33.2	11.0	3.5	0.25
NP128	?	Adult	-20.3	12.4	41.2	13.9	3.5	2.84
NP22/Path	M	46-59	-19.5	13.6	35.9	12.7	3.3	0.71
NP29/Path	M	46-59	-19.3	14.2	40.5	14.1	3.4	5.53
NP35/Path	M	46-59	-20.6	11.9	40.9	14.0	3.4	5.97
NP52/Path	M	36-45	-19.0	14.3	34.1	11.7	3.4	1.64
NP101/Path	M	46-59	-19.7	13.2	41.1	13.7	3.5	1.38

Path = pathological (Paget's disease) samples

Appendix 7e: Isotope data for Norton Priory faunal bone collagen

Lab no.	Species	$\delta^{13}C$	$\delta^{15}N$	%C	%N	C/N	% Collagen
NP/A/GR81A	Cattle	-22.1	7.5	41.7	14.8	3.3	7.2
NP/A/GR42	Cattle	-22.2	7.5	41.8	15.0	3.3	8.7
NP75/103/41B	Cattle	-21.8	7.7	42.0	14.9	3.3	1.8
NP75/103/42E	Cattle	-21.9	8.5	42.8	14.6	3.4	0.2
NP75/103/42F	Cattle	-22.6	6.7	41.0	14.4	3.3	0.3
NP75/103/42G	Cattle	-22.1	7.1	41.8	14.5	3.4	1.9
NP75/103/55B	Cattle	-22.8	6.4	42.6	15.1	3.3	10.3
NP77/109/45F	Cattle	-22.2	7.3	42.5	14.9	3.3	16.5
NP77/109/45G	Cattle	-23.4	6.0	41.7	14.6	3.3	5.8
NP79/113/110	Cattle	-21.9	8.7	41.2	14.1	3.4	0.2
NP79/113/117D	Cattle	-23.0	6.1	37.0	12.5	3.5	1.4
NP/A/GR81B	Sheep	-21.0	6.2	42.0	14.6	3.4	11.6
NP/A/GR56	Sheep	-22.3	8.3	42.7	15.3	3.3	10.6
NP/A/GR72	Sheep	-22.0	8.1	43.3	14.2	3.6	0.9
NP/A/GR74	Sheep	-23.0	9.4	38.0	12.9	3.4	3.3
NP75/103/42D	Sheep	-22.0	4.4	42.3	14.7	3.4	6.6
NP75/103/55A	Sheep	-21.3	6.2	42.4	14.8	3.3	10.9
NP77/109/45D	Sheep	-22.1	10.6	42.1	14.6	3.4	9.6
NP77/109/45E	Sheep	-21.9	7.2	42.1	15.0	3.3	13.6
NP79/113/117B	Sheep	-22.5	9.2	42.2	13.7	3.6	0.3
NP75/103/41A	S/G	-22.5	5.1	36.8	12.9	3.3	1.0
NP75/103/42C	S/G	-22.1	7.6	42.3	14.7	3.4	10.2
NP79/113/117A	S/G	-22.2	9.6	41.6	13.8	3.5	0.3
NP77/109/45H	Red deer	-21.5	4.2	42.3	14.9	3.3	10.6
NP/A/GR7	Pig	-21.4	8.9	42.7	15.1	3.3	13.1
NP/A/GR35	Pig	-21.7	8.0	41.7	14.6	3.3	5.0
NP75/103/42A	Pig	-21.2	8.7	43.3	15.0	3.4	8.5
NP75/103/42B	Pig	-21.2	8.7	42.4	14.8	3.4	8.1
NP75/103/54	Pig	-21.5	9.8	41.5	14.8	3.3	3.9
NP75/103/64	Pig	-21.5	9.9	40.6	13.2	3.6	1.8
NP77/109/45A	Pig	-21.3	5.9	43.2	14.6	3.5	0.3
NP77/109/45B	Pig	-20.9	7.9	42.8	14.9	3.4	15.2
NP77/109/45C	Pig	-21.4	6.6	42.3	14.4	3.4	8.5
NP79/113/100	Pig	-22.2	9.3	41.8	14.6	3.4	7.4
NP75/103/41C	?Bear	-19.6	8.0	41.7	15.1	3.2	0.7
NP77/109/5	Cod	-14.4	15.8	39.7	12.6	3.6	0.3

Appendix 7f: Isotope data for Chester fish bone collagen

Lab no.	**Species**	**$\delta^{13}C$**	**$\delta^{15}N$**	**%C**	**%N**	C/N	**% Collagen**
CCF.1	Cod	-17.0	12.8	45.3	15.6	3.4	0.3
CCF.2	Cod	-12.9	16.0	42.7	14.1	3.5	0.3
CCF.3	Cod	-12.9	13.4	42.2	14.0	3.5	0.3
CCF.4	Conger eel	-13.9	12.5	43.8	15.4	3.3	0.2
CCF.5	Cod	-12.6	17.7	43.5	15.1	3.4	0.2
CCF.6	Cod	-14.0	13.5	43.3	14.7	3.5	0.2
CCF.7	Cod	-12.2	17.5	43.4	15.0	3.4	0.2
CCF.8	Cod	-13.5	11.9	44.1	14.8	3.5	0.3
CCF.9	Cod	-14.2	8.7	43.7	15.8	3.2	0.3