Health Status in Lowland Medieval Scotland:
A Regional Analysis of Four Skeletal Populations

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Abstract

This research examines the health of those living within the lowland, east coast region of Scotland from 500-1500 AD utilizing historical, archaeological, and skeletal material. Although the study area was a central part of medieval Scotland, it has not been the focus of any larger scale research into health, including any previous statistical analyses.

This study presents the osteological analysis of skeletal remains of four medieval populations (385 individuals) from eastern, lowland Scotland: Ballumbie (N=197 individuals), Isle of May (N=58), St Andrews Library (N=72), and Whitefriars (N=58). Additionally, this research provides a contextualized discussion of the similarities and differences in health of these four lowland populations, focusing on the broad themes of location (rural/urban) and status (high/low). The four study populations are compared statistically through prevalence rates of disease. A compilation of disease prevalence rates for twenty-three other medieval Scottish populations was created to provide further contextualized comparisons of health. The discussion of health from the perspectives of location is framed within the context of access to health care, population density/pathogen load, diet, and subadult mortality. Discussions of status focus on differences in housing and diet between the upper and lower status individuals living in medieval society. The role of pilgrimage is explored for the Isle of May with respect to health, illness, and the treatment of the sick.

The analysis of four medieval populations in the lowland, east coast region of Scotland illustrate that although they were close geographically, each population had unique aspects to their skeletal health due to differences in their location and status.

Lay Summary

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Declaration

I hereby declare that:

(a) This thesis has been composed by myself

(b) This work is my own

(c) That no part of this thesis has been submitted for any other degree or professional qualification

Marlo A. Willows

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1. Introduction

Archaeological research can be useful to infer details about past lifestyles, what it was like to live in a specific part of the world in a specific time period. An important aspect of research into the past is the health status of a population. The Oxford definition of health (2013) is “the state of being free from illness or injury.” Bioarchaeological techniques allow researchers to investigate illness or injury in the past through osteological analysis. This research provides a glimpse into the lives of those living in lowland medieval Scotland and how their lifestyle could have potentially affected their health. In particular, this research uses four skeletal populations to evaluate how location (rural/urban) and status (high/low) affected their health status, considering factors such as access to health care, diet, population density, subadult mortality, and types of housing.

The four populations chosen for this research are Ballumbie, the Isle of May, St Andrews Library and Whitefriars. The site of Ballumbie consists of a rural long cist cemetery from the early medieval period as well as a cemetery from a later medieval parish church. The burials span nearly 1000 years during a time when 90% of Scottish people lived in the rural countryside (Barrell 2000, Yeoman 1995). Ballumbie was chosen to represent rural populations, since it is one of the larger medieval rural populations excavated and has had very little published about it as of yet. For comparative purposes, the St Andrews Library assemblage was chosen to represent medieval urban populations in the lowland, east coast of Scotland. The St Andrews Library assemblage contains burials from the Holy Trinity Parish Church which dates from the fifteenth to the sixteenth century. The assemblages from Ballumbie and St Andrews offer insights into the lifestyle of lay populations of this region; but this thesis also aims to compare and contrast them with the experience of neighbouring monastic communities. Monastic populations were included to discern how lifestyle differences, such as types of housing and diet, could affect the skeleton. One of these monastic assemblages comes from the Whitefriars cemetery in Perth, and dates from the fourteenth to the seventeenth century. These burials have never been analyzed nor published before, and a major aim of this thesis is therefore to conduct a proper analysis of this previously unexamined collection of material. The final site in this study is the Isle of May, an island which housed a monastic population during the Middle Ages. The burials from this site date from the fifth to the sixteenth century.

Since the majority of early settlements were concentrated around the east coast of Scotland, where the medieval Kingdom of Scotland was centered, most of the historical and archaeological evidence we have is from this area, making it ideal for research (Barrell 2000, Yeoman 1995). An important aspect of the east coast of Scotland is that it shared the political associations with the Kingdom of Scotland as well as trade and travel connections with mainland Europe (Dennison and Simpson 2000). These unique aspects require lowland, east coast of Scotland around the Forth, Tay, Tweed, and Dee to be considered a region on its own. The *study area* for this research focuses on the health of medieval populations living in this lowland, east coast region of Scotland.

Although the study area was a central part of medieval Scotland, it has yet been the focus of any larger scale research into health, including any previous statistical analyses. This research, therefore provides an opportunity to evaluate the health of those living within the lowland, east coast region of Scotland from roughly 500-1500 AD utilizing historical, archaeological, and skeletal material. The analysis of four medieval populations in the study area have illustrated that although they were close geographically, each population had unique aspects to their skeletal health.

1.1 Aims and objectives

This thesis has two central aims. The first aim is to present the osteological analysis of skeletal remains of four medieval populations (385 individuals) from eastern, lowland Scotland. The second aim is to provide a contextualized discussion which addresses the similarities and differences in the health status of these four lowland populations along the broad themes of rural/urban and low/high status society.

To evaluate their health status, these four populations are compared to each through prevalence of disease with appropriate statistical analysis. Demography and stature are also compared. None of the four populations have been compared to each other or analyzed statistically previously. A compilation of disease prevalence rates for twenty-three other medieval Scottish populations was also created to provide contextualized comparisons of health within rural, urban, low and high status environments.

Discussions regarding rural and urban lifestyle differences will consider access to health care, diet, population density, and subadult mortality. Discussions of status focus on differences in housing and diet between the upper and lower status individuals living in medieval society. Although monks were meant to live an ascetic life, the similar housing conditions and diet in monastic and elite environments require monastic populations to be classified in the same category as elites for comparisons of skeletal health (section 1.3.2). Due to the religious significance of one of the study populations, the Isle of May, separate attention will be provided to pilgrimage and its role during the medieval period in regards to health and illness.

1.2 Bioarchaeology

While archaeology is the study of the past through material remains, bioarchaeology is the study of the past through skeletal remains. Prior to presenting the materials, methods, and results of this research, it is important to introduce the basics of bone anatomy and the usefulness of bioarchaeology in learning about past populations. Limitations within bioarchaeology will also be discussed in this chapter.

1.2.1 Bone anatomy and identification of disease

There are 206 bones in the adult human body serving the purpose of protecting the vital organs, acting as an anchor for the muscles, tendons, and ligaments, and storing fat and blood cells (Cox and Mays 2000, White and Folkens 2005). Bones are made of fibrous protein, collagen, and calcium phosphate crystals which harden it (Currey 2002). There is also water in bones, which aids in mechanics. Most bones are hollow and the medullary cavity within contains blood-forming marrow (Cox and Mays 2000, White and Folkens 2005). Structurally, the two components of bone are trabecular bone, which is the honeycomb structure that is the site for blood-forming marrow, and cortical bone, the solid and compact outer surface (Ortner 2003, White and Folkens 2005). Muscles, tendons and ligaments insert into cortical bone. The periosteum is a vascularized sheath that covers the outer surface of cortical bone. This specialized layer is made from osteogenic or bone-forming tissue which helps to form new bone during ontogeny and also, if stimulated, after stress or trauma from an injury (Ortner 2003, White and Folkens 2005).

At the microscopic level, there are three primary types of cells involved in forming and maintaining bone tissue: osteoblasts, osteocytes, and osteoclasts (Waldron 2009, White and Folkens 2005). Osteoblasts are cells that form the bone. They are concentrated just beneath the periosteum and are responsible for synthesizing and depositing bone material (Ortner 2003, White and Folkens 2005). When calcium phosphate crystals combine with cell material produced by the osteoblasts, calcification occurs. Osteocytes are the osteoblasts that are now surrounded by the bony matrix in the body of the bone (White and Folkens 2005). Blood vessels pass through openings, called haversian canals, in these cells. While osteocytes appear during growth, osteoclasts replace osteocytes when growth is completed. Osteoclasts are bone-destroying cells and are responsible for the resorption, or removal, of bone tissue. White and Folkens (2005:43) explains "the reshaping, or remodeling, of bone takes place at the cellular level as osteoclasts remove bone tissue and osteoblasts build bone tissue. The opposing processes of bone formation and resorption allow bones to maintain or change their shape and size during growth."

During development, bones begin as a cartilaginous model, followed by deposition of bone matrix. The primary ossification centers begin turning cartilage into bone first, then the secondary centers ossify, connecting the primary centers together to ultimately form a complete bone (White and Folkens 2005). Long bones grow by apposition; the diaphysis (or shaft) grows outward by depositing bone on the cortex and removal of bone by osteoclasts in the medullary cavity (White and Folkens 2005). Bone from the flared end of the diaphysis, the metaphysis, is deposited onto the diaphysis, lengthening and widening the shaft at the same time. Normal development can be interrupted from factors such as hormone imbalances, nutritional deficiencies, abnormal mechanical loading, trauma, or disease (Ortner 2003).

Once development is complete, the ends, or epiphyses, of the bone have fused on to the diaphysis. This generally occurs around 18-25 years of age. Maintenance and bone repair become the essential tasks of the skeletal system. German anatomist Julius Wolff's research into mechanical loading on bone led to what is now known as Wolff's law, which states that bone can respond and adapt when it is strained with external force such as weight bearing and muscle activity (Kennedy 1989, Waldron 2009). Mays (2003:5) explains that "an increase in mechanical stress tends to produce bones which are more robust, i.e. are thicker and stronger, with more ridges for muscle attachment; a reduction in mechanical forces tends to have the opposite effect." However, when there is an abnormal amount of stress, bones can fracture. The repair process begins immediately when blood flows into the fractured area to form a hematoma, or bloody mass that seals off the blood vessels. The periosteum is usually torn where the fracture occurred, which stimulates its osteogenic layer to begin forming a callus, fracture repair tissue (White and Folkens 2005). Diseased bone alters the remodeling process by either producing an excess of bone (proliferative lesions) or destroying bone (erosive lesions) and sometimes both (Waldron 2009). The periosteum plays an important role in disease processes as well as trauma, in the case of disease it becomes inflamed as part of the normal immune response. However, there are four possible scenarios following acute inflammation, resolution, scarring, the formation of an abscess, or chronic inflammation (Waldron 2009). The particular disease process causing the inflammation and an individual's variable immune system will determine the severity of the bone response and how quickly the bone will resolve (which it may not in chronic diseases such as tuberculosis) (Waldron 2009).

Teeth have a separate anatomy. They are made up of the crown, which has an occlusal surface used for biting and mastication, a neck, and a root (White and Folkens 2005). The roots are embedded in the alveolar bone of the maxilla and mandible. The crown in covered by enamel, which is a hard, cell-free layer made up of water, mineral, and organic material (Currey 2002, White and Folkens 2005).

Enamel, the hardest tissue in the body, does not have collagen, like other bones, which allows for its durable surface. Under the enamel is the dentin, mineralized connective tissue that has no cells. The dentin forms first and then enamel mineralizes on its surface. Enamel formation moves outwards, adding new material to the outer surface of the developing tooth (Currey 2002). Deciduous teeth develop first, and then are replaced by permanent teeth. Since enamel is so hard, it is very resistant to chemical and physical destruction. Often in both archaeological and forensic contexts, when all other bones have been destroyed, teeth remain intact.

Teeth are also very informative about the individual that possessed them. Teeth can be used to estimate age through development and attrition rates. Reichs (1998:253) explains that "like bones, teeth progress through maturational stages, undergoing continuous change in size and shape. Each tooth follows the same sequence, through initial crypt formation to final apical root closure." Teeth from an individual can be evaluated macroscopically and the stage that each tooth is in developmentally fits into a standardized age range (Buikstra and Ubelaker 1994). Age can also be estimated with the amount of dental attrition, or wear, an individual has. "Dental attrition generally proceeds continuously during life" (Ubelaker 1999). The diet of an individual can affect the pattern of dental attrition on an individual. "Chewing hard abrasive particles can produce microscopic wear on teeth…consistent correlations have emerged between dental microwear patterns (frequency and size of pits and scratches) and some abrasive diets" (Mahoney 2006:39). Likewise, the reduction of dental wear that occurred with the introduction of agriculture in North America indicates reduced coarseness of food along with differences in food preparation (Buikstra 1994, Mahoney 2006).

One of the most useful applications within bioarchaeology is establishing a demographic profile of a skeletal population. As will be discussed further in section 3.1.3, bioarchaeological analysis of human remains can determine how many males or females are present in a population and how old each individual was when they died. The analysis is also able to determine how tall each individual was during their life and whether they suffered from disease. Bioarchaeological analysis of human remains evaluates variation in a bone and determines whether it is normal variation, such as with non-metric traits, or abnormal variation. There are five ways that skeletal disease can manifest: abnormal bone formation, abnormal bone destruction, abnormal bone density, abnormal bone size, and abnormal bone shape (Ortner 2003:45). Further evaluation of the abnormal bone changes can determine whether the changes are from a congenital or acquired cause. Acquired bone changes could be due to factors such as injuries or disease processes. Abnormal bone changes are placed into disease categories that often include: congenital disease, metabolic disease, infectious disease, traumatic lesions, joint disease, dental disease, and miscellaneous disease (Ortner 2003, Roberts and Manchester 2007, Waldron 2009, White and Folkens 2005). Buzon (2012:60) explains

> the plasticity of the skeleton allows for functional adaptation to environmental changes, whether natural or cultural. The skeleton is thus a reflection of a lifetime of interaction with the world, displaying physical responses to damage, mechanical stress, and disease. This plasticity signifies that the skeleton is a record of the history of social relationships.

Bioarchaeologists 'read this record' and then can make interpretations regarding the health status of an individual or population.

1.2.2 Limitations in Bioarchaeology

In every bioarchaeological study there are inherent limitations that should be acknowledged. Often an issue in bioarchaeology is how representative an assemblage is of the original living population. The term 'population' refers only to the total number of individuals recovered from a site that could be analyzed. It should be noted that the term population is used in epidemiology when the total number of living individuals is known and the factors can be controlled (Waldron 2007). In the study of human remains, many factors cannot be controlled, and in fact the individuals that are eventually studied from a site are only a small proportion of individuals that died in a specific region. According to Waldron (2007) a closed population, in epidemiology terms, never has individuals that enter or leave, for example all individuals that died in a specific region. A human remains assemblage, or skeletal population, does not represent the living population, but only the individuals that died, were buried at a site, and also recovered for analysis.

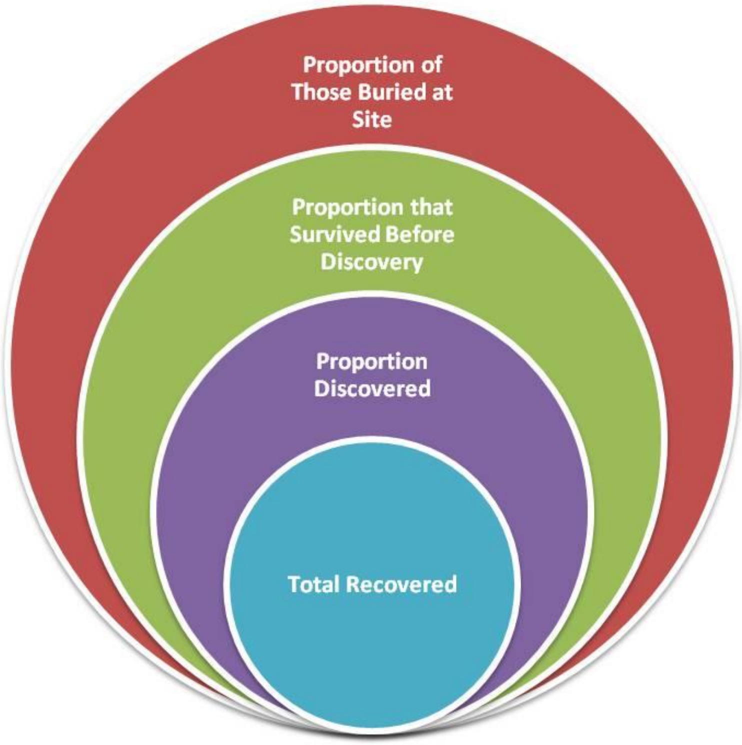


Figure 1 Extrinsic factors adapted from Waldron 2007

A question that all bioarchaeologists ask is how representative are the populations studied in relation to the total amount of individuals that were buried? Waldron (2007:28) explains that there are four main extrinsic factors that determine what skeletons are studied; the proportion of those buried at the site being studied, the proportion who survive until discovery, the proportion of those discovered, and lastly, the proportion of those recovered. In Figure 1, those in the largest circle are the proportion of that larger closed population that are actually buried at that particular site. The factors involved with who is buried at a specific site or cemetery could be geographic location, religious associations, sex, age, or many other factors (Daniell 1997, Gilchrist 2005, Waldron 2007). For example, in early medieval Britain clergy were the only members of the community that could be buried within monastic cemeteries (Andrews 2006). However, a Papal decree in 1312 relaxed the rules and allowed lay benefactors to bury their dead within the monastic cemetery (Andrews 2006, Stones 1989). There may have be varying practices among the different monastic orders.

The next largest circle in Figure 1 represents the proportion of the skeletons that survive before discovery (Waldron 2007). Factors that could affect survival are construction at the site which could destroy skeletal elements, removal of a cemetery to another location, and normal taphonomic processes that are affected by the soil that the skeletons were interred in, burial practices, such as use of coffins or shrouds, and animal or plant disturbance. The next largest circle represents the skeletons that were discovered by the excavators. Factors that could influence whether skeletons are discovered are whether there is a project location that happens to be the location of a site, or the project is funded to remove a specific section of a site that includes where some skeletons are buried, or even if a site with skeletons buried is even known. A cemetery or site with skeletons buried might be known to exist but skeletons will not be removed for analysis unless there is a specific purpose. Perhaps there is new construction that is going to disturb a cemetery, so the skeletons are removed; or a cemetery might be destroyed for another purpose, again demanding the skeletons to be removed. In the best circumstances, a cemetery is excavated with a specific research agenda in place, but again the dimensions of the excavations are generally set by an outside force, which is a factor in which skeletons will eventually be removed and studied.

Lastly, the smallest circle represents the actual skeletons that are recovered. This is usually controlled by a contractor, or excavator, or funding body that sets the dimensions of the excavation. Even if more skeletons are found outside of those dimensions previously set, they most likely will not be recovered due to these external factors. Other intrinsic factors that can affect which skeletons are removed and analysed are burial practices, normal taphonomic processes, soil pH, drainage, temperature, and grave depth (Haglund and Sorg 1997, Klepinger 2006, Pinhasi and Bourbou 2008, Turner-Walker 2008). Once the focus is narrowed to that very last circle (Total Recovered), it is clear that there are many factors that determine which skeletons will actually be studied.

Even beyond these factors mentioned, there are other factors that determine which skeletons will be studied even after they are removed from a site. For example, if a skeleton is too poorly preserved or damaged, it might be removed from the study. In the cases with poor preservation due to extreme fragmentation or poor cortical bone preservation a researcher may decide whether or not to include the remains in the analysis. Preservation of bone at each site should be discussed in studies since it potentially could affect results. Since each of these extrinsic factors reduce the number of skeletons that are actually studied, by the time one gets to the narrowest circle, the entire population, by an epidemiological definition, and number of skeletons analyzed can be drastically different.

Preservation of cortical bone and extreme fragmentation is a main limiting factor for the Whitefriars population. Frequent flooding of the Tay in Perth likely produced the poor preservation of bone (Bowler 2004, Holdsworth 1987). Accurate identification of lesions from infectious, metabolic, and joint disease as well as trauma was limited, possibly influencing the rates reported. Due to these limitations and in order to ensure the accuracy of the statistical results in the results chapter, chi-square tests for each type of disease were run with and without Whitefriars to see if the outcome changed. With the removal of Whitefriars, none of the outcomes for any of the chi-square tests changed. Therefore, the statistical results mentioned in this thesis are considered accurate even with the poor preservation of the Whitefriars assemblage.

A further limitation in bioarchaeology is that few disease processes affect the skeleton, most only affect soft tissue (Aufderheide and Rodríguez-Martín 1998, Ortner 2003). Diseases that only affect the soft tissue in most cases are whooping cough, smallpox, enteritis, chicken pox, scarlet fever, diphtheria, croup, and respiratory diseases (Roberts and Cox 2003, Roberts and Manchester 2007). Even for diseases that can affect the skeleton, such as tuberculosis, many times it is only the chronic or most severe cases that will be detected in the skeleton. The last issue occurs even when one has a well-preserved skeleton since frequently some bones are missing. If a disease is not present, it does not necessarily mean it could not have been present, but only that the disease could not be detected on the bones present. For example, if a skeleton is missing the vertebral column, diseases that could affect the spine would not be detected, but in actuality that individual might have died from tuberculosis.

1.2.2.1 Sample sizes

While a large assemblage may be best to answer many bioarchaeological questions, the extrinsic factors mentioned earlier often drastically reduce what a potential sample size an excavation may ultimately produce (Waldron 2007). The sample size refers to the total number of individuals from a population that is studied and reported upon. Sample sizes for the same assemblage may change through time as well, as more of a site is excavated or more skeletons are analyzed. For example, the Whitefriars study population used for this research was once excavated in 1982 and published with a sample size of twenty-one individuals (Stones 1989); however a further excavation of the site in 2008 produced a sample size of fifty-eight individuals (this study). Since different areas of the cemetery were excavated at the first and second excavation, there are also different demography profiles for the same site, reflecting the burial patterns of the cemetery.

Also limiting sample size is the size of the cemeteries in any location during the past. In less densely populated areas of Scotland there are few large cemeteries. Instead, an assemblage may only include less than ten skeletons. It would be difficult to make any large scale interpretations about a population when there are so few skeletal remains. Any statistical analysis with small sample sizes could also lead to biased interpretations of the data. However, bioarchaeological research at these small sites are also imperative because those remains might be the only information regarding a particular region or time period. An attempt to overcome these limitations were made by using statistical tests based on guidelines presented by Mays et al. (2004). Additionally, statistical tests such as chi square, one-way ANOVA, bivariate correlation, and an independent-samples t-test, were used to compare multiple populations to ensure larger sample sizes. Statistical analysis on small populations alone were avoided for bias.

1.2.2.2 Crude prevalence rates and true prevalence rates

Prevalence is used commonly in bioarchaeological research, however a distinction should be made between 'crude' prevalence rates and 'true' prevalence rates. A crude prevalence rate (CPR) refers to the number of individuals with a disease or condition divided by the total number of individuals in the sample (Mays et al. 2004). A 'true' prevalence rate (TPR) calculates the number of elements affected divided by the number of elements present in the sample. Most skeletal reports present only CPR and only occasionally present both. Therefore if comparisons are to be made between multiple populations, usually only CPRs can be used (Mays et al. 2004). If there are missing bones or poor preservation, using CPRs can potentially bias the results (Waldron 2007). Whenever possible using a mixture of CPRs and TPRs are advisable.

Confusion can arise when using different prevalence rates. For example, Lunt (1986) examined medieval dentitions from two sites in St Andrews: Kirkhill and Hallowhill. She presented her results based on analysis on the dentition alone. The report (Lunt 1986) claims that 30% of Hallowhill skeletons are under nineteen years of age, which is true when only looking at the skeletons with dentition. However, when looking all articulated skeletons (as compiled in this study), only 15% of the population are under nineteen years of age. Lunt then compares the Hallowhill data to Kirkhill, claiming that 24% of the population is under nineteen years. Again, by looking at all skeletons instead of just the dentition, the percentage of those under nineteen should be 20%. Both of these percentages are normal or even low compared to other medieval populations (on average 20% of the population is a subadult); however Lunt claims Hallow Hill's subadult mortality is much higher than other medieval populations and that Kirkhill is just slightly higher. Lunt interprets her 'high' subadult percentages at Hallow Hill as "particularly severe epidemics of childhood fevers." However, Lunt (1986) found little Linear Enamel Hypoplasia (which one would expect with childhood disease), which surprised her since she felt there was a high percentage of subadult mortality. The only explanation Lunt could present was that the diseases that killed the subadults must have been ones that are not associated with LEH. In this case if crude prevalence rates and true prevalence rates were used, there would have likely been other interpretations of the data.

1.2.2.3 The Osteological paradox

Determination of whether a person was healthy or unhealthy when they died sheds light on what is termed in paleopathology the 'osteological paradox' (Wood et al. 1992). An individual that died without any skeletal or dental lesions could be viewed as either healthy for not suffering from any disease, or unhealthy because their immune system was not strong enough to fight off the disease, and they died before a lesion could form. A consequence of the osteological paradox could be under-estimating the true prevalence for disease if a person died before a lesion formed. Conversely, the true prevalence for disease could also be over-estimated since the individuals analyzed are the ones in their age range that did not survive, perhaps from being 'frail' (Wood et al. 1992). Though, the presence of a disease process is related to a greater risk of dying, even if it is indirectly. Therefore, those with a disease process present are often considered less healthy. Bolsen and Miler (2012:121) explain "those that die at a given age tend to be the sickest of most poorly nourished members of their cohorts, or the people by necessity or choice routinely engage in dangerous activities." However, Ortner (2003) urges caution when making inferences regarding health of a population since changes to bone tend to be associated with chronic response to disease. In fact, Ortner (2003:56) argues "that skeletal paleopathology may indicate a better host response to a disease because the host lived through the acute stage when other similarly afflicted individuals may have died. Thus, absence of skeletal disease may imply death due to acute conditions, whereas evidence of skeletal disease indicates a sufficiently adequate immune response to ensure survival to the chronic stage." Therefore, when defining the health status of a population, multiple perspectives should be evaluated before conclusions are made.

1.3 Themes in Bioarchaeology

1.3.1 Sex

Since gender is a socially constructed concept, only biological sex can be identified in bioarchaeology (Armelagos 1998). However, many studies use the prevalence rates in males and females to address various themes within the field of bioarchaeology, archaeology, and even history. Research into carious lesion patterns in males and females can detect differences in diet (Lukacs 2008, Lukacs and Largaespada 2006). Patterns in osteoarthritis as well as other forms of joint disease are used to infer activity patterns including gender-based division of labor (Bridges 1992, Derevenski, 2000, Lovell 1994). Life expectancy and overall susceptibility to disease is addressed through the use of mortality profile. For example, in many populations there tend to be more females than males in the young adult age range (18-24 years), which is often associated with maternal stress including childbirth itself as well as infection and malnutrition (Roberts and Manchester 2007, Sullivan 2005). Trauma patterns have been studied to determine domestic abuse in past societies (Novak 2006). Even differences in status of males compared to females in a population or region can be inferred based on location of burials within a cemetery.

1.3.2 Status

Documentary evidence can provide insight into the status of a cemetery and those buried within it. For example, Glasgow Cathedral is known as a high status cemetery in Scotland, evident by its continual expansion in the twelfth and thirteenth centuries and magnificent structure (Driscoll 2002). According to Driscoll (2002) many of those buried in the cathedral would have been wealthy benefactors. Further evidence of the high status position of those buried at Glasgow Cathedral enjoyed were the high amount of recovered coffins during excavations, which could generally only be affordable for the elite in medieval Scotland (Driscoll 2002, Stones 1989, Tarlow and Stutz 2013). By contrast, St. Helens at the wall in York is historically known for being one of the most impoverished parishes (Palliser 1980) and therefore considered a low status cemetery. Without documentary evidence, the socioeconomic status of individuals can be difficult to discern from their skeletal remains alone; however, some assumptions can be made. For instance, we can expect that the individuals buried at most of the monastic cemeteries were generally of higher status (Lowe 2009, Müldner et al. 2009, Sykes 2006, Woolgar 2006). Either the individuals were from the monastic community, or they were wealthy enough to afford to be buried amongst the monastic community. As mentioned in section 1.2.2, until a papal decree in 1312, only monks could be buried within a monastic cemetery. From the fourteenth century onwards, it became increasingly popular to be buried within a monastic cemetery rather than a parish church because the souls of the deceased were included in daily prayers (Daniell 1997). Those that were buried in monastic cemeteries left money or land to the monasteries. The location within a church, cathedral or monastery where one was ultimately buried was also tied to status, the closer the burial was to an altar or shrine was especially sacred, and therefore highly regarded and expensive (Müldner and Richards 2007, Tarlow and Stutz 2013). Likewise, burial within a church was preferable to burial locations in the churchyard since space was limited and only the wealthier could afford it (Tarlow 2010). Conversely, lower status individuals were buried in the churchyard of the parish churches, or even outside of the churchyard. This often included children of lower status parents, un-baptized infants, criminals, and sometimes those with specific 'more sinful' diseases such as leprosy (Daniell 2007, Gilchrist 2012). Research at Wharram Percy found that adults were more likely than juveniles to be buried within the church, illustrating the status differences in burial location (Mays 2001).

Whether an individual enjoyed a higher or lower status during life often affected their health, and therefore important when discussing the health status of a population. Those that enjoyed a higher status often suffered from fewer stressors on their body, whether related to their living environment, types of occupations, or nutrition (Buzon 2012). Trauma from warfare complicates this picture, however, since it was the aristocratic families that were involved. Compared with high-status individuals, "lower-status individuals may suffer additional biological stresses with regard to undernutrition, disease-load, unhealthy living environments, lack of medical care and physically demanding lives" (Robb et al. 2001:213). Though, even high status individuals are not buffered from all diseases, as will be discussed further in section 5.2. Roberts and Cox (2003:16) provide a warning regarding status: "[w]e must also remember than excavation cannot often differentiate between successive phases of activity. Cemetery samples are simply a group of individuals who came to rest at the same place; they may not be from the same period, socio-economic background, ethnic group or culture." Therefore, status may not always be possible to determine or could potentially be mistakenly assumed for an individual or population.

1.3.2.1 Status and Diet

The diet of an individual can result in pathological changes in the skeleton. Wealthier diets included a greater amount and variety of types of meat. The wealthy were also not as closely tied to the harvest cycle, and therefore their skeletons likely would not have as many metabolic disturbances as poorer individuals (Woolgar 2016). Lower status individuals could suffer, especially in poor harvest or famine, from malnutrition, vitamin deficiencies, and anemia, all which can impact the skeleton. The amount of fish was also tied to status, which often is demonstrated in different isotopic signatures between the higher and lower status groups (Müldner et al. 2009).

While deficient diets can lead lower status individuals to suffer from metabolic disease, high status diets can also lead to pathological changes in the skeleton, particularly with dental disease. The presence of carious lesions generally indicates a diet of cariogenic foods such as quickly fermentable carbohydrates found in refined sugar and dried fruit (Hardwick 1960). Also, more frequent eating can have the same effect with an increase in carious lesions (Thylstrup and Fejerskors 1986). If upper and lower status diets were different in a population, then skeletal evidence such as metabolic disease or carious lesion patterns often informs research about status (Goodman 1994, Kerr 1990, Sullivan 2005, Walker et al. 2009, Walker and Hewlett 1990). Another condition that could be influenced by diet is diffuse idiopathic skeletal hyperostosis or DISH. DISH is characterized by extensive calcification of ligaments, cartilage, or muscle attachment sites, also known as entheses. Rogers and Waldron (2001) argue the etiology of DISH is a multisystem hormonal disorder and that obesity and type II diabetes could be contributing factors. Further discussions on status and diet can be found in section 5.2.3.

1.3.3 Infant mortality

Population structure can provide insights into the rate of infant mortality for a site (Chamberlain 2006). Populations with high infant mortality may relate to population density, infectious rates, hygiene practices, and even maternal health. Neonate/infant mortality comparisons may be biased, however, since non-baptized neonates were often buried in different locations to the rest of the cemetery population in the medieval period (Gilchrist 2012). Infants, along with neonates, were also sometimes buried in different locations, and if those locations were not within the purview of excavations, the demographic data may be unintentionally skewed. An example of how this can easily happen is with the two Whitefriars excavations. In the 1982 excavation there were 21 burials excavated and none were of immature skeletons (Cross and Bruce 1989). However, in the more recent excavations 40% of the skeletons were immature. In fact, 10% of the burials were individuals under 2 years old. These two excavations of the same site tell a completely different picture of the population, and both of these reports may still be unrepresentative if more of the site is excavated at a later date. While the scope of an excavation is an issue in many of the interpretations of a site, nowhere is it more obvious than in interpretations of infant mortality. Further discussion on infant and subadult mortality can be found in section 5.1.4.

1.4 Previous Research into Health of Medieval Scotland

Previous research into health in medieval Britain, from a historical or an archaeological approach, covers England in much greater detail than Scotland, and in many cases does not discuss Scotland at all. Medieval Scotland should first be distinguished from medieval England, Wales, and Ireland before it can be strategically compared with other regions illustrating similarities and differences between them. Similarly, there is a plethora of research into health or medicine in medieval England, while there are very few solely on medieval Scotland, let alone regional studies within Scotland.

Historical research into health during the medieval period in Scotland (and other European countries) often concentrates on what are called the 'three main scourges': bubonic/pneumonic plague, syphilis, and leprosy. While plague ('the Black Death') certainly affected the majority of Europeans during the later medieval period, it will not be examined in this study. The progression of the plague was swift; a person infected with the plague generally died within a week, leaving it no time to change the skeleton in any way (Appendix 14). The interest in this study is not necessarily finding a cause of death, but instead investigating how an individual's lifestyle contributed to their health. While syphilis and leprosy are two diseases that can affect the skeleton, these are only two out of many other diseases from which individuals in lowland medieval Scotland suffered. Expanding the research beyond those 'three main scourges' enables a more complete picture of what life would have been like for individuals on a daily basis.

1.4.1.1 English Studies

The seminal work on health in Britain from an archaeological perspective is *Health and Disease in Britain from Prehistory to the Present Day* (Roberts and Cox 2003). This book is likely the most complete synthesis of health using skeletal analysis; however, out of seventy-one early medieval populations compared, only three were Scottish, and out of sixty-two late medieval populations, only six were Scottish. The authors explain their focus on England: Scotland lacks sufficient excavated material and the acidic soil prevents preservation of skeletal remains (Roberts and Cox 2003:24). In comparison, this study synthesizes twenty-three Scottish early and late medieval populations for contextualizing the study populations. While Roberts and Cox (2003) are correct that there are many more medieval English excavations with much larger assemblages, many medieval Scottish excavations were not included in their publication and since the 2003 publication date larger excavations in Scotland have occurred dating to the medieval period, which should now be collated for larger research questions.

Medieval Life: Archaeology and the Life Course (Gilchrist 2012) does the best at incorporating archaeology and history into the study of medieval life; however this book again only covers England. While only one chapter covers disease, the use of osteological research is effective. A seminal work on death in Britain from a historical perspective is *Death and Burial in Medieval England* (Daniell 1998). Only England is discussed in this work; moreover, the research also fails to incorporate any osteological evidence. *Living and Dying in Britain, 1100-1540: The Monastic Experience* (Harvey 1995) is a historical account which describes life in an English monastery, neglecting comparisons with Scottish monasteries. *Death in Towns: Urban Responses to the Dying and the Dead, 100-1600* (Bassett 1992) is a collection of papers focusing on medieval Europe with a focus on England alone. One chapter (Gilchrist 1992) explores life and death in late medieval English hospitals with archaeological evidence. Similar studies with a focus on medieval hospitals in Scotland would be valuable, but are lacking in the literature. *The English Hospital: 1070-1570* (Orme and Webster 1995) explores the history of hospitals in medieval England through historical research alone. *Death in Medieval England: An Archaeology* (Hadley 2001) includes a minimal amount of skeletal evidence to discuss death in England only. A significant book in the study of diet and connections to health is *Food in Medieval England: Diet and Nutrition* (Woolgar et al. 2009). The multi-disciplinary volume synthesizes data from history and archaeology using scientific approaches including zooarchaeology and isotope analysis to explore the effects of diet on the skeleton. There are multiple historical accounts on medieval medicine, yet Scotland is not discussed in any of them: *Medieval Medicus: A Social History of Anglo-Norman Medicine* (Kealey 1981), *Doctors and Medicine in Medieval England: 1340-1530* (Gottfried 1986), *Medieval and Early Renaissance Medicine* (Siraisi 1990), *Medicine in Medieval England* (Talbot 1967), *Medieval English Medicine* (Rubin 1974), *Medicine and Society in Later Medieval England* (Rawcliffe 1998).

1.4.1.2 Scottish Studies

Overall health in medieval England has been covered extensively including volumes on medicine, diet, osteoarchaeology, burial archaeology, and history. On the other hand, medieval Scotland has had few studies about health, nutrition, medicine, or hospitals (Hall 2006, MacLennan 2003). As mentioned in the above section the seminal work *Health and Disease in Britain from Prehistory to the Present Day* (Roberts and Cox 2003) only covers nine populations from medieval Scotland (three from early medieval and six from late medieval) and the authors themselves emphasize their English focus. While individual population reports sometimes compare one or two populations with each other (Roberts 2000, Henderson 2006, Anderson 1994), the majority only describe the population under question with little interest in more comprehensive comparisons. *Three Carmelite Friaries* (Stones 1989) compares the skeletal remains from Aberdeen (1980 excavation), Linlithgow, and Whitefriars, Perth (1982 excavation). One aspect the volume covers is health, though since only three populations are considered the conclusions are limiting. Additionally, both Aberdeen and Perth have had expanded excavations since this publication (Stones 1989) rendering many of the findings outdated and invalid.

The diet in medieval Scotland is reviewed in *Food of the Scots* (Fenton 2007) which is part of an ethnology series called Scottish Life and Society. While the volume provides insights into food eaten in Scotland, it is not specific to the medieval period and does not evaluate the topic using scientific methods, such as isotope analysis, nor include much archaeology.

Only a few studies have concentrated on medicine or hospitals in medieval Scotland. *Unto yone hospitall at the tounis end': the Scottish medieval hospital* (Hall 2006) provides a list of the status and condition of identified medieval hospitals, however it does not review archaeological or skeletal material. The most well-known medieval hospital in Scotland is Soutra Aisle, established in 1164 and run by Augustinian monks (Yeoman 1995). Brian Moffat is the archaeo-botanist who directed the *Soutra Hospital Archaeoethnopharmacological Research Project* (*SHARP*) and subsequently published six reports (SHARP reports 1-6, Moffat 1986-1998) that specifically investigated the plant and blood material found in excavations as evidence of medicine and blood-letting practices. Skeletal remains have been found on the site, yet no research has been completed on them at the present (Moffat

1998). St. Nicholas Farm, a known leper hospital in St Andrews was excavated in 1986-87, though little skeletal material survived, and none presented with leprosy (Hall 1995).

The only recent medical history focusing on Scotland is *The Healers: A History of Medicine in Scotland* (Hamilton 2003). While the volume also covers other periods, the historical research into medieval medicine in Scotland is far more in depth than any other volume. Unfortunately, this still only provides a historical perspective with little mention of archaeology or skeletal evidence. In addition, the volume shadows other medical history investigations by mostly discussing the 'three scourges,' truncating a complete view of health and disease in Scotland during the medieval period.

Another excellent work on medieval Scotland is *A History of Everyday Life in Medieval Scotland: 1000 to 1600* (Cowan and Henderson 2011). This volume is one in a series of four where each volume discusses life of everyday individuals in different time periods in Scotland. The volume on medieval Scotland discusses various aspects of life, however only one chapter is on health and disease and is written by historian Richard Oram. While Oram (2011) attempts to compare health in four populations using skeletal evidence, he again follows other medical historians and focuses almost solely on the 'three scourges'. A similar book on life in medieval Scotland is *Townlife in Fourteenth-Century Scotland* (Ewan 1990), yet this book generalizes health and health care in only one page. In one instance historian Elizabeth Ewan attempts to use skeletal evidence to shed light on disease, nevertheless, she misinterprets information from *A Tale of Two Burghs: The Archaeology of Old and New Aberdeen* (Evans and Murray 1987). Evans and Murray (1987; 35) explain

> "Only very rarely is it possibly to ascertain from the skeleton a cause of death, except in the case of obviously serious injury, or where an illness has been so long-term that it has begun to affect the bones, as might be the case with chronic diseases such as leukaemia, or secondary tumours from a soft-tissue cancer." [Evans and Murray 1987: 35]

Instead, Ewan (1990: 38) quotes "skeletal evidence revealed townsfolk suffered from tuberculosis, leukaemia, and cancer […]". The last, and perhaps most important, failure of historical research into health is that many of the documentary sources only attest to the lifestyle of those enjoying a higher status. Those considered to have lower status, often also including women and children, are frequently left out of historical documents, and aptly coined *the historically invisible* (Funari et al. 2003).

1.5 Introduction to the study samples

The skeletal samples analyzed for the present study derive from Ballumbie, a rural parish church north-west of modern Dundee (Hall, unpublished), the Isle of May, a monastic cemetery located on a small island in the Firth of Forth (James and Yeoman 2008), St Andrews Library, a portion of the cemetery of Holy Trinity Church excavated in 2003 for a lift installation at the library (Rees et al. 2008), and Whitefriars, a monastic cemetery in Perth that is a continuation of previous excavations in 1980 (unpublished). The total number of skeletons examined is 385 (Ballumbie N= 197, Isle of May N=58, St Andrews Library N=72, Whitefriars N=58). The majority of the burials date from the fifth to fifteenth centuries AD. These four populations were chosen for this study since they represent rural, urban, monastic, and lay environments in eastern, lowland medieval Scotland.

1.6 Significance and structure of the thesis

As discussed above, historical research into health in medieval Scotland, while useful, mostly focuses on the ‘three main scourges’ - the historically visible, and rarely includes and even sometimes misinterprets the archaeological evidence. Archaeological research into health considers the historically invisible and uses scientific approaches such as excavations, skeletal analysis, environmental studies (parasite remains, medicinal plant materials), and isotope analysis. However, as illustrated, archaeological research into health in medieval Scotland is limited from fewer excavations, little comparative studies, and fewer studies using isotope analysis. Previous discussions of health in medieval Scotland are usually from either a historical or an archaeological perspective; uniquely in this study, both of the two discourses are evaluated for a more informed discussion. Additionally, differences between the study populations are demonstrated through a focused regional analysis. The four study populations have never been compared to each other or analyzed statistically. The investigation of the study populations (385 individuals) sheds light into the health of individuals living during the medieval period in the eastern, lowland region of Scotland discovering differences due to location (rural/urban) and status (monastic/elite vs. lay/non-elite).

Chapter 2 will introduce the four populations providing historical and archaeological backgrounds. Chapter 3 sets out the methods utilized for skeletal, isotopic, and statistical analysis and the results are presented in chapter 4. Chapter 5 addresses the similarities and differences in health status between the study populations particularly within the broad themes of location (rural/urban) and status (monastic/elite vs. lay/non-elite). A further discussion of the Isle of May will examine its connection to health and illness through the scope of pilgrimage during the medieval period. Chapter 6 summarizes the conclusions from the data, reflects on the limitations of the present research, and conveys recommendations for future research. Study population data is compiled on the accompanying CD and references and other supporting material are contained in Volume 2.

1.7 Terminology

There are many definitions for the term *medieval*, yet they are unique to the historical and cultural background for each country. For the purposes of this study, the medieval period starts after the Romans withdrew from Scotland and the beginning of the people called the Picts (fifth century), and ends before the Reformation in 1559 AD. In general, this broad definition of *medieval* covers the fifth-fifteenth century and reflects the chronological limits of the skeletal material from the study populations. *Female* and *male* refer only to biological sex and do not imply gender, which is a social construction. *Adult* refers to individuals over the age of 18, while *subadult* refers to individuals under the age of 18. *Population* and *assemblage* are interchangeable and both refer to individuals buried within the same archaeological site. *Study populations* refer to the four archaeological sites analyzed by the author: Ballumbie, the Isle of May, St Andrews Library, and Whitefriars. As previously mentioned, *study area* refers to east coast, lowland Scotland. For the purposes of separating out urban and rural environments, *urban* refers to having a burgh status, having urban characteristics with governmental control such as a market place. When discussing status *monastic* refers to involvement in a religious institution, whether as a monk, prior, friar or others affiliated with the order that potentially could be buried in a monastic precinct. *Lay* refers to those unaffiliated with a monastery and therefore buried in a parish church or churchyard.

2. Materials: Study Populations

Figure 2 Map of the four study populations adapted from d-maps.com

2.1 Ballumbie

2.1.1 Archaeological Setting

In 2005, the construction company Stewart Milne Homes began building a new housing project northeast of Dundee. During land-stripping the construction workers discovered human remains and the Scottish Urban Archaeological Trust (SUAT) was brought in to begin an eight-week rescue excavation.

The following information regarding the history and archaeology of Ballumbie was obtained from a watching brief (Hall 2005), and published in a short summary introducing the excavation in Discovery Excavation (Hall and Cachart 2005), an unpublished report written by the lead archaeologist of SUAT, Derek Hall (Hall unpublished), and an article in Current Archaeology (Hall 2007b). These papers form the basis for the summary to follow.

Ballumbie is in Tayside region of eastern Scotland. It is in the present day Council Area of Angus, which was formerly known as Forfarshire. Ballumbie was designated a parish church in 1470, originally in the parish of Lundie and in the diocese of St Andrews (Cowan 1967). Lundie is located nine miles west of Ballumbie and three other parishes stood between Lundie and Ballumbie: Auchterhouse, Strathmartine and Mains (Hall unpublished). Since neither Lundie nor Ballumbie was appropriated to a monastery, there are few early references to them, however by the mid sixteenth century Ballumbie seems to have been established as a separate parish. Cowan (1967) explains "the revenues of the church were erected into a prebend of the collegiate church of Foulis Easter before 1538 and so continued." Foulis Easter is just under 10 miles away from Ballumbie. During the Reformation it is referred to as a church and a parsonage. It is possible that Ballumbie ceased as a parish church soon after the Reformation (Hall unpublished).

2.1.2 Geography

Until 2005 the exact location of the church of Ballumbie was unknown; historical records last mention Ballumbie in the sixteenth century. The earliest map reference to a church in the vicinity of Ballumbie is in Robert Edwards' Map of the Shire of Angus (1678) (Figs. 3 and 4). Modern day Ballumbie is a residential area in northeast Dundee. While Dundee was one of the main burghs in Scotland, medieval

Ballumbie was a rural countryside area four miles northeast of the Burgh of Dundee. Three miles south of Ballumbie runs the river Tay. During excavations a simple rectangular stone building, measuring 14m x 4m, was found that was assumed to be the Ballumbie church, which was mentioned historically to be in the area (Hall 2007b). Attached at the south-east side of the church was a small chantry chapel that the archaeologists termed the ‘laird’s aisle.’ The laird’s aisle measured 4m square and contained a small altar with a tiled roof (Hall 2007b). Seven individuals were buried within the laird’s aisle, four of those individuals were buried within a mural tomb in the south wall of the aisle (Hall unpublished). The ground plan of the church and long cist cemetery is found in Figure 5.

Figure 3. Edward, Robert Angusia Provincia Scotiae. Shire of Angus 1678.
(Ballumbie is highlighted.) Reproduced with the permission of the National Library of Scotland.

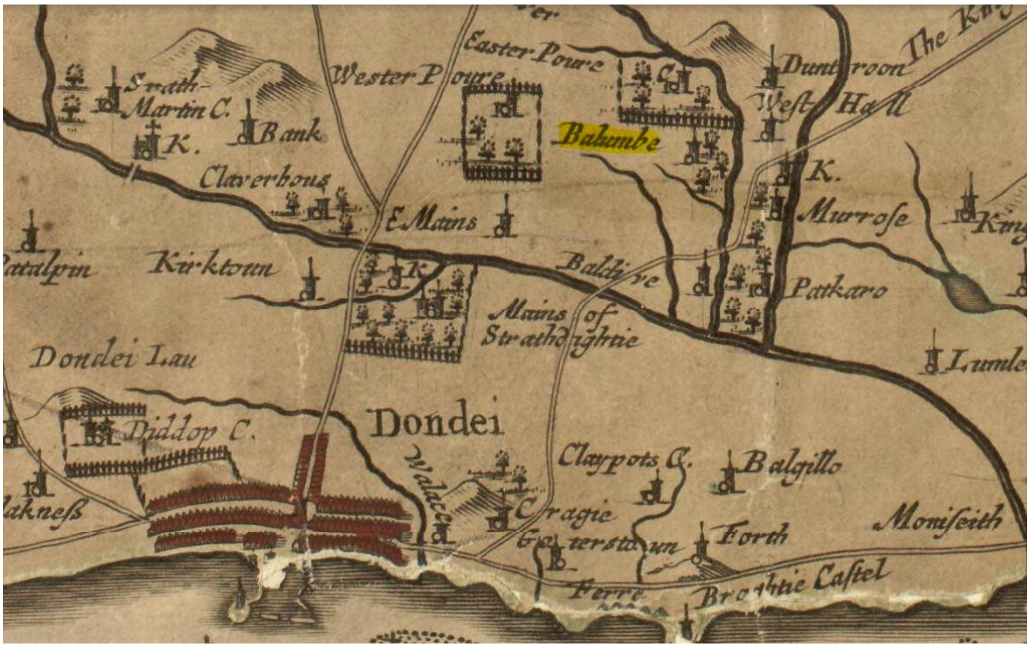
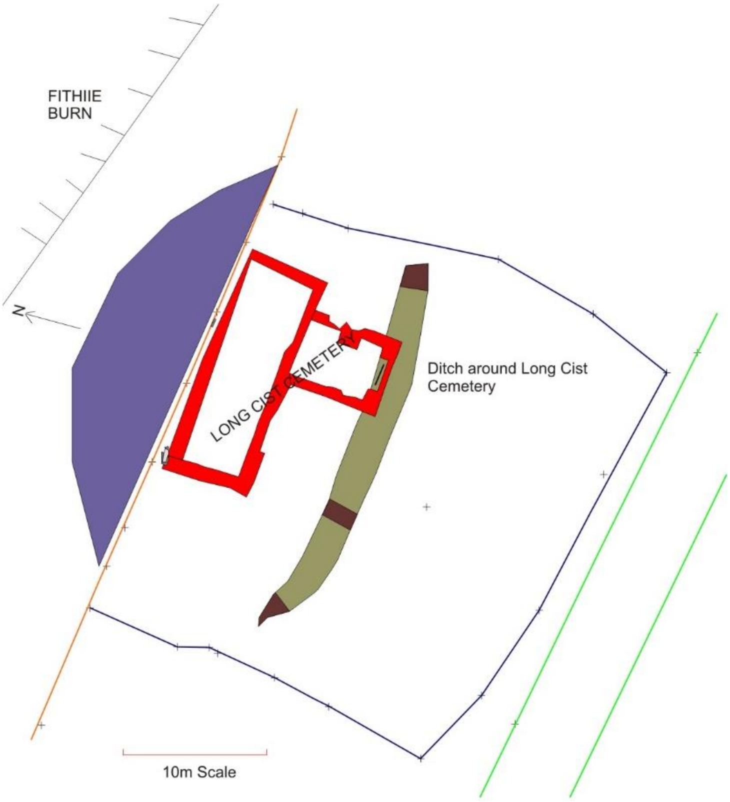


Figure 4. Edward, Robert Angusia Provincia Scotiae sive The Shire of Angus 1678, close-up. (Ballumbie is highlighted.) Reproduced with the permission of the National Library of Scotland.



GROUND PLAN OF BALLUMBIE CHURCH AND UNDERLYING LONG CIST CEMETERY

Figure 5. Ground plan of Ballumbie church and underlying long cist cemetery (Hall unpublished)

2.1.3 The Burials

Ten burials were submitted for radiocarbon dates by SUAT in 2007 (Figure 6). The earliest radiocarbon date of the site is from SK 747 and dated to 1435±35 BP, which is between 560 and 660 AD (Hall, unpublished). SK 747 was buried in the long cist cemetery. The most recent radiocarbon date is from SK 501 and dated to 350±35 BP, which is between 1450 and 1640 AD (Hall unpublished). SK 501 was buried inside the medieval church and, interestingly, was the only skeleton buried facing east, possibly on accident. These dates suggest there was roughly one thousand years of occupation at the site, the cist cemetery in the early medieval period and then the parish church and churchyard cemetery in the late medieval period. Since there is no information regarding grave depth, no chronology of the burials is attempted.

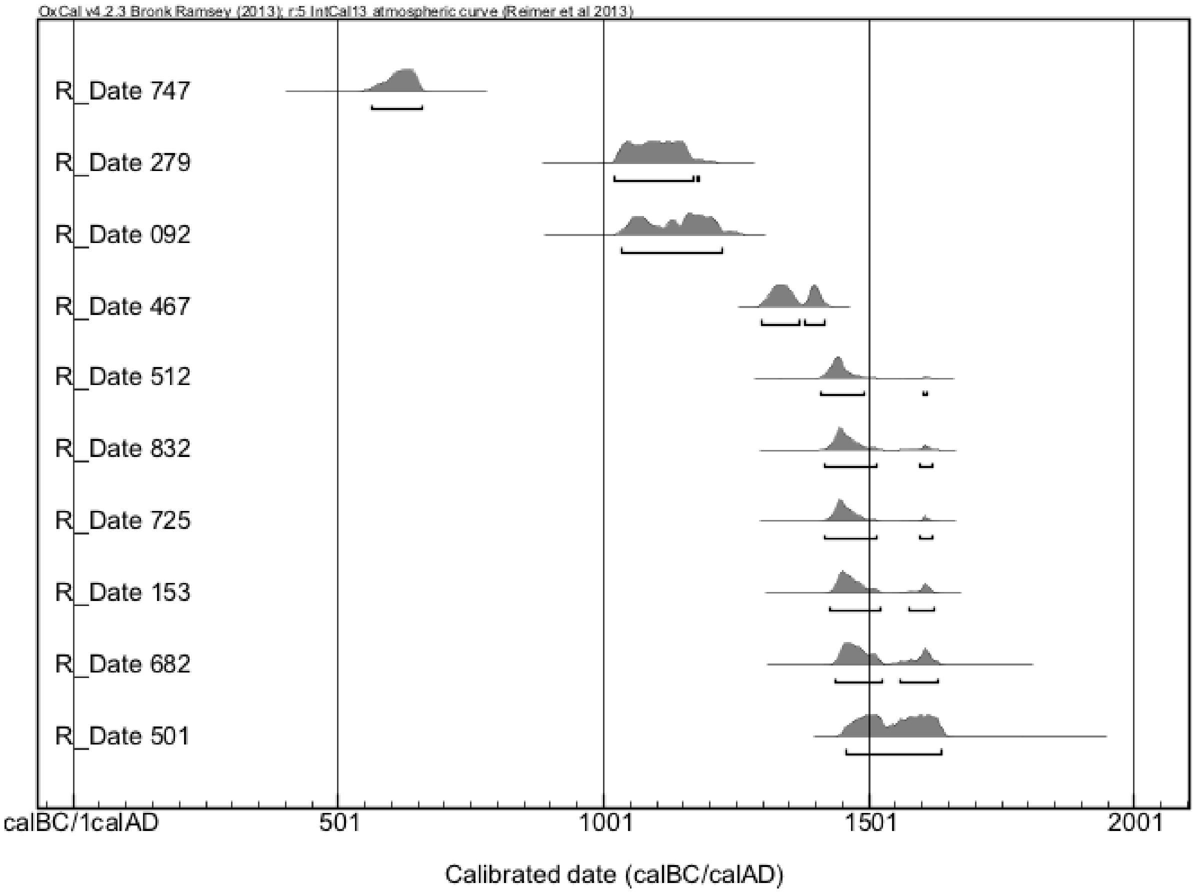


Figure 6. Radiocarbon dated burials for Ballumbie

Produced in OxCal v. 4.2; Bronk Ramsey 2010.

Burials associated with the late medieval activity were discovered inside the church and in the churchyard. Below the church a previously unknown Early Christian long-cist cemetery was discovered, defined by a ditch. There were at least 41 cists, 19 of which still contained burials (Hall unpublished). Out of the total 197 articulated skeletons excavated, 103 were buried in the cemetery associated with the church, 52 inside the church, 7 buried in the laird's aisle, 18 within the long cist cemetery, 7 were considered pre-church but were not buried in cists, and 10 had no burial location information provided (Hall unpublished). The burials were placed into three phases, those in the long cist cemetery and those considered pre-church were in Phase 1, those buried inside the church or in the cemetery associated with the church were in Phase 2, and the laird's aisle is Phase 3 (Appendix 7).

The laird's aisle likely houses the burials of the Lovel family. The Lovels were a Norman family and settled in Somerset after the Norman Conquest. Henry Lovel came to Scotland under David I and acquired the barony of Hawick in Roxburghshire (Hall unpublished). It remains unknown how the Lovels eventually acquired Ballumbie, however Hall (unpublished) explains "the first association of both is in 1409 when Richard Lovel, lord of Ballumbie, was a juror on an inquest before the regality court of Arbroath Abbey." A charter in 1555 mentions Ballumbie as including "all the lands of Ballumby with manor, tower, fortalice, demesne lands, mill, mill lands, cottages and pertinents" (Hall unpublished). They remained the lords of Ballumbie until 1597 when it was seized by the crown and given to James Elphinstone, and later Lord Balmerino. Once the Lovels left Ballumbie their castle fell into ruin, all that remained was the farm of Ballumbie. Figure 7 illustrates the location of each articulated skeleton.

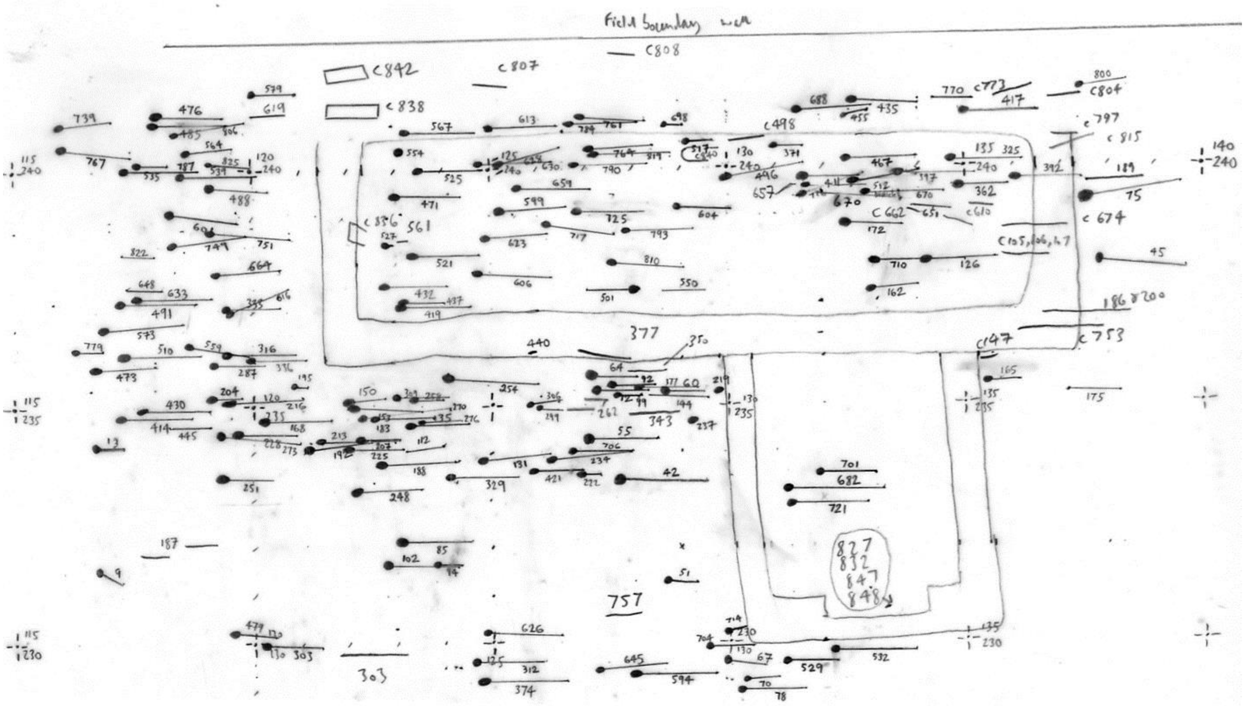


Figure 7. Burial plan (Hall unpublished). Refer to Appendix 6 for a larger version.

2.1.4 Burial Practices, Grave Containers and Furnishings

The majority of burials had a typical Christian burial with their head aligned to the west; however one individual, SK 501, a middle adult female, was facing east instead (Hall 2007b). The cist burials were associated with three fragments of cross-incised stones, further suggestive of early Christianity (Hall unpublished). One long cist burial (SK 467), radiocarbon dated to 1290-1370 AD, was found buried with a coin and SK 512, buried inside the church and dated to 1400-1500 AD, was found with a bracelet. While there is no information provided regarding grave containers, burials inside the church tended to have multiple skeletons in one grave (Figure 8).

Figure 8. Burial 521: inside Ballumbie church (Hall unpublished)

2.1.5 The Study Sample

The Ballumbie skeletal collection is currently stored at the University of Edinburgh and includes several hundred contexts of both articulated and disarticulated skeletal material. The entire collection had been under the care of SUAT from 2005 until 2009 when they were transferred for permanent curation and analysis at the University of Edinburgh. The skeletal material had been previously examined by a consultant hired by SUAT, but to date this analysis remains unpublished. SUAT previously numbered the contexts and determined there were 200 articulated skeletons. As the research goals of this study was to compare individuals, three contexts (SK 831, SK 834, SK 841) that contained commingled remains were not included in this study. One hundred and ninety-seven articulated skeletons were analyzed for the present study. The context numbers assigned by SUAT have been retained for this study. The study sample was analyzed at the archaeology laboratory at the University of Edinburgh.

2.1.5.1 Condition of the Material

The samples had been previously washed by SUAT and stored in plastic boxes. All contexts had also been placed in large plastic bags and labeled with context numbers. The skeletal remains had been cleaned previously although the precise methods used are unknown.

2.2 Isle of May

2.2.1 Archaeological Setting

The Isle of May is located at the mouth of the Firth of Forth, a prime location since it was on route to the main centers of power, trade, and population in Scotland (James and Yeoman 2008). Prior to the tenth century, settlement on the island was small-scale and seasonal (James and Yeoman 2008). Excavations found evidence of metal-working and wool spinning during this early medieval period at the Isle of May. Sheep, goats, pig, seal, fish, and seabirds provided the inhabitants meat, milk, wool, skin and oil (James and Yeoman 2008). A wooden church with a thatched roof was likely used prior to the tenth century, however no evidence of it is likely to be found since the site was reused for a stone church later (James and Yeoman 2008). The first stone church was built in the late tenth century, expanded fifty years later, and again in the late eleventh century when a square chancel was added onto the church (James and Yeoman 2008). The long cist portion of the cemetery dates to the fifth to the seventh century. Long cists cemeteries use stone slabs to line and sometimes cover the grave and are associated with early Christian burials (Daniell 1997, James and Yeoman 2008, Proudfoot 1996). James and Yeoman (2008) suggest the long cist phenomena is related to the conversion of the southern Picts.

In 1140 AD a daughter house to the Benedictine priory in Reading (Berkshire) was founded by David I on the Isle of May and dedicated to All Saints (Baxter 2016, Hammond 2010). The Cluniac Benedictine priory only survived on the Isle of May for two centuries and abandoned it in favor of Pittenweem, an Augustinian priory on the east coast of Scotland, in the late thirteenth century (Dilworth 1995, Yeoman 2008). Since the island was small, covering about 57 hectares, the entire island formed the monastic precinct (Yeoman 1995). The coastline surrounding the Isle of May is rocky and high cliffs fall on the west and south-west sides of the island with caves in the south end (Eggeling 1985). Similar to the Outer Hebrides, the Isle of May remains treeless (Eggeling 1985). Grassy areas are found in the less rocky parts of the Island; however Yeoman (1995) describes the usable area left for cultivation was not only limited in size but also was not fertile.

> "…[E]nvironmental analysis indicates that cereals could never have been cultivated, and that the island could support only about fifty sheep and a few cattle. The excavations have shown that sea-birds and seals were consumed, along with large quantities of fish paid as a teind (tenth) of every catch from the boats which harvested the renowned fisheries around the May, and used the monks' harbor. Otherwise they were wholly dependent on supplies from their estates, and on trading fish for other foodstuff at local markets" (Yeoman 1995:25).

As Yeoman (1995) points out, the Isle of May was known for fishing and the monks relied on payment from local fishermen. The twelfth century version of the 'Life of St. Kentigern' describes the abundance of fishing at the May "abounded so much that from every shore come many fishermen, English, Scots, and men from all shores of Belgium and France for the sake of fishing, all of whom, the May receives in its harbours" (Forbes 1874). The rabbits that continue to thrive on the Isle of May today were introduced to the island by the Benedictines for their own use and also for trade. Due to the wind and often rough waters, the Isle of May can seem remote and isolated (Eggeling 1985). Life on the Isle of May would have been tough for the monks, with few comforts, especially since the Cluniac monks were from Reading Abbey, one of the wealthiest abbeys in England (Baxter 2016). Even attaining fresh water would have been problematic for the inhabitants, only one well collected drinkable rain water, and even that was brackish (James and Yeoman 2008).

David I created the endowment… "on condition that they [Reading Abbey] should place and maintain nine priests of their brethren to celebrate divine service for the soul of the donor, and the souls of his predecessors and successors, the Kings of Scotland" (Stuart 1868:ix). At the heyday of the Isle of May monastery, there were no more than thirteen monks and a few servants who lived there (Yeoman 1995). Income to the priory during the twelfth and thirteenth century was provided from royal and noble endowments including harbor dues at Anstruther and Pittenweem, a tithe of the fishing from the waters around the May, lands in East Neuk, tofts in Haddington and Berwick, and income from the chapel at the royal castle of Perth (Duncan 1957, James and Yeoman 2008). Those funds helped build the priory buildings which included a cloister, prior quarters, chapter house, refectory, and latrine block (James and Yeoman 2008). The latrine comprised of either a long toilet seat or perhaps four cubicles. There was no continual source of running water, so the chutes would have required occasionally flushing out. There was lime present, which could indicate purification of the latrines (James and Yeoman 2008). Although the Cluniac monastery was only there from the mid twelfth century until the early fourteenth century, there seems to be three phases to the church. Even though there is no archaeological evidence, documentary sources mention several altars in the church including one dedicated to St. Ethernan and another to St. Mary (James and Yeoman 2008, Stuart 1868).

The Isle of May changed hands between Reading and the St. Andrew Cathedral Priory several times during the thirteenth century; both sides were rejected from the island twice and then regained possession of the island twice (James and Yeoman 2008). In 1314 Reading was finally deprived of the Isle of May at which point the monks re-located to Pittenweem (Baxter 2016, James and Yeoman 2008). Although the priory re-located, the monks continued to maintain the Isle of May church, mostly in ruins now, and land for another two centuries. Peter Yeoman (1995:25) explains, after the Isle of May was transferred to Pittenweem, the canons "kept a single member of their convent on the island to maintain the shrine, to give hospitality to pilgrims and to receive their money!" Due to its location and religious significance, the Isle of May continued to be a popular pilgrimage destination, including many visits from King James IV, throughout the medieval period (Duncan 1956, Eggeling 1960, James and Yeoman 2008, Yeoman 1999).

In 1549, after the monastery had already been destroyed by the English and the church was no longer receiving any profit from the island, The May was feued to Patrick Learmonth of Dairsie, Provost of St Andrews (Eggeling 1985, James and Yeoman 2008). The remaining church buildings were converted into a small laird's house after the reformation. In 1580 the Isle of May was used as a place of quarantine for ships arriving at the Tay with persons 'infectit with the pest' aboard, who were charged to withdraw themselves with their ships to the Isle of May until the ships could be cleaned and had obtained a license to depart (Eggeling 1985). In the seventeenth and eighteenth century there was a small village on the Isle of May to maintain the lighthouse and the last villager, John Wishart, died in 1730 at the age of 45 years (Eggeling 1985, James and Yeoman 2008). In World Wars I and II, a naval communications center was located on the island and in 1956 the May changed hands one last time to Scottish Natural Heritage, who currently maintains it.

The excavations at the Isle of May were conducted between 1992-1997 by GUARD as part of a University of Bradford Survey, commissioned by Fife Regional Council. Excavations first set out to investigate the site of the priory but were expanded to also include the cemetery. The burials had been previously studied and the results published in Tayside and Fife archaeological committee monograph #6 (James and Yeoman 2008). However, the skeletal remains were not analyzed statistically and were not compared thoroughly with other medieval Scottish populations as in this study.

2.2.2 Geography and geology

The Isle of May is a small island in the Firth of Forth, 8 kilometers off the coast of the East Neuk of Fife. It is known locally as The May and measures 1.5km long and only 400m wide (Figure 9). Since it lies in the mouth of the River Forth it is visible from both Fife and Lothian. The island is currently owned and managed by Scottish Natural Heritage as a national nature reserve; boats regularly take visitors to bird watch from Anstruther, Scotland. The 0.5 square kilometers of the island consists of a rocky shore with two beaches, 45m high cliffs, shallow pools surrounded by peat, and a small grassy meadow. According to James and Yeoman (2008:2), the site was founded on “a sheltered, raised pebble beach, which had been revetted on the east side to create a level platform.”

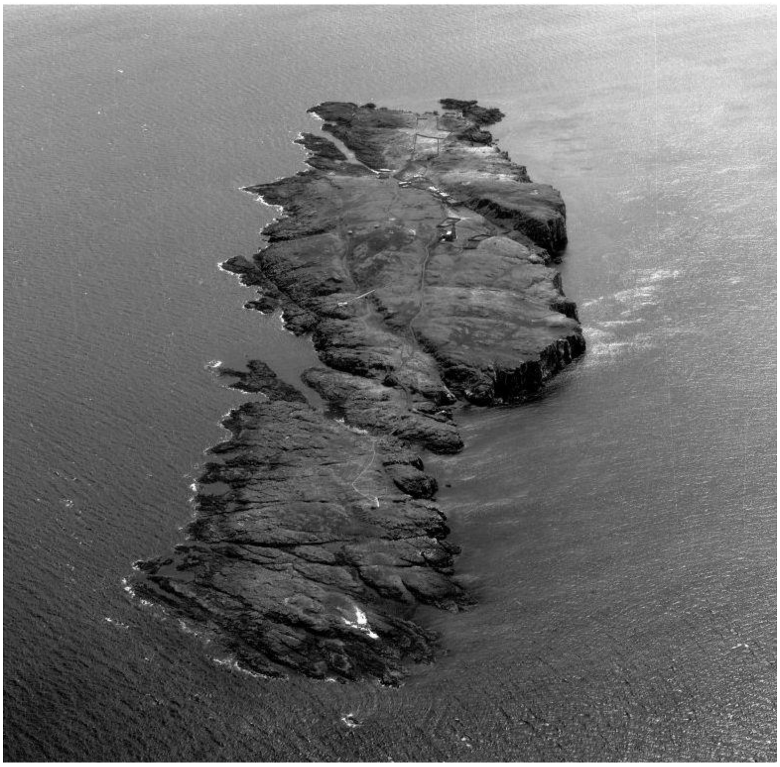


Figure 9. Aerial view of the Isle of May. Copyright RCAHMS

2.2.3 The Burials

The medieval priory overlay an early medieval monastic settlement including a tenth century stone church and a burial ground where 58 articulated inhumations were excavated (Figure 10). The excavators conclude “there was a planned conceptualization of the site as a large platform cairn, at least 60m N-S and 22m E-W, with a road leading to its center around which burials were placed” (James and Yeoman 2008: 37). There were multiple building phases of the church; although the cemetery also had multiple phases, the phases of burials could not be related to specific structures. The cemetery is located in a raised-beach platform and formed of “loosely compacted, large, rounded beach stones” (James and Yeoman 2008:15) and was “devoid of soil or sand.” Lack of soil is likely the reason for the excellent preservation of bone excavated from the cemetery. Similar preservation of bone could be seen in the Iron Age site Knowe of Skea in what was called ‘rubble deposits,’ the excellent preservation also linked to limited soil (Gooney unpublished). The earliest burials at the Isle of May, from the fifth to the seventh century, were cisted graves with side and cover slabs, while burials from the eighth to the twelfth century were cut into the raised beach (James and Yeoman 2008). The cisted graves likely belong to the monks from the Pictish monastery, corroborating the mostly older male skeletal remains excavated. The graves from the eighth to the twelfth century included other age ranges as well as a couple of females. These graves are likely the visiting pilgrims evident from the age/sex ratio as well as the increase of pathological bone.

While some monasteries had schools and novitiates for older children, the Isle of May did not seem to have these provisions (Duncan 1956, Eggeling 1985, James and Yeoman 2008). There is no mention of oblates, postulants, or novices at the Isle of May, so it can be assumed the monks were already established and had taken their vows. Also, since it was a small dependent priory, it is likely the monks were sent from the mother house and would not have had the power to recruit new members. Each of these reasons support the theory that the young individuals buried at the Isle of May were pilgrims. Few burials were found that were contemporary with the life of the priory. These burials were predominately male, however the inclusion of a 7-9 year old child indicates pilgrimage continued through the life of the priory. Burials continued in the cemetery until as late as the mid-seventeenth century, however not as frequently as in earlier centuries (James and Yeoman 2008). During construction of the priory, human remains that were disturbed were reburied in a number of pits throughout the cemetery (James and Yeoman 2008).

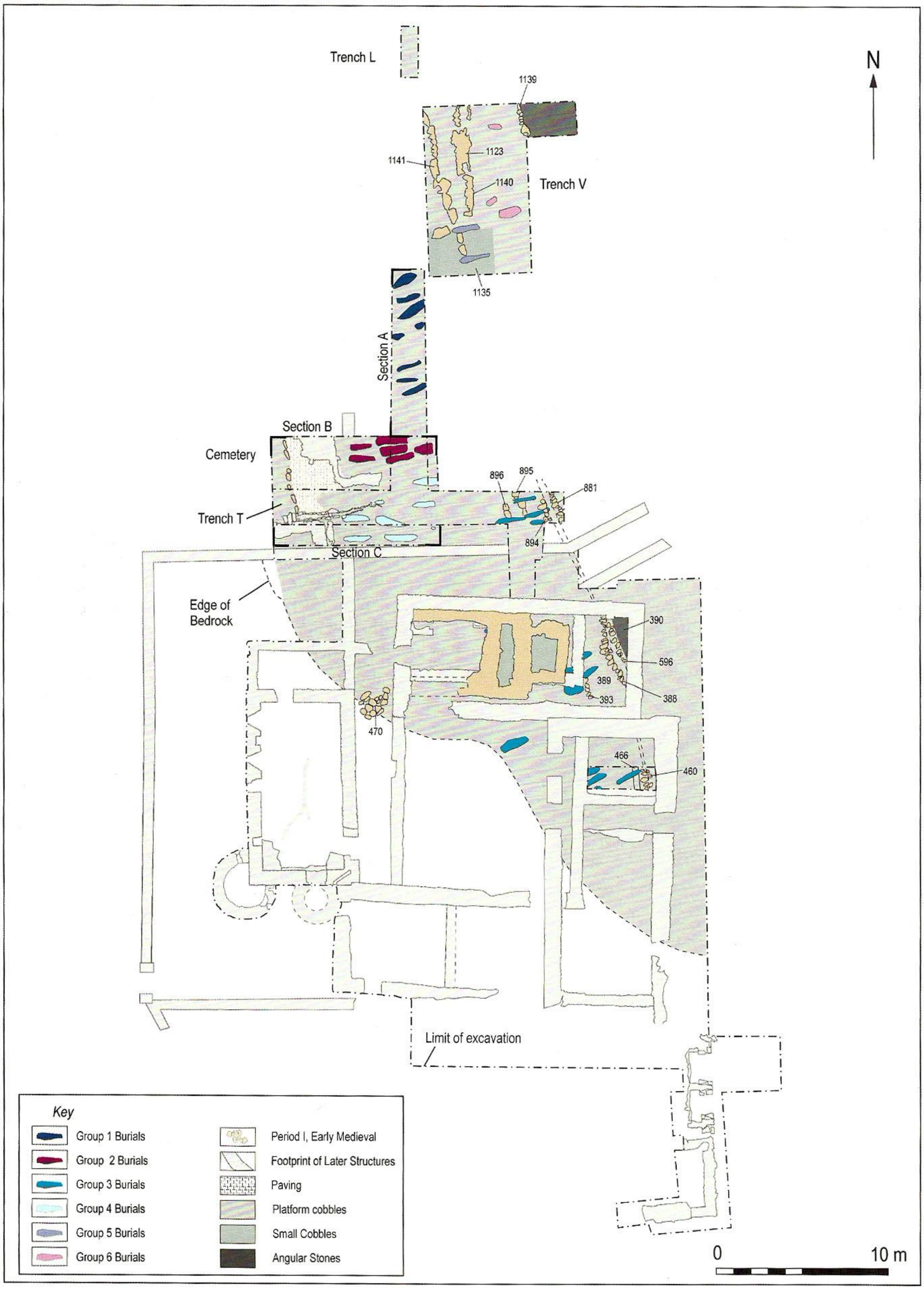


Figure 10. Isle of May excavated burials (James and Yeoman 2008)

Between previous research and this study twenty-one skeletons have been radiocarbon dated. The earliest radiocarbon date at this site was SK 869 at 1520± 70

BP, which spans 404-649 AD and the most recent date was SK 1120 from 370±50 BP, which spans 1445-1637 AD (James and Yeoman 2008) (Figure 11). Based on radiocarbon dates and stratigraphic evidence, the burials were organized into six burial groups specific to a period of occupation: 48 of the individuals were buried between the fifth and mid-twelfth century and 10 between the eleventh and seventeenth century (James and Yeoman 2008). This indicates that most of the occupation and use of the cemetery was before the thirteenth century, when the Benedictine priory was established, corroborating what is known about the island historically. While the site was used for a thousand years, there seems to have been a period of transition between the tenth and twelfth century when burials shifted from long cists to dug graves (James and Yeoman 2008). Table 1 illustrates the six burial groups and the number of individuals buried within that phase of the cemetery. The date associated with each burial group is extrapolated from James and Yeoman (2008). A list of skeleton numbers associated with each group can be found at Appendix 8.

Table 1 Isle of May Burial Groups with Estimated Date and Number of Individuals (after James and Yeoman 2008)

Burial Group	Estimated Date	No. of Individuals
1	5th-7th C.	13
2	8th-10th C.	21
3	Late 10th-12th C.	14
4	Mid 12th-14th C.	6
5	13th-14th C.	3
6	15th-17th C.	1

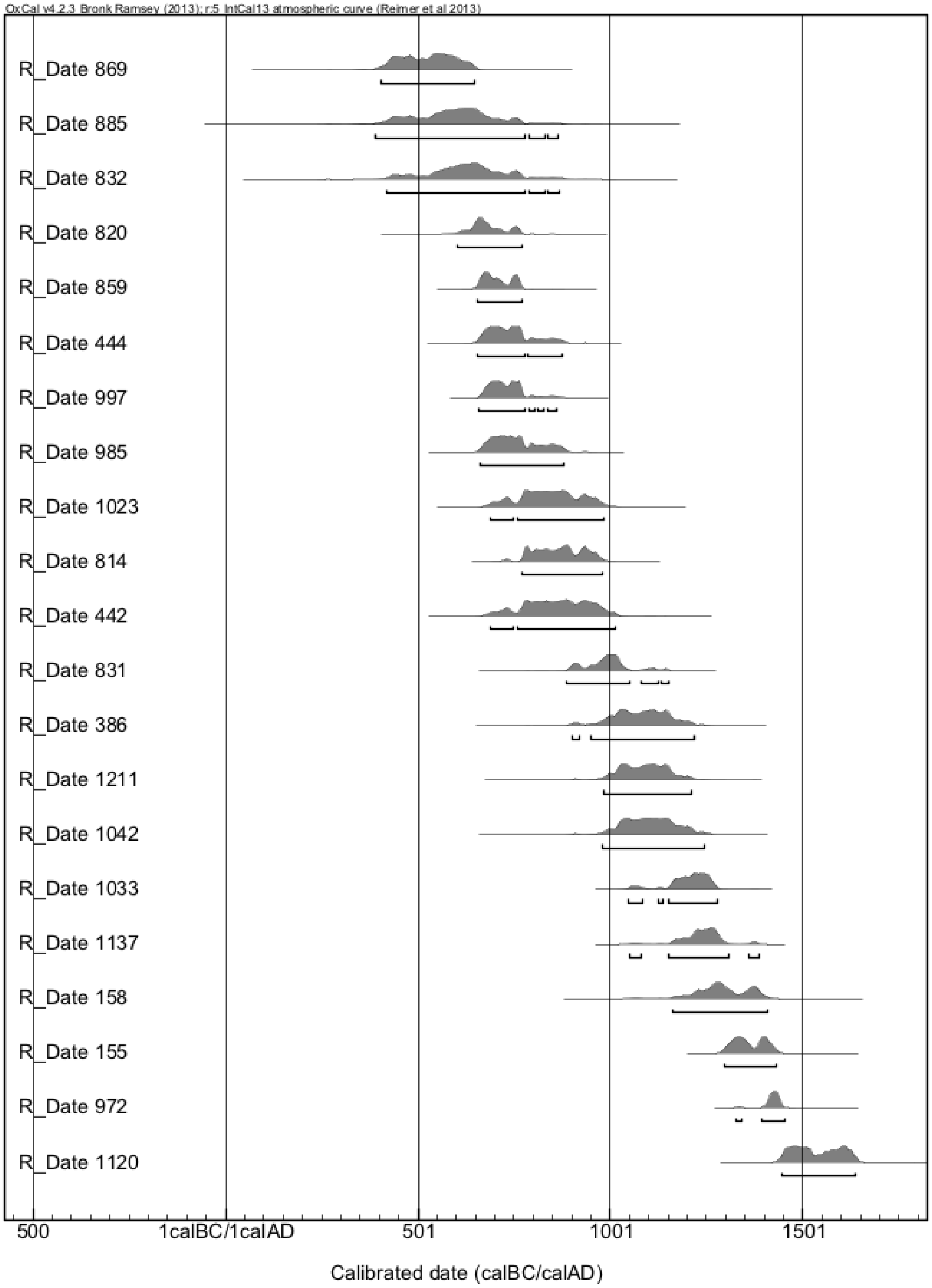


Figure 11. Radiocarbon for Isle of May burials (after James and Yeoman 2008)

2.2.4 Burial Practices, Grave Containers and Furnishings

As mentioned previously, the burial ground included both long cists and grave pits. Table 2 lists the numbers of individuals buried in dug or cist graves.

Figure 10 illustrates the location of the six burial groups spread across the site. Groups 1 and 2 were laid out in neat, N-S rows without intercutting, and aligned roughly on the kerbed roadway.

"In contrast, Group 3 burials were scattered across the centre of the platform, beneath what would later become the church, cloister and chapter house. What starts as managed burial grounds later becomes sporadic burial around a cult focus" (Maldonado 2011:227). The earlier (pre-tenth century) graves tended to be aligned WSW/ENE and the later ones oriented E-W, parallel to the churches. It is likely these earlier burials are oriented to an earlier monastic building, the remains of which have not been found (James and Yeoman 2008).

An interesting feature of the burials at the Isle of May was the use of white quartz pebbles. "A handful of cists contained spreads of white quartz pebbles in their fills; these may have been used as surface markers for graves...[which] would have had to be carefully gathered and brought to the grave from elsewhere (Maldonado 2011:230)." Another possibility is that the quartz pebbles were used in graves with multiple individuals to separate 'tiers' of burial, perhaps between monastic and lay individuals.

Table 2 Types of Graves at Isle of May

Type of Grave	No. of Individuals
Long Cist	36
Dug	21
Unknown	1

2.2.5 The Study Sample

The skeletal remains from the Isle of May are curated by the National Museum of Scotland and they have been on loan to the University of Edinburgh since October 2010 for the purpose of this study. From 1997 until 2010 the assemblage was stored at the National Museum of Scotland's storage facility in Port Edgar. There are both disarticulated and articulated remains in the excavated collection; however the disarticulated remains were excluded from this study because the focus is to compare individuals. All 58 articulated skeletons that were excavated were analyzed. These 58 are estimated to represent twenty percent of the entire cemetery (James and Yeoman 2008). The skeletal assemblage was analyzed for this study at the archaeology laboratory at the University of Edinburgh.

2.2.5.1 Condition of the Material

The assemblage is stored in labeled bags in cardboard boxes, generally one skeleton to a box, but sometimes shared. The skeletal remains had been cleaned previously although the precise methods used are unknown.

2.3 St Andrews Library

2.3.1 Archaeological Setting

St Andrews is a coastal town located in eastern Scotland in Fife. While the current place name derives from Scotland's patron saint, the previous name was Kinrimont, or in Gaelic Cennrigmonaid, on record as early as 747 AD when it was a Pictish royal monastery (Campbell 2013, Hall 1997, Simpson and Stevenson 1981). The administrative center of the church moved from Dunkeld to Kinrimont in the early tenth century, becoming the seat of the principal bishop of Scotland (Campbell 2013, Hall 1997, Simpson and Stevenson 1981). There was likely a lay settlement outside of the ecclesiastical precincts, similar to the ecclesiastical site at Whithorn (Hall 1997). St Andrews was first founded as an ecclesiastical burgh in 1144 and eventually earned royal burgh status in 1620, however it attended the general council in 1357 and was active in the Parliament from 1456 AD (Campbell 2013, Simpson and Stevenson 1981).

The first religious construction in St Andrews was a Pictish monastery built in the eighth century (Hall 1997). An Augustinian priory was established later in the mid-twelfth century, currently called St Andrews Cathedral (Cowan and Easson 1976). The Cathedral was the largest church built in Scotland at the time, which was in 1160. Storm damage in 1273 required a partial rebuilding, a fire in the choir and transepts in late fourteenth century and more storms in the fifteenth century damaged the cathedral further (Simpson and Stevenson 1981). The building was finally left to decay after the reformation (Campbell 2013, Simpson and Stevenson 1981).

While the authenticity is now debated, throughout the medieval period it was believed that the relics of St Andrews were brought to Kinrimont in the eighth century (Campbell 2013, Simpson and Stevenson 1981). For the next eight centuries St Andrews became a major pilgrimage destination to worship at the shrine for the relics (Simpson and Stevenson 1981, Turpie 2015). Campbell (2013) argues that the burgh of St Andrews was consciously modelled on the Vatican Borgo, with two major streets converging on the cathedral. Campbell believes the intention was for St Andrews to be recognized as an apostolic see like its rival Compostela in order to encourage pilgrimage. While the majority of Scottish burghs were established with a single-street plan that had a castle at one end and a church/palace at the other, St Andrews had a unique three-street plan. Further analysis showed the original plan was for two streets (North and South Streets) and that Market Street was intended as a back lane for the two-street town (Campbell 2013).

St Andrews had large pilgrimage numbers, indicated by the necessity of Queen Margaret to establish a free ferry across the Firth of Forth in the eleventh century, from where is now aptly called North and South Queensferry (Campbell 2013, Turpie 2015). Campbell (2013) estimates up to 15,000 pilgrims could have visited St Andrews to see the apostle's relics in one year. The official hostel for pilgrims was at St. Leonards and established by 1140 (Campbell 2013, Simpson and Stevenson 1981). In the 15th century pilgrimage diminished and the hostel served as a hospital for old and infirm women until 1522 when it was converted into part of St. Leonard's College (Campbell 2013, Simpson and Stevenson 1981, Turpie 2015). A leper hospital called St. Nicholas was founded in the twelfth century near the southern limit of St Andrews and was later converted into a hospital for the poor in the sixteenth century (Hall 1995).

Overseas trade was important to St Andrews; however it was not one of the top-ranking burghs on the east coast in terms of trade. In fact, a national taxation organized for burghs north of the Forth disclosed St Andrews was charged with half of the amount of tax that Dundee, Aberdeen, or Perth were charged (Simpson and Stevenson 1981). Simpson and Stevenson (1981) believe that St. Andrew's low status for overseas trading was due to poor harbor facilities. The inconvenient location of the harbor required goods to arrive in Dundee's port and then carried over land to St Andrews (Hall 1997, Simpson and Stevenson 1981). St Andrews did excel at education, however, the University of St Andrews was founded in 1413 and later other colleges were founded within the university: St. John's (1419), St. Salvator's (1450), St. Leonard's (1511), and St. Mary's (1538) (Simpson and Stevenson 1981). St Andrews also had a well-developed fishing industry, which supported its inhabitants (Simpson and Stevenson 1981).

The burgh of St Andrews was never walled; the only area with defensive walls enclosed the precinct of the cathedral and priory. The castle, or Bishop's Palace, was built in the early thirteenth century and was protected on the east and north by the sea, and by a large ditch elsewhere (Simpson and Stevenson 1981). The castle was rebuilt by the English in 1336 since it was damaged during the Wars of Independence. The building was also damaged by French troops in May 1547. After the reformation the Archbishops moved to the Novum Hospitium of the Priory and by 1654 the castle was no longer inhabitable (Simpson and Stevenson 1981).

There were multiple phases of development, shown by the location and subsequent relocation of the market place (Hall 1997). The streets were widened and the limits of the town expanded; at one point the Friaries were located at the western extremity of the town (Hall 1997, Simpson and Stevenson 1981). Development stagnated in the early sixteenth century, Simpson and Stevenson (1981:24) believe it was "due to a combination of factors, the limited land available for expansion in relation to the physical position of the town, improved methods and materials used in building construction, and the fluctuation economic fortunes of the burgh." The average rig was nine meters wide. A house was generally built on the street front with space between the building and the road. The space in front of the buildings were later extensions for commercial purposes and the backland areas were also developed along the close, making the street accessible (Hall 1997). Houses in the twelfth to fourteenth centuries were made of wood and sat at right angles to the street within the allotted burghage plot (Simpson and Stevenson 1981). Stone buildings became more common in the thirteenth century.

The town of St Andrews grew under the influence of this new Scottish ecclesiastical centre, as the seat of the greatest bishopric in Scotland along with Dominican and Franciscan Friaries. The Parish Church of Holy Trinity was originally built in 1112 within the cathedral precinct but with the growing size of the town and the influence of the merchant classes, a new parish church was necessary. With land grants from multiple wealthy burgesses the new parish church, was built between 1410 and 1412 (Rees et al. 2008). Holy Trinity Parish Church also included a large graveyard that was bounded by a row of houses to the north and enclosed by a wall on three sides (Rees et al. 2008). The cemetery was enlarged in 1430, indicating the heavy use of Holy Trinity within the community (Simpson and Stevenson 1981). Holy Trinity Church would have been the primary burial site for the dead in the burgh, except those associated with the friaries (Rees et al. 2008). The high density of use is evidenced from the excavation where skeletons were in close proximity both vertically and laterally (Rees et al. 2008). Closure of the churchyard probably occurred around the Reformation c.1560, however inhumations could have continued for several decades after that (Rees et al. 2008, Simpson and Stevenson 1981). The church was repaired in 1749 and nearly rebuilt in 1798 with continued repairs in the early twentieth century leaving only small parts of the medieval structure surviving (Simpson and Stevenson 1981). Other than St Andrews Library assemblage, which are burials from Holy Trinity Church, there are two other assemblages from St Andrews that have been used in this research for comparative purposes, St. Mary's Church Kirkhill and Logies Lane. Figure 12 is Geddy's plan of St Andrews, dated to 1580 and illustrates Holy Trinity Parish Church and its churchyard.

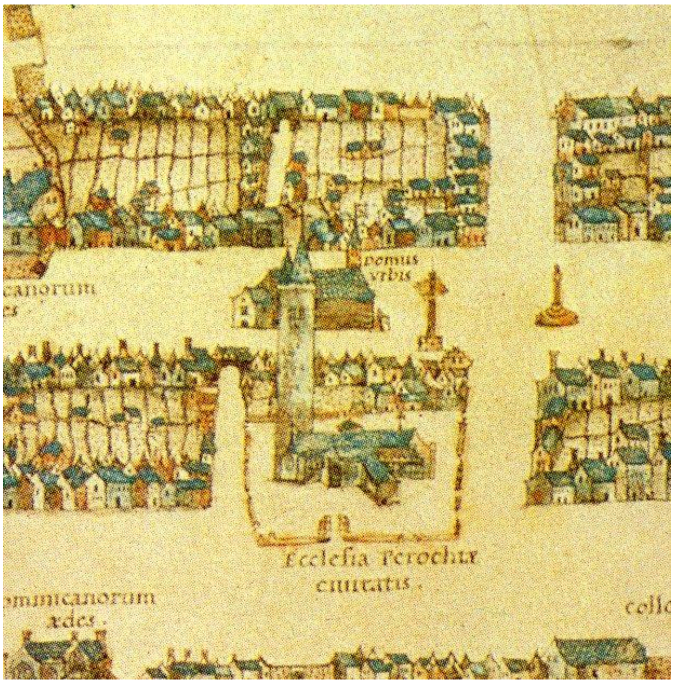


Figure 12 Holy Trinity Church c.1580AD (Geddy Map, NLS)

2.3.2 The Burials

St Andrews Library is part of an early nineteenth century building built on the northwest corner of the graveyard of the Holy Trinity Parish Church. As part of redevelopment of the library in 2003 to include a lift shaft, the area of the intended shaft and an adjacent wall of the library were excavated by Rathmell Archaeology (Rees et al. 2008). There had been two previous excavations of the graveyard at the Holy Trinity Parish Church, in 1988 and 1991 by SUAT (Cardy 1997b). In those earlier excavations 121 individuals were excavated, though due to the size of the trenches, no complete burials were recovered (Cardy 1997b, Rees et al. 2008). During the 2003 excavation of the lift shaft and adjacent wall, 72 articulated skeletons and many more disarticulated remains were removed. The lift shaft measured just 3m by 3m (Figure 13). Eight layers of interments were identified, the density of burials revealing the intense use of the cemetery. The burials were excavated in three layers ranging from 21.7m to 19.72m OD (Figure 14). While the excavation also recovered a large amount of disarticulated bone, only the articulated skeletons were analyzed for this study. Twenty-seven of the articulated skeletons were previously analyzed by Kathleen McSweeney and published by Rees et al. in the Tayside and Fife Archaeological Journal (2008). Forty-four skeletons were also analyzed by Dawn Gooney for her Master's Dissertation (2006), specifically to examine non-metric traits in the remains. In neither of the previous projects were the skeletal remains analyzed statistically nor compared thoroughly with other medieval Scottish populations as in this study. Due to the secure dates of graveyard use from historical documentation, radiocarbon dating has not been conducted on the St Andrews Library remains. A list of skeleton numbers associated with each burial layer can be found at Appendix 9.

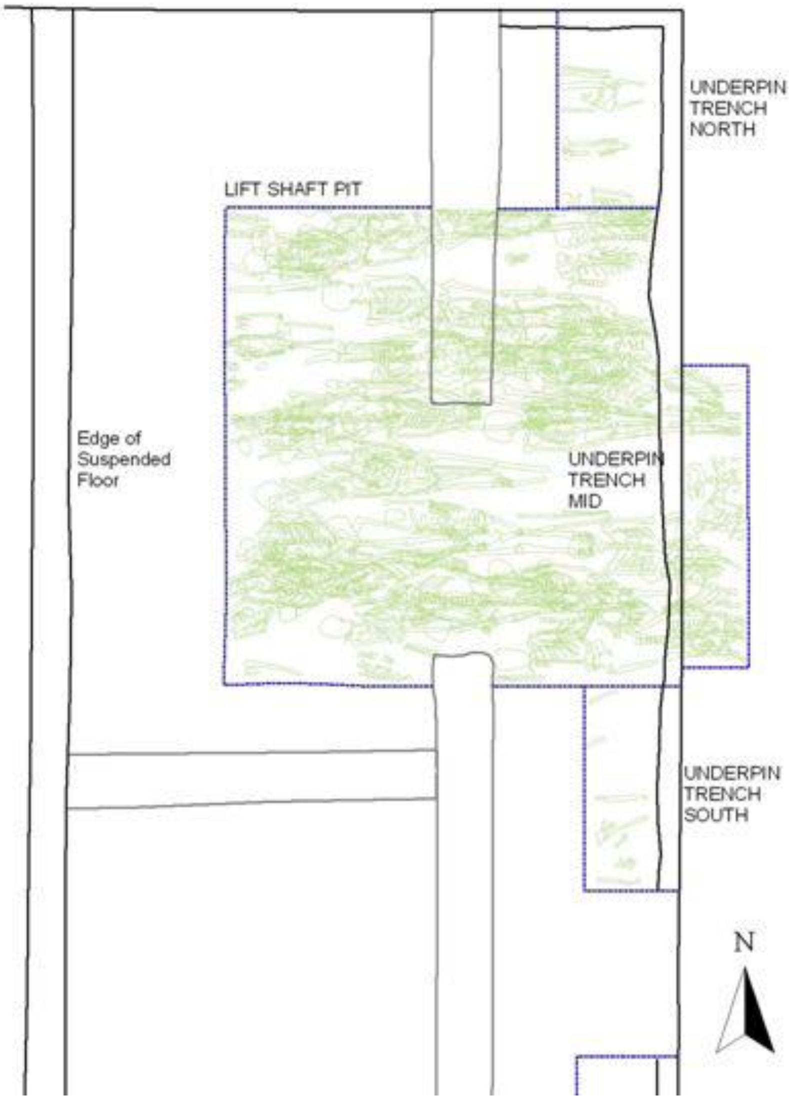


Figure 13. Site plan showing the limits of the lift shaft and trench

From Data Structure Report for St Andrews Library Rathmell Archaeology Ltd. 2003

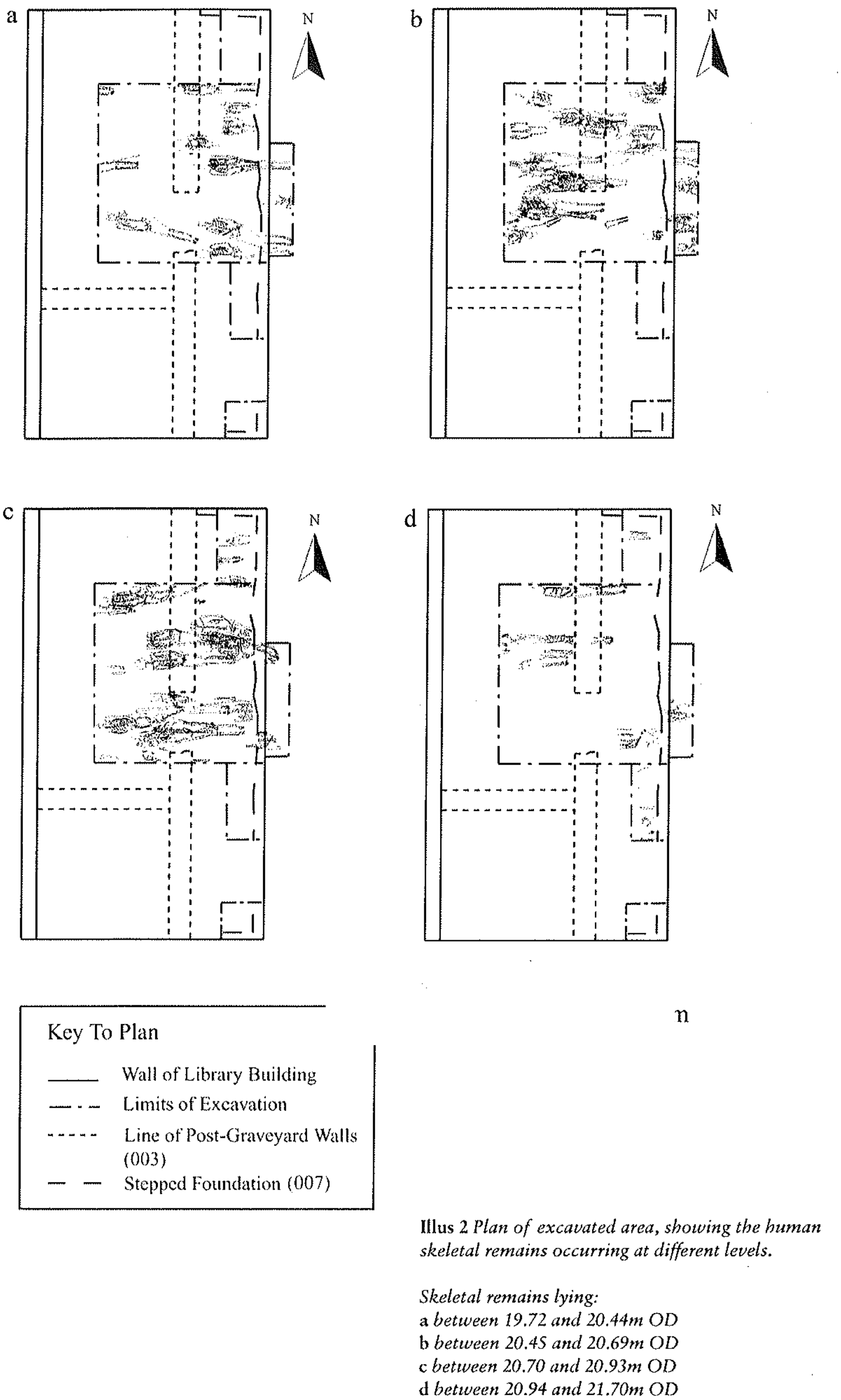


Figure 14. Plan of excavated area at St Andrews showing skeletal remains at different levels (Rees 2008)

2.3.3 Burial Practices, Grave Containers and Furnishings

The majority of the articulated skeletons were aligned E to W, with their heads lying to the W. No grave goods were recovered associated with any of the burials. Because of the density of burials in such a small area there was much intercutting and truncating of the burials over the cemetery use. Many of the skeletons were missing skulls, arm bones, leg bones or consisted of just a number of articulated skeletal elements.

2.3.4 The Study Sample

The St Andrews Library assemblage is currently curated at the University of Edinburgh. It had previously washed and stored in plastic boxes. Context numbers assigned by Rathmell were retained for this study. Before analysis for this study the assemblage had been inventoried and each context had been given its own plastic box. As mentioned earlier, a portion the St Andrews Library assemblage has previously been analyzed. All 72 articulated skeletons removed during the 2003 excavation by Rathmell were analyzed for this study.

2.3.4.1 Condition of the Material

Besides the previous research, the St Andrews Library assemblage has been used since 2005 for teaching for the University of Edinburgh's Masters Programmes. Due to the extensive handling of the skeletal remains from this assemblage, many elements had additional post mortem damage such as flaking of cortical bone, fragmentation of elements, and occasionally misplacement of elements. For example, Context 45 included skeletal elements from two easily distinguishable individuals who were therefore given separate context numbers, 45a and 45b. Both contexts only consisted of leg and foot bones.

2.4 Whitefriars

2.4.1 Archaeological Setting

This site was a medieval friary over which now lies Whitefriars Street and Riggs Road in Perth. The name Whitefriars is a nickname for the Carmelite order dedicated to the Virgin Mary who inhabited the friary, at that time called Tullilum (Cowan and Easson 1976). Tullilum was located a half a mile west from the medieval burgh of Perth on the main road leading into the burgh (Hall 1989) (Figure 15). The first surviving reference to Tullilum is a charter of Malcom IV, dated 1157, which grants Tullilum to Dunfermline Abbey (Spearman 1989). Historical references report that the chapel was transferred to the Carmelite friars around 1260 AD and that the friary buildings were eventually demolished in May of 1559 AD.

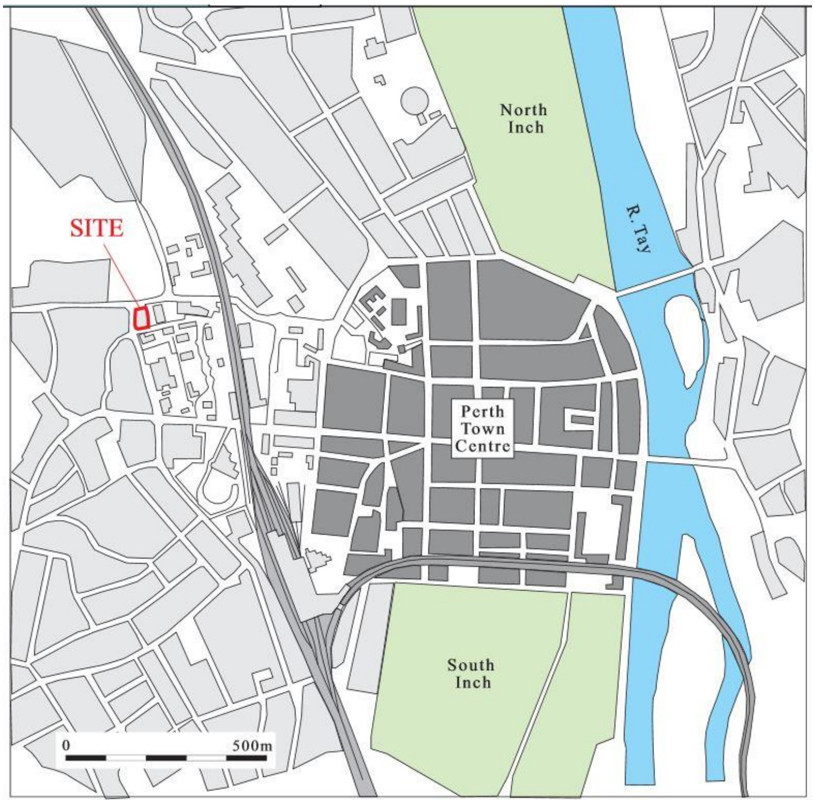


Figure 15. Whitefriars site location in relation to Perth (archaeological evaluation SUAT 2007)

Along with the Whitefriars friary that is a study population for this research, three other assemblages were collated and reviewed from Perth for comparative purposes: Horse Cross, St. John's Kirk, and Kinnoull Street. Perth lies on the banks of the River Tay and because of the depth of the Tay, ships could bring trade from north and south routes (Bowler 2004, Simpson and Stevenson 1982). Perth received burgh status by David I (1128-1153 AD) as well as a charter by William the Lion (1165-1214 AD) (Bowler and Perry 2004). Perth was set up with the single street plan, the high street dates before 1127 when it was founded by David I. During the Wars of Independence Perth became a walled city by Edward I in 1304 until the late eighteenth century (Bowler 2004, Holdsworth 1987). In 1562 Perth's population is estimated to 5,642-6,075 people, using marriage and burial registers as well as census data (Bowler 2004).

Scone abbey, where the principal seat for the Kingdom of Scotland was located, was less than three miles away from the Burgh of Perth. Because of the proximity to Scone, Scottish kings often held parliaments and general councils in Perth, occasionally resided in the Dominican Friary, and used it to house the royal court as well as royal visitors (Bowler 2004, Simpson and Stevenson 1982, Yeoman 1995). Perth's origins and prosperity was because of its advantageous location for trade. Simpson and Stevenson (1982:4) describe its success in trade "[d]uring the reign of David I, Perth outstripped other burghs in ship-customs and a sizeable number of gifts from burgh rents went to endow religious foundations." Perth exported hides, cloth, wool, fleece, timber and occasionally salmon, rabbit skins and woolen cloth (Simpson and Stevenson 1982). Because of its location on the Tay, Perth may have traded with countries such as Germany, France, and other Baltic countries (Simpson and Stevenson 1982). Before Dundee was a royal burgh, Robert I ordered all ships to land at Perth, however trade was lost to Dundee once it also became a royal burgh (Perry 2005). Evidence from archaeological excavations reveal many industrial trades including weaving, brewing, tanning, dyeing, and metalworking (Holdsworth 1987, Simspon and Stevenson 1982). There were also several hospitals in medieval Perth, including a leper hospital (Bowler 2004).

Although there is no information regarding the building of Perth castle, we do know that it was short lived and destroyed in 1209 AD (Simpson and Stevenson 1982). The Dominican Friary was built on part of the castle site in 1240 AD and was the usual residence for Scottish monarchs when they visited Perth (Simpson and Stevenson 1982). Perth changed hands during the Scottish Wars of Independence back and forth between the English and Scottish (Bowler and Perry 2004).

The Carmelite friary of Tullilum is only one of several monastic friaries founded at Perth. The Dominican Friary was founded in 1231 and granted the land on the castle site. The royal grants, guests and patronage contributed to the Dominican friary being among the wealthiest in Scotland (Simpson and Stevenson 1982). On the other side of the scale was the poorer foundation of Carmelite friary.

A Franciscan friary and a Carthusian monastery were also founded in Perth. Each friary and monastery was destroyed in May 1559.

The Carmelites received their name from Mount Carmel in Israel where the order first started. The Carmelites eventually became a mendicant order as were European based orders. However, prior to 1215 AD Carmelites led an ascetic life where each hermit had an individual cell separated from others and they were expected to limit their speech (Andrews 2006, Egan 1992). Monks did not own personal items, instead everything was communal. For their diet, there was "complete abstinence from meat and a fast that is observed each day except Sunday from the feast of the Exaltation of the Cross, 14 September, until Easter Sunday" (Egan 1992:108). Meals were eaten in isolation and life was focused on solitude and prayer (Andrews 2006). When the first four Carmelite foundations in England occurred between 1242 and 1247 these rules were followed. The first foundations were in rural locations, which contrasted to the Dominicans and Franciscans in the urban locales. Monasteries in urban settlements were more prosperous because of the closeness of benefactors and recruits (Egan 1992). The secluded hermit lifestyle must not have been successful because in 1247 AD a general assembly was convened to address the severe restrictions and new relaxed revisions were approved by the pope in October of that year (Andrews 2006, Egan 1992). Now Carmelites could settle in towns and cities, they could eat together, the length of silence was shortened, and the monks could now eat meat when outside the religious houses preaching and begging (Andrews 2006, Egan 1992). Carmelite monasteries were now more similar to the other religious orders such as the Dominicans and Franciscans (Andrews 2006). In 1253 the pope allowed the Carmelites to preach, hear confession, they could receive donations from benefactors and in 1261 they were could allow the lay to frequent their churches (Andrews 2006).

Monastic precincts often included the church, cloister, infirmaries, almshouses, barns, storehouses, gardens and orchards, workshops, kilns, mills, stables, chapels, and graveyards (Yeoman 1995). In the fourteenth century the Carmelite monasteries were used by the lay to store valuables and sign treaties. Carmelite monks were often present in noble and royal entourages. As early as 1262 there is explicit instructions by the pope that lay servants and benefactors could be buried in the friary's cemetery (Andrews 2006). The monks were buried at a distance from any secular tombs, but masses were said for both the souls of the deceased monks, servants, and benefactors of the order. In the fourteenth century the emphasis on personal poverty and communal austerity was lost. Instead, friars owned property and regularly received gifts from donors.

Tullilum was the first Carmelite house founded in Scotland, likely around 1262. The endowment was described in Walter Bower's Scotichronicon as 'a spacious house,' 'stately chapel' and that it was decorated with rich work (Simpson and Stevenson 1982, Stones 1989). In 1335 there is reference to a burgess gifting land, a ditch, and a stone wall to augment their garden because their garden was not producing enough vegetables (Stones 1989) after which the garden was able to grow fruit, herbs, and wood for timber (Stones 1989). Soil analysis from the 1982 excavation found several plant species that were used during the medieval period for medicinal purposes including hemlock, burdock, parsley piert, and elderberry (Stones 1989).

Tullilum was paid 5 merks annually from the crown and additionally received alms from the king between 1381-1386 and 1496-1505. Carmelite rents and properties were mostly around Perth, but several were further away in Wester Dowlell and Monedie at Port of Mentieth west of Stirling (Stones 1989). Closer to Perth they owned land in Upper and Nether Tullilum, Unthank, Dawghach, Crawhill. In Perth, the friars held thirty rentals from burgesses including crofts and even tenements. Stones (1989:98) explains "the majority of these plots and crofts had been committed to pay a few shillings each year in return for prayers for the souls of their former owners." While the Carmelites certainly were not as wealthy as the Dominicans or Carthusians, since they received greater royal support, Tullilum and its friars still had considerable wealth.

In the fourteenth century the bishops of Dunkeld kept a residence and store houses at Tullilum. Although the bishop of Dunkeld also had town houses in Perth, Edinburgh, and Dundee, as well as rural residences in Dunkeld, Cluny, Kinwaid, most of the bishop's accounts were rendered in Tullilum, indicating that was his main center of business (Stones 1989). While the bishop and the friars were two separate institutions, the friars received gifts from the bishop including meal, candles, and a horse (Stones 1989). The bishop chose the prior and even sent two monks to go to Aberdeen to study (Stones 1989).

Refurbishment of the bishop's residence as well as the convent began in 1507 which included a roof repair. A new window in the hall of Tullilum was installed in 1513 as well as a granary above the larder, a new kitchen, and extensions in the church. Documentary sources report that by the mid-sixteenth century there were fewer donations to the Friars and that the buildings had become ruinous (Simpson and Stevenson 1982). A loan from an important burgess, John Gray helped to repair the monastery in 1551, only to be destroyed in 1559 during the Reformation. However, although the sum of £30 was requested for repairs, that request was often made by monasteries to raise cash for the friars themselves (Stones 1989). The lands of Tullilum were feued to Patrick Murray in 1568 and underwent several ownership changes such as the Glover Incorporation in 1692 and Robert Comb in 1740, in which case the grounds were levelled to create a garden (Stones 1989).

Due to frequent flooding of the Tay, archaeologists have found rich, waterlogged deposits, shedding light on medieval life in Perth (Bowler 2004, Holdworth 1987). Houses were rebuilt every few years, and often did not last more than twenty years. Peter Yeoman (1995) believes this was due to the technique of construction or the building materials. Perth also suffered from regular fires due to the crowded nature of the backlands and frontages (Bowler and Perry 2004, Yeoman 1995). Houses in the backlands were wooden, small, and single story usually between six to eight meters in length and three to four meters in width (Bowler and Perry 2004, Yeoman 1995). The walls were usually wattle and daub, covered by clay, dung, mud, peat, or turf. Some walls were even double skinned to have better insulation. Byres would have open walls to allow better ventilation.

From the thirteenth century newer construction techniques seemed to try to prevent wood rot from occurring as quickly likely to limit rebuilding. On the street frontage some wooden buildings were two stories, which in a flood in 1209 the inhabitants took refuge in their upper rooms (Bowler and Perry 2004). The majority of houses had thatch roofs. Doors were made of wood and were lockable, indicated by the padlocks commonly found during excavations. Windows were small and had wooden shutters and floors were composed of sand, clay, or gravel. The wealthier houses had wood floors, the most impressive structures excavated was an aisled hall dating to the thirteenth century that had a plank-in-sill façade (Bowler and Perry 2004). Many houses included a byre, indicated with a stone floor and a drain. Hearths were situated in the center of the house; however sometimes external hearths were used. The poorer houses had few pieces of furniture, sometimes only a chest or a bench. Lighting was accomplished from candles made from sheep fat or ceramic lamps burning linseed or fish oil.

Wooden framed cesspits were also found even with a wooden toilet seat still in situ (Holdsworth 1987). Moss was found inside the pit, used as toilet paper. A partition made of wattle was used to create privacy. By the fifteenth and sixteenth centuries stone houses were more common, however wooden houses were still more prevalent (Bowler and Perry 2004). Numerous well and cisterns were found dug into the ground; however sometimes cesspits were dug too close to the water supply which resulted in contamination. Eggs of parasitic worms were also found in the cesspit material suggesting the people using the latrines were infected. The latrine material also demonstrated the diet of at least one person in Perth, which was mainly of cereals, but supplemented by meat, fish, shellfish, eggs, fruits and seeds (Holdsworth 1987). Floors and midden samples contained waste from the industries of leathermaking, dyeing, linen and oil production. Cottage industries seemed to exist in the poorer section of the community. For example, a home was also the site for cobbling and another home included an oven large enough to be shared by a number of bakers. Holdsworth (1987:212) suggests "these people practiced small scale industries to supplement their subsistence level life style."

The site was originally excavated in 1982 by SUAT as a rescue mission in advance of industrial unit development (Stones 1989). This first excavation was subsequently published in a Society of Antiquaries of Scotland monograph along with two other excavations from other Carmelite orders in Aberdeen and Linlithgow (Stones 1989). The exact position and size of the friary complex was unknown prior to the 1982 excavation (Hall 1989). During this early excavation the friary church and two conventual buildings were located as well as an associated burial ground (Figure 16). Although 3600 sq m was under threat by new development, resources could only cover a series of machine trenches to locate structural remains (Hall 1989). Due to these limitations imposed by the developers, none of the exposed walls could be excavated and even parts of the friary buildings were destroyed during the development (Hall 1989). Another problem encountered during the excavations was the estuarine clay that the site was built on. The clay tended to bake hard and crack when exposed to long periods of sunshine (Hall 1989). In 2008, SUAT commenced a second excavation in preparation for more industrial unit development directly next to the original 1982 excavation (Figure 17). Unfortunately, the project was stopped before the entire cemetery was excavated due to unforeseen circumstances (Hall, personal comm. 2010). The skeletons that were removed in this second rescue excavation in 2008 are the subject of this research.

No information, including site plans, grave location, grave depths, or chronology of the site regarding the 2008 excavation has been released to date. The only information about the Whitefriars site that could be used for this study is gathered from the 1982 excavation (Stones 1989) and the archaeological evaluation report prepared by SUAT in 2007 (Hall 2007a).

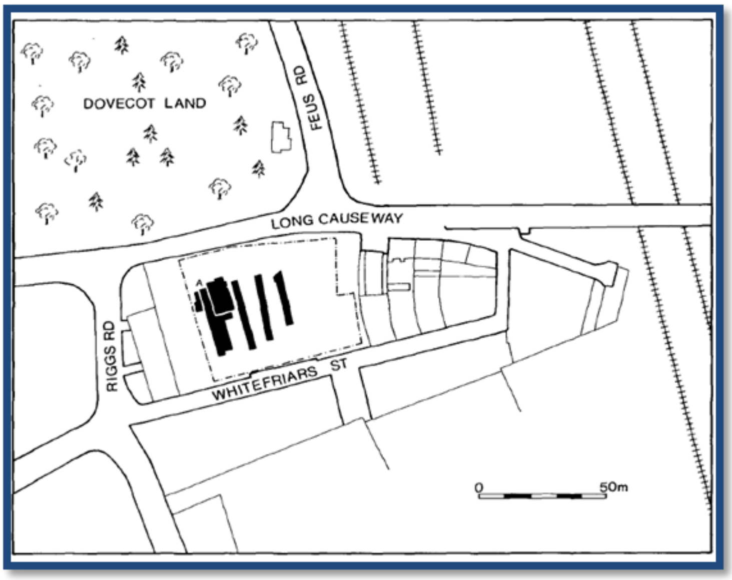


Figure 16. Site plan from 1982 excavation at Whitefriars (Stones 1989)

2.4.2 The Burials

Burials were interred during the friary period, 1262 AD to 1559 AD, but also after this, perhaps as late as the seventeenth century (Hall 1989). Later burials could even be associated with a nearby Victorian cemetery or could potentially be plague victims, though these scenarios are deemed less likely (Hall 1989). Radiocarbon dating was attempted for several specimens but was not possible due to the low collagen amounts in the remains. Twenty-one skeletons were excavated in 1982; however examiners mention that 'few data could be obtained as the condition of the bones was poor' (Cross and Bruce 1989:119). As indicated earlier, the estuarine clay that surrounds the site posed problems during the 1982 excavation such as baking hard and cracking when exposed (Hall 1989). These conditions would pose great risks to skeletal remains and most likely is the cause for such poor condition of the bones. This poor condition also affected the remains excavated in 2008 and created limitations for this study during analysis (section 1.2.2). Seventy-nine articulated skeletons were removed during the 2008 excavation. Due to financial constraints, SUAT was unable to complete the analysis of the skeletal remains, which were instead donated to the University of Edinburgh for analysis and research.

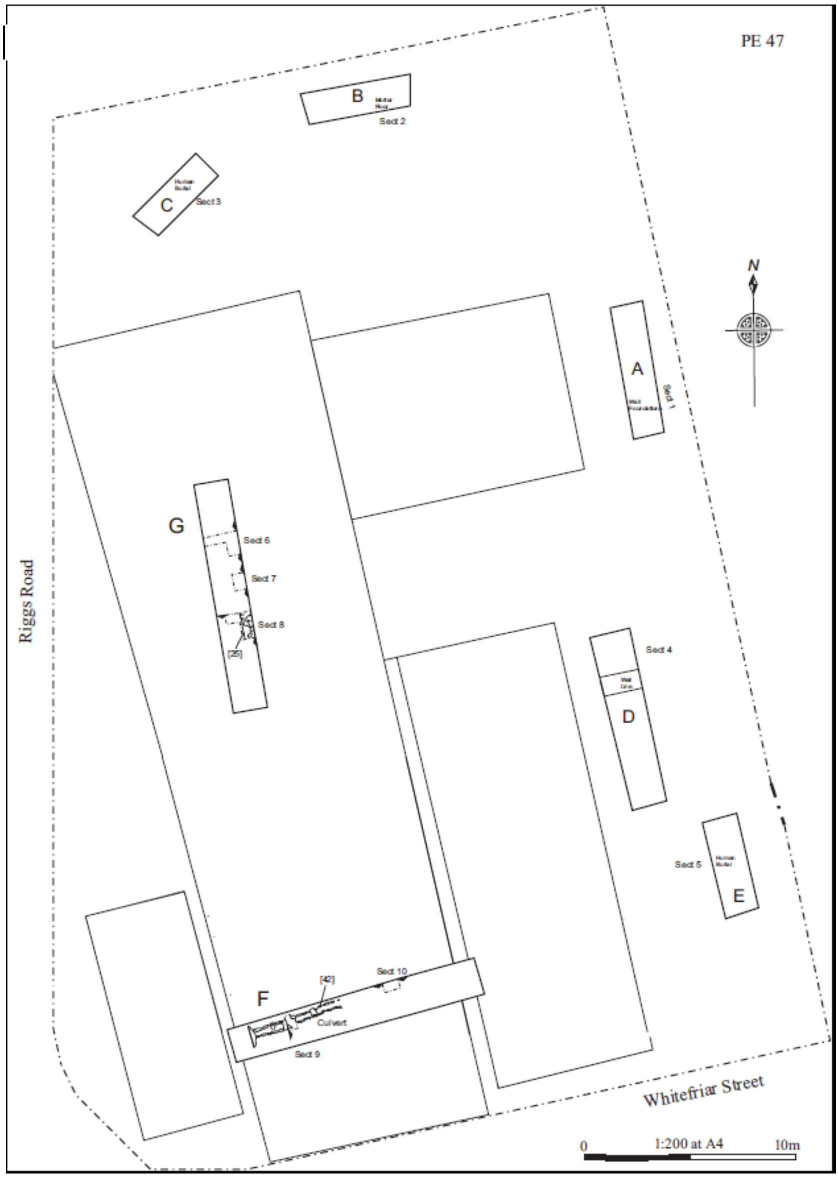


Figure 17. Whitefriars trench location plan (archaeological evaluation SUAT 2007)

2.4.3 Burial Practices, Grave containers and Furnishings

During the 1982 excavation five skeletons were found to be buried in wooden coffins, which were preserved (Boyd 1989). All inhumations were buried with their heads to the W; several graves that are thought to have been buried inside the church were lined with planks (Hall 1989). Plank-lined graves were most likely reserved for especially important people. Close to where the altar would have stood were multiple burials of adult men and women. The mix of sexes Stones (1989:104) suggests "represent the burials of important members of the friary community or its benefactors." One skeleton (SK 13) was found lying face down in the layer associated with the destruction of the friary (Hall 1989). The archaeologists have two possible interpretations for the position of the skeleton: either a fresh burial was exhumed and thrown into the ditch during the demolition of the friary or the individual was murdered and thrown into the top of the ditch and covered over (Hall 1989). Robber trenches were found in the post friary layers as well as several empty plank-lined graves. No jewelry or grave goods were found in association with any of the burials (Hall 1989).

As mentioned previously, the papal decree in 1312 permitted laymen to be buried within the friary cemetery as long as a portion of the fee was handed over to the church (Stones 1989). At least from the fourteenth century onwards the burial rites were relaxed since we do have men and women buried in Whitefriars. It is likely that benefactors were buried at Whitefriars, and especially important ones buried in coveted locations near the high altar. The plank-lined graves of females near the high altar found during the 1982 excavation are most likely these high status benefactors (Stones 1989). The males in the plank-lined graves near the altar could also be benefactors but could also be the friars themselves. Females and subadults in friary buildings or graveyards could also represent confraternities. The location of the friars are not possible to determine at Whitefriars. In 1982 there were no areas discovered with only male skeletons nor were any buckles from habits found in any graves.

Since the 2008 excavation was from the same churchyard as the 1982 excavation, it is likely there were other individuals buried in coffins or plank-lined graves in the 2008 excavation as well. It is also likely that the individuals excavated in 2008 were buried with their heads to the W; however, to date there is no information available regarding the burial practices, grave containers, or furnishings from the 2008 excavation.

2.4.4 The Study Sample

The Whitefriars assemblage used in this study was excavated in 2008 by SUAT and stored until 2010 in a transitory facility in temporary plastic and cardboard boxes. The remains had not been washed prior to storage; therefore the skeletal remains were stored with wet mud and clay that, in some cases, began to mildew. Some skeletal remains were discovered with bird feces on them as well. The Whitefriars assemblage was gifted to the University of Edinburgh in 2010 and transported to the archaeology laboratory facilities at the University. The remains were then transferred to new plastic boxes.

2.4.4.1 Condition of the Material

Due to the amount of clay and mud compacted on the remains, they had to be washed prior to analysis. The skeletal remains were washed in plain tap water using soft brushes. In some cases the clay had hardened, therefore water from the tap was trickled slowly on the remains until the clay loosened. The bones were then dried naturally on drying racks; drying took between twenty-four and seventy-two hours depending on the state of the bone itself. Once the remains were clear of the clay it was obvious that they were in poor condition. The majority of the bones were highly fragmented. A clear example of the limitations imposed by the fragmented nature of the assemblage is with the estimation of stature, which could only be completed for nineteen skeletons. Similarly, with the remains from the 1982 excavation, the stature of only one individual could be estimated (Cross and Bruce 1989). Along with high fragmentation, the cortical bone of the skeletal remains was also highly affected from the clay in which they were interred. The majority of the cortical bone on the skeletal remains was cracked and flaking. Due to time constraints, only fifty-eight of the estimated seventy-two articulated remains recovered were analyzed for this study. The skeletal remains from the 2008 Whitefriars excavation remain curated at the University of Edinburgh.

3. Methods

Skeletal and dental remains were analyzed macroscopically with the use of magnifying lamps when necessary. No radiology or histology was carried out for this study.

3.1.1 Skeletal and Dental Inventories

Detailed skeletal and dental inventories are important for the description of materials, for the calculation of pathology prevalence rates, and as a basis for comparative statistical analyses (Buikstra and Ubelaker 1994, Waldron 2009). Initially each skeleton was recorded on a separate Microsoft Excel spreadsheet, however it became apparent that this method would not provide the ability to sort all skeletons together (e.g. sorting by skeletons with a scapula present to determine how many scapulae fractures are present in an assemblage). A new method was therefore employed with all elements from an assemblage recorded on a single spreadsheet (Appendix 2). Each element was recorded as a single unit. Dentition was recorded on a separate pre-designed spreadsheet so that each tooth position could be assigned a score for various conditions (e.g. unerupted, eruption, present, present but damaged, carious lesion, etc.) (Appendix 4). Each assemblage also had a summary spreadsheet where each skeleton was recorded on a separate line with demographic and pathological information that could then be reviewed and sorted more efficiently (Appendix 5).

3.1.2 Preservation

To assess the condition of the skeletal material several measures were employed. Each identified bone had a written description with explanations of the completeness of the bone as well as the amount of post mortem damage. According to guidelines recommended by Byers (2010), each identified bone was also placed into one of three categories based on the completeness and preservation of bone.

Good = Bone surface is in good to excellent condition with little or no post-mortem damage. Surface pathology, if present, would be visible.

Fair = Bone surface is in fair condition. There is some post mortem damage but bone surface pathology, if present, would still be visible.

Poor = Bone surface is in poor to very poor condition. There is widespread post mortem damage. Surface pathology, if present, is unlikely to be visible, but morphological changes such as fractures or congenital conditions probably would be.

Lastly, each skeleton was given a summarized condition value (good, fair, poor) where the average of all skeletal elements was used as well as a visual assessment of the percent of the total skeleton present.

3.1.3 Demography

3.1.3.1 Sex

Humans are moderately sexual dimorphic, which means the females tend to be smaller than the males of any particular population (Frayer and Wolpoff 1985, Ubelaker 1999). Males also tend to be more robust than females in a population with thicker muscles marking, or entheses, on their bones. Other differences between males and females can be demonstrated with the cranial and pelvic bones (Lovell 1989, Phenice 1969, Walker 2005, Ubelaker 1999). Features in the pelvis that are used in the determination of sex are the result of morphological differences relating to childbirth (Lundy 1986). Female pelves are designed for successful delivery of an infant, which results in certain differences from the male pelvis. When comparing females pelves to males, the pubis bone length is medio-laterally longer, the subpubic angle is greater, the subpubic concavity is present, there is a ridge on the ischiopubic ramus (Phenice 1969), the greater sciatic notch is wide (Walker 2005), the preauricular sulcus is usually present, the auricular area is raised and the ventral arch is present (Phenice 1969). The pelvic outlet for females is wide or bowl-shaped, the blade of the ilium is flared and lower, and the sacrum is wide and straight (Buikstra and Ubelaker 1994, Walker 2005, Schroeder et al. 1997).

While the estimation of sex using the pelvis is considered highly accurate, estimates made from the cranium alone are not as accurate but can be useful in conjunction with pelvic bones or solely in the absence of pelvic bones (Ubelaker 1999). Selection pressures on the size and shape of the pelvis are strongly tied to parturition and bipedality, however similar selection pressures on the size and the shape of the skull do not exist (Meindl et al. 1985). This relaxed sexual dimorphism results in less accurate sex estimation based on skull morphology alone, which is estimated at 92% (Williams and Rogers 2006). For female skulls, a nuchal line or crest may be less pronounced, the mastoid process are generally small, the superior margin of the eye orbit is sharp, the supraorbital torus is slight, the chin is rounded and has a midline point, the frontal bone is more vertical (Buikstra and Ubelaker 1994, Williams and Rogers 2006, Duric et al. 2005). “Although males tend to have larger, more robust skulls than females, estimating sex based on cranial features can be a challenging process. Populations vary markedly in this respect” (Buikstra and Ubelaker 1994). Since morphological features vary temporally and spatially, the criteria used need to be appropriate for the skeletal remains reviewed (Brickley 2004b, Maat et al. 2007). For example, because sexual dimorphism tends to be slight in Scottish populations (Bruce et al. 1997, Cross and Bruce 1989, McSweeney 2005), greater weight was placed on skull and pelvic morphology rather than post-cranial metrics.

Without DNA data, there are currently no widely accepted methods for estimating the sex for subadults, since sexual dimorphic features do not manifest themselves until puberty (Bass 1995). While several methods have been proposed, none have a high degree of accuracy (Cox and Mays 2000, Vlak et al. 2008). For this reason, sex estimation was not attempted for subadults in this study.

3.1.4 Sex estimation

3.1.4.1 Morphological assessment

Morphological features in the cranium and pelvis were visually assessed to determine sex. Traits were scored on a scale of 1-5, from most feminine to most masculine (Brickley 2004b). Table 3 lists the morphological traits used to assess sex and Appendix 3 provides an example of a decision table used to estimate sex.

Table 3 Morphological traits used in sex determination

Element	Trait	Scoring System	References
Cranium	Forehead shape Supraorbital ridge Supraorbital margins Nuchal area Mastoid process	Each scored 1-5	Acsádi and Nemeskéri 1970; Buikstra and Ubelaker 1994; Bass 1995
Pelvis	Greater sciatic notch Subpubic angle Subpubic concavity Ventral arc Ischiopubic ramus ridge Preauricular sulcus	Each scored 1-5	Phenice 1969; Buikstra and Ubelaker 1994; Bass 1995

3.1.4.2 Metric assessment

Metrical assessments on postcranial elements were also employed to aid in estimating sex, however for the majority of the time this was only used in conjunction with visual assessment of the pelvis and skull features. This was especially necessary for the individuals in the St Andrews collection. For example, the majority of individuals that were determined to be male based on skull and pelvic morphology had tibial distal breadths that were closer to the mean for females. In these cases, greater weight was placed on skull and pelvic morphology. Methods on post-cranial metrics provided by Bass (1995) were employed in this study (Table 4). A list of all cranial and post-cranial measurements utilized in this study is provided at Appendix 1.

Table 4 Measurements used in sex determination
(after Bass 1995)

Bone	**Measurements**
Sacrum	width 1st body; maximum anterior breadth; sacral index
Scapula	length glenoid cavity
Humerus	max diam head; epicondylar width
Radius	maximum length; radiohumeral index
Pelvis	ischium-pubis index
Femur	diameter head; circumference shaft; bicondylar width
Tibia	proximal breadth; circumference at nutrient foramen; distal breadth

3.1.4.3 Final assessment of sex

Separate assessments of sex were established for the pelvis, cranium, and post-cranial metrics. Each characteristic/element was categorized as female, probable female, male, probable male, or indeterminate. For the final overall assessment of sex, the pelvis was given the greatest weight, then the cranium, and lastly post-cranial metrics. Individuals who were too incomplete or had conflicting pelvic, cranium, and post-cranial metrics were categorized as undetermined.

3.1.5 Age at Death Estimation

Age at death estimation is useful to evaluate health status at an individual or population level. Population structure can provide insights into past lifestyles, such as weaning age, infant mortality, age related disease processes, and life expectancy (Chamberlain 2006). For subadults, age at death is determined from developmental methods, which assess both skeletal and dental development. While genetics predetermines the rate of development, nutrition and disease can influence the rate and timing of growth and maturation (White and Folkens 2005). However, subadult age at death estimations are considered to be highly accurate and can be viewed in narrow ranges. After the skeleton fully matures, developmental methods are no longer useful and instead degenerative methods are employed (Bass 1995). Adult age at death estimations are less precise due to a high level of variation as a result of environmental and genetic factors seen after maturation (O'Connell 2004). Therefore, age ranges for adults are wider than those for subadults.

3.1.5.1 Subadult Age Estimation

For perinates, long bone length was used to assign age in gestational weeks using regression tables adapted from Fazekas and Kosa (1978) and provided by Scheuer and Black (2000). The length of the femur was the preferred method, if it was not present or intact, other long bones were used. If no long bones were intact, the appearance or fusion of other bones was used to estimate age, again ranges provided by Scheuer and Black (2000). In these cases, the basioocciput was used often, since this element was often present and intact.

For older subadults age estimation was assessed with combined methods of dental development and eruption, epiphyseal fusion, and long bone length. If the assessments were contradictory, estimates made from dentition were given the greatest weight since malnutrition and disease can affect long bone length and epiphyseal fusion rates to a greater extent (Brickley 2004c, Cardoso 2007). Table 5 summarizes the methods employed to age subadults.

Table 5 Summary of subadult aging methods

Age Group	Method	Reference
Perinates	Long bone diaphyseal length	Fazekas and Kosa, reproduced in Schaefer et al. 2009, Scheuer and Black 2000
	Cranial and post-cranial ossification	
Infants, juveniles, and adolescents	Dental development and eruption	Ubelaker 1999 Van Beek 1983
	Epiphyseal fusion	Schaefer et al. 2009
	Long bone diaphyseal length	Maresh 1970, reproduced in Schaefer et al. 2009

3.1.5.1.1 Dental Eruption

Humans have two sets of teeth throughout life, deciduous and permanent. The development of both deciduous and permanent teeth can be measured and used to estimate age of individuals under the age of twenty one, since the last tooth forms at that approximate age, although there is some variation up to thirty years of age (Ubelaker 1999, White and Folkens 2005). Dental development is the most accurate method for estimating age (Brickley 2004c, Ubelaker 1999). Since dental development is strongly controlled by genetic factors, environmental factors such as disease do not affect teeth to the same degree as the rest of the skeleton. Sequences of formation and eruption of teeth have been established after compilations of previous studies (Buikstra and Ubelaker 1994, Burns 1999, Folayan et al. 2007, Ubelaker 1999). These sequences are in the form of a dental chart that shows images of teeth from the maxilla and mandible at ages from five months in utero up to thirty-five years. To establish the age of a skeleton, the teeth are examined to see if the tooth is erupted, in complete occlusion, or still developing. Then the teeth are matched up to the dental chart to see which image matches the tooth development accurately (Burns 1999). Dental development does differ for Native Americans, so if the individual is known to be Native American, approximately six months should be subtracted from the age (Tompkins 1996). In this study the chart developed by Ubelaker (1999) was referenced, although not based on European populations, the margins of error are provided allowing for more accuracy (Brickley 2004c). Age estimates were also assessed based on crown and root development according to Van Beek (1983) where teeth were not fixed in the alveolar bone.

3.1.5.1.2 Epiphyseal Fusion

Each epiphysis fuses onto the other segments of bone at regular rates during development (Brickley 2004c, Lundy 1986, Scheuer and Black 2000). The degree of fusion at the epiphyses can be used to estimate age (Scheuer and Black 2000, Webb and Suchey 1985). At first the epiphyses are separate, held into place by a cartilage plate, fusion begins centrally and moves out to the margins, the epiphyses are fused but noticeable lines where fusion occurred are present, and lastly, epiphyses are completely fused with the epiphyseal line obliterated. There is also variation between males and females in the rate of fusion. On average, females mature one to two years before males (Scheuer and Black 2000, Webb and Suchey 1985). Since sex determination is not accurate on subadults, the widest range for both male and female fusion was used. Once the bone is analyzed for the degree of fusion, the phase of development is determined. Each phase corresponds to an age range. Long bone diaphyseal length age estimates are based on the standards of Maresh (1970).

3.1.5.2 Adult Age Estimation

Degenerative changes are used for estimation of age in adults. Degenerative changes can be measured macroscopically or microscopically (Ubelaker 1999). One of the more reliable aging techniques for adults is the assessment of dental attrition (Brothwell 1981, Miles 2001, Scott 1979). In general, teeth that are more worn down come from an older individual and teeth that are not worn at all come from a younger individual (Meindl and Russell 1998). However, according to Ubelaker (1999:92) "attrition rates can vary among populations and individuals because of differences in diet, occlusion, morphology, and even the use of teeth as tools." Enamel, the hardest tissue in the body, does not have collagen, like other bones, which allows for its durability. Since enamel is so hard, it is very resistant to chemical and physical destruction. Under archaeological conditions, even if little remains of a skeleton, the dentition tends to survive well. For this reason, it remains a useful aging method. Brothwell's method for recording dental attrition is widely accepted (Whittaker 2000) and therefore used in this study. When there were discrepancies between dental attrition and the other aging methods, the latter methods held greater weight due to the possible limiting factors mentioned above.

Pubic symphyses are where the two innominate bones that make up the pelvis articulate. The symphyseal face, the surface of articulation on the pubic bone, starts to change in appearance after growth is completed. Changes to the morphology of pubic symphyses provide another means of aging an adult skeleton, however the precision is low and the age ranges are broad (Berg 2008, Buikstra and Ubelaker 1994, Jackes 2005, Meindl and Russell 1998). The Suchey-Brooks system has six phases, the first being the youngest, and the sixth the oldest (Brooks and Suchey 1990). Certain features are concentrated on, such as a ventral rampart, and ridge-and furrow system. Morphological changes on the auricular surface of the ilium are similarly assessed to estimate age (Lovejoy et al. 1985, Meindl and Russell 1998). While the method of Lovejoy et al. (1985) is widely employed, it has similar limitations to the Suchey-Brooks method with low precision and broad age ranges (Murray and Murray 1991). However, when used in conjunction with other methods, both the pubic symphysis and auricular surface methods can aid in age estimation (Bedford et al. 1993, Murray and Murray 1991).

Late fusing epiphyses such as the iliac crest, medial clavicle as well as the fusion of the first and second segments of the sacrum can also aid in estimation of younger adults (Black and Scheuer 1996, Owings Webb and Suchey 1985, Schaefer 2008, Schaefer et al. 2009). Rib ends (specifically the fourth rib) can also be used to estimate age based on the amount of bony changes to the sternal end (Işcan and Loth 1986, Işcan et al. 1984, 1985, Loth et al. 1994). While the method described applies to the fourth rib, Işcan et al. (1984) explain that changes are similar in the third and fifth rib as well. Even so, the third to the fifth ribs are not always distinguishable or present. Histologic analysis allows for the resorption of cancellous bone to be viewed microscopically, as well as changes in the cells of the bone (Ubelaker 1999, Lundy 1986). Microscopic methods are not routinely applied in skeletal analysis due to the destructive nature and the costs involved (Brickley 2004a). Histology was not employed in this study.

In the present study, adults were aged from the assessment of molar attrition (Brothwell 1981); auricular surface morphology (Lovejoy et al. 1985); pubic symphysis morphology (Brooks and Suchey 1990); epiphyseal fusion (medial clavicle, iliac crest, and ischial tuberosity), fusion of the first and second sacral bodies (Schaefer et al. 2009), and changes to the sternal end of the fourth rib (Işcan and Loth 1986, Işcan et al. 1984, 1985).

When no other methods were available, the complete eruption of a third molar, the presence of arthropic changes at joints, or complete fusion of epiphyses were used to broadly categorize a skeleton as an adult (Brickley 2004c, Buikstra and Ubelaker 1994, Rogers et al. 2004, Ubelaker 1999). The skull is made up of 22 bones that fuse together at sutures during an individual's life (Ubelaker 1999, White 2005). The degree of suture closure can be measured and used to estimate age (Meindl and Lovejoy 1985, Meindl and Russell 1998). Since tests of cranial suture closure have been proven inaccurate (Key et al. 1994.), this method was not employed to age adults in this study. Table 6 summarizes the adult aging methods used in this study.

Table 6 Summary of adult aging methods

Area	Method	References
Dentition	Dental (molar) attrition	Brothwell 1981
Pelvis	Public symphysis morphology	Brooks and Suchey 1990
	Auricular surface morphology	Lovejoy et al. 1985
	Fusion of the iliac crest (≥20 yrs)	Schaefer et al. 2009
	Fusion of the ischial tuberosity (≥ 20 yrs)	Schaefer et al. 2009
Clavicle	Fusion of the medial epiphysis (≥25)	Black and Scheuer 1996
Rib	Rib end morphology	Iscan and Loth 1986, Iscan et al. 1984, 1985. Loth et al. 1994
Sacrum	Fusion of the S1-S2 (≥30 yrs)	Schaefer et al. 2009

3.1.5.3 Final assessment of age-at-death

Using the methods outlined above, individuals were assigned to one of eleven categories listed in table 7. All ages are in years unless otherwise specified.

Table 7 Age categories used in this study

Descriptive Category	Age Range
Neonate	Fetal-2 mo
Infant	2 mo-2yr
Young Juvenile	2-6
Old Juvenile	7-12
Adolescent	13-17
Young Adult	18-24
Young Middle Adult	25-35
Middle Adult	36-45
Old Adult	≥46
Adult	≥18
Subadult	< 18

3.1.6 Stature

While genetics provides the potential stature for an individual, other factors such as childhood stress, nutrition, age, and posture, influence whether that potential is achieved (Brickley 2004c, Eveleth and Tanner 1990). Stature can be estimated with quantitative measurements. Stature can be estimated from measurements of the skeleton *in situ* (Petersen 2005), however these measurements were not provided for the study populations. The Fully Method (Fully 1956 *in* Raxter et al. 2006) also relies on measurements of a series of contiguous skeletal elements from the skull to the foot, which in archaeological contexts is rarely possible. Steele and McKern (1969) estimate stature based on fragmentary remains, however due to limitations in accuracy this method should only be used if no other method is possible and stature estimation is necessary (e.g. forensic applications) (Byers 2010). Trotter and Gleser (1952) established the correlation between long limb length and stature and developed regression formulas for each long bone. Measurements of representative bones can be applied to the appropriate formulae for that bone to estimate stature of an individual (Lundy 1986, Trotter and Gleser 1952, 1977). There is variation among different populations with the correlation of body height and limb proportion. Therefore, separate formulae have been developed for different populations. There is also variation between males and females, therefore the formulae are sex specific (Lundy 1986, Trotter and Gleser 1952, 1958, 1977). Brothwell and Zakrzewski (2004) argue that the regression formulae provided by Trotter and Gleser (1952) may not be accurate for all European populations, however since this method is widely applied in archaeology, it is used here for comparability with other populations. For this study, measurements of the length of long bones were taken with an osteometric board. The femur is the most reliable bone to use for stature calculations (Ubelaker 1999); therefore it was used if available. If the femur was not available, the lower leg bones were used next, followed by the humerus and lastly by the lower arm bones.

3.1.7 Non-metric data and muscle markers

Studies of non-metrical traits in Britain have been more common in the past than currently. Within a cemetery, non-metrical traits have been used to suggest family clusters or even potential inbreeding (Brothwell and Zakrzewski 2004). While there have been studies linking certain non-metric traits to chronic stress (Larsen 1997), there has been little research determining whether these links are causative and/or significant (Brothwell and Zakrzewski 2004). Due to constraints on time, no attempts were made to systematically record non-metric traits. It has been estimated that up to a fifth of a population may have the propensity to ossify soft tissues (Waldron 2009), therefore entheseal changes to muscle attachment sites were only recorded if unusually pronounced or indicative of pathology (e.g. DISH).

3.1.8 Documentation and Diagnosis of Pathological Conditions

Many diseases only affect soft tissue, and those that do affect the skeleton are often not distinguishable (Ortner 2003). The distribution of abnormal bone can aid in identifying disease (section 1.2.1). Paleopathological analysis requires the use of standardized definitions and diagnostic criteria to ensure comparability between other researchers. Waldron's (2009) 'operational definitions' have been employed in this study for the majority of conditions. Diagnoses of pathological conditions were also aided by Ortner (2003), Aufderheide and Rodríguez-Martín (1998), Mann and Hunt (2005), and Resnick and Niwayama (1995). Further research was conducted when required. All abnormal bone changes were assigned the following categories: infectious disease, congenital, trauma, metabolic disease, joint disease, and dental disease. Any changes that could not be placed into the previous categories were placed into the broad category of 'other disease.' Originally another category of 'bone formers' (Waldron 2009) was included, however since it was not comparable to the most other research, conditions that would be placed there (e.g. DISH) were placed into other categories. Unless otherwise stated, diseases were recorded on a presence/absence basis.

The following pathologies were placed into the above categories:

- **Infectious Disease:** periostitis, osteomyelitis, syphilis, tuberculosis, septic arthritis, hypertrophic pulmonary arthropathy (HPO)
- **Congenital Disorders:** sacralization, lumbarization, spina bifida, spina bifida occulta, transitional vertebra, chondroectodermal dysplasia, acromegaly, tarsal coalition, acrocephalopolysyndactyly
- **Trauma**: Fractures, spondylolysis, spondylolisthesis, osteochondritis dissecans, dislocations
- **Metabolic Disease**: cribra orbitalia, porotic hyperostosis, osteopenia, osteoporosis, rickets, scurvy
- **Joint Disease**: extraspinal arthropathies, spinal joint disease, ankylosing spondylitis, fused vertebra from OA, Schmorl's nodes, DISH, eDISH, erosive arthropathy
- **Dental disease**: caries, abscesses, hypoplasia, antemortem tooth loss, periodontal disease
- **Other disease:** chondroblastoma, dermoid cyst (teratoma), Legg-Perthes, hydrocephaly, metastatic tumor, button osteoma

The following sections define the conditions considered as well as the diagnostic criteria employed in this study.

3.1.8.1 Infectious Disease

Non-Specific Infections- where a particular infectious disease cannot be inferred

- **Periostitis-** infection and inflammation of the periosteal bone represented by new woven bone formation (active) or lamellar bone (healed) (Waldron 2009). Periosteal new bone formation can occur with other disease processes as well, including traumatic and neoplastic disease (Aufderheide and Rodríguez-Martín 1998). However, in most infections, periosteal bone formation is the most significant characteristic (Ortner 2003), which is why it is included in infectious disease in this study. In cases where another disease process is absent (e.g. neoplastic disease), periostitis is considered a response to an infectious pathogen. The location of the lesion and aspect of the element affected was noted (e.g. distal humerus shaft).

- **Osteomyelitis-** infection of bone and marrow, most often bacterial but can also be viral, fungal, or parasitic (Resnick and Niwayama 1995). The traits of osteomyelitis that aid in diagnosis are the sequestrum, which is a segment of necrotic bone that is separated from the living bone. The involucrum is a layer of living bone that has formed outside of the existing bone. An opening in the involucrum is a cloaca where tissue from the periosteum and pus is released (Resnick and Niwayama 1995).

Specific Infections- where we can infer the particular disease that caused the lesion(s)

- **Tuberculosis-** infectious disease caused by the *Mycobacterium bovis* and *Mycobacterium tuberculosis*. There are two modes of infection, inhalation and ingestion and the bacterium spreads hematogenously from the lungs to other organs; only 3-5% of cases have skeletal involvement (Roberts and Buikstra 2003). The vertebral column, hip, and knee are most common sites of skeletal involvement. The lesions are mainly destructive with little bone regeneration. Collapse of partially destroyed vertebral bodies is common and can lead to severe deformities. Typically an angulated posterior projection appears at the site of maximum involvement leading to kyphosis ('Pott's Disease') (Resnick and Niwayama 1995). Bony ankylosis of vertebral bodies can be associated with fusion of vertebral bodies. Not uncommonly, four to eight vertebrae are coalesced into a large osseous mass, particularly in areas of angular spinal deformity (Resnick and Niwayama 1995). Other diseases that can manifest similar changes and can be mistaken for tuberculosis are: brucellosis, typhoid spine, fungal infections, sarcoidosis, septic arthritis, Paget's disease, ankylosing spondylitis, and rheumatoid arthritis (Ortner 2003).
- **Acquired (Venereal) Syphilis-** chronic infectious disease caused by *Treponema pallidum*. There are two forms, acquired or congenital. Acquired syphilis is transmitted by direct and intimate contact with moist infectious lesions of the skin and mucous membranes (Ortner 2003, Resnick and Niwayama 1995). Infection develops in approximately 25-30% of the sexual

partners of persons with syphilitic lesions (Resnick and Niwayama 1995). Children may even acquire the disease by sharing a bed with an infected person. Three to six weeks after the organism has entered the body, a primary lesion develops at site of inoculation (Resnick and Niwayama 1995). Around six weeks later a generalized skin eruption, known as secondary syphilis develops. The patient can heal from both primary and secondary syphilis and be without symptoms for an extended period of time, called latent syphilis, although the disease will still be progressing in many organs. Ten to thirty years later patients can progress to tertiary syphilis where gummas are evident in almost every organ, particularly the skin and the bones. Fifty percent of patients never progress to tertiary syphilis (Resnick and Niwayama 1995).

- **Congenital syphilis**- chronic infectious disease caused by *Treponema pallidum* that is passed from mother to fetus. Soft tissue changes can occur first, for example, as fissures around the mouth and anus. Bone changes that can occur are collapse of the nasal bones, perforation of the palate, anterior bowing of the lower leg (saber shin) and Hutchinson's teeth (Resnick and Niwayama 1995). Exacerbation of the disease usually occurs between 5-20 years of age and resembles acquired syphilis (Resnick and Niwayama 1995). Dactylitis often occurs with periosteal proliferation and osseous expansion largely confined to the phalanges of the fingers and toes (Resnick and Niwayama 1995). Dactylitis can also occur in sickle cell anemia, tuberculosis, yaws, small pox, and leukemia; however syphilitic dactylitis is bilateral and sometimes symmetrical, whereas in other diseases it may not be (Ortner 2003, Resnick and Niwayama 1995).
- **Septic Arthritis-** bacterial or fungal infection that affects the joints causing arthritis can spread to other bones and joints quickly if untreated and lead to death (Ortner 2003, Resnick and Niwayama 1995). One third of the cases involve the knee and a further third involve the hip joint. The acute and final stages resemble tuberculosis in dry bone, though there is less bone destruction in septic arthritis (Ortner 2003).

- **Hypertrophic Pulmonary Arthropathy (HPO)-** can be primary or secondary in nature (Mays 2002, Ortner 2003, Resnick 2002), in both cases the midshafts of long bones are most affected, though in primary cases the periostitis tends to extend from the epiphyses (Resnick 2002, Rothschild and Rothschild 1998). The skeleton has symmetric periostitis most pronounced in the tibia, fibula, radius, and ulna. Primary cases often have periostitis extending to the epiphyses and bony outgrowths. Outgrowths are common on the ischium, pubic symphysis, acetabulum, and iliac crest (Resnick and Niwayama 1995). Primary HPO is congenital in nature; generally affects prepubescent subadults while secondary HPO affects older individuals suffering from chronic respiratory infections (Aufderheide and Rodríguez-Martín 1998, Mays 2002). Tuberculosis is often the main cause of HPO in archaeological populations (Mays 2002, Ortner 2003, Rothschild 1998). Other causes are intrathoracic diseases and pulmonary infections due to air pollutants; in modern populations HPO is commonly associated with lung cancer and emphysema (Mays 2002, Resnick 2002).

3.1.8.2 Congenital Disorders

- **Spina Bifida**- spina bifida cystica occurs when the neural arches in the vertebra fail to unite in the midline and a portion of the spinal cord herniates outward through the opening (meningomyelocele) (Waldron 2009). Depending on the location of the meningomyelocele, it can have drastic affects including paraplegia, hydrocephaly, and even death. Conversely, spina bifida occulta is when there is a cleft in the vertebra with no neural tube defect. The frequency of this condition in a given population is as high as 25%, usually in L5 or S1; therefore it should be considered a normal variant and not an abnormality (Barnes 1994). Spina bifida occulta can also result from a neural tube defect as well, an example when the entire dorsal plate of the sacrum fails to fuse (Barnes 1994). The width of the spinal canal and whether the edges are raised help to diagnose whether the neural tube is affected. The term *spina bifida* should only be used if it is severe with neurologic consequences. The sacral hiatus, which affects the third to fifth sacral vertebra, should not be confused with *spina bifida occulta* (Barnes 1994, Waldron 2009).

- **Other Spinal Anomalies**- Transitional vertebra occurs when there is a variation in the number of regional vertebra and there is a cranial or caudal border shift (depending on direction). Transitional vertebra takes on the characteristics of the adjacent vertebra in the neighboring region (Barnes 1994). Lumbarization is when the first sacral vertebra takes on the appearance of a lumbar vertebra; likewise sacralization is when the fifth lumbar takes on the appearance of a sacral vertebra (Barnes 1994).
- **Tarsal coalition**- an osseous coalition of tarsal bones, most commonly located in the calcaneonavicular, talocalcaneal, and talonavicular areas. Tarsal coalitions can result in chronic hindfoot pain (Percy and Mann 1988). The condition may be isolated or part of other syndromes such as Apert's syndrome (see below) (Aufderheide and Rodríguez-Martín 1998).
- **Hydrocephaly**- an abnormal accumulation of fluid in the skull. Without proper surgical treatment, 50% of children affected die in the first five years of life. Twenty-five percent of cases are congenital, while other cases are from trauma, infections, or tumors (Aufderheide and Rodríguez-Martín 1998).
- **Chondroectodermal dysplasia**- a short limbed dwarfism characteristic of short stature, acromelic (distal shortening of limbs), polydactyly, hypoplastic ilia, shortening of the tubular bones (especially the phalanges), carpal fusion, and fibular shortening (Resnick and Niwayama 1995). Acromesomelic dwarfism presents with tibiae, fibulae, radii, and ulnae are shortened compared to the more normal length of the femora and humeri (Aufderheide and Rodríguez-Martín 1998). Death in childhood due to cardiac and pulmonary complications is common. The skull and spine are unaffected, however dentition is often hypoplastic (Aufderheide and Rodríguez-Martín 1998).

- **Acrocephalopolysyndactyly-** known as Apert's syndrome. A hereditary disease with coronal synostosis at birth, hydrocephaly, delayed dental eruption, syndactyly in the hand and foot, possibly bone ankylosis, shortening of the upper limbs, and carpal or tarsal coalition are possible characteristics of this condition (Aufderheide and Rodríguez-Martín 1998).
- **Acromegaly-** a pituitary disturbance resulting in an excess production of thyroxine by the thyroid. Acromegaly is the result of an acidophilic adenoma of the pituitary occurring as an adult (Ortner 2003). Changes include elongation of the mandible, elongation of ribs, enlarged tufts on phalanges, and unusually large size of skull and post-cranial bones compared with the rest of the given population (Ortner 2003).

3.1.8.3 Trauma

Roberts and Manchester (2007) define trauma as any bodily injury or wound. While in archaeological remains, fractures are the most frequent form of trauma found (Waldron 2009), dislocations, disruption in nerve or blood flow, and abnormal shaping of a bone are all forms of trauma (Ortner 2003). The timing of when the trauma occurred is important to record as well. Antemortem trauma occurs during life, perimortem trauma occurs at or around the time of death, while postmortem trauma occurs after death. Separating out postmortem damage is crucial to accurately describe prevalence of trauma in past populations (Ortner 2003, Waldron 2009).

- **Fractures-** a break that goes completely through the bone. Infraction is when a break occurs, but there is no complete separation (Ortner 2003). Both partial and complete separation of bone is considered a fracture in this study. "Fracture most often is the result of abnormal stress applied to one or more bones. This stress can be dynamic, meaning sudden high stress, or it can be static in which the stress is low initially but gradually increases until the break occurs" (Ortner 2003:120). The repair process begins immediately when blood flows into the fractured area to form a hematoma, or bloody mass that seals off the blood vessels. The periosteum is usually torn where the fracture occurred, which stimulates its osteogenic layer to begin forming a callus, or fracture repair tissue

(White 2005). The callus first consists of fibrous connective tissue that bridges the broken bone surfaces, tying them together. Once the osteoblasts respond, the callus is mineralized and forms bone. This process takes around six weeks (White 2005). A previous fracture is evident with the presence of a callus, or with obvious disruption to the normal bone contour if the callus has been remodeled. However, in some cases fractures can only be noticeable through radiograph analysis. Radiography was not available for this study.

There are several types of stress that each affects the bone in different ways. These types of stress are tension, compression, torsion, bending, and shearing (Lovell 1997). Many fractures are the result of more than one type of stress. Once a callus forms, the type of stress that caused the fracture is usually not identifiable (Ortner 2003). If the fracture is perimortem trauma, at the time of death, then the type of stress may be identified and helpful in determining the cause of death.

- **Dislocation**- occurs when there is complete loss of contact between two osseous surfaces that normally articulate (Resnick and Niwayama 1995). A subluxation represents a partial loss of this contact. A closed subluxation or dislocation exists when the skin and soft tissues remain intact over the injured joint; an open one exists if there is an associated soft tissue injury that exposes the joint to the outside environment. A diastasis is an abnormal separation of a joint that normally is only slightly moveable like the tibiofibular syndesmosis or the sacroiliac joint. In these cases the joint capsule and protective ligaments have been damaged (Resnick and Niwayama 1995).
- **Spondylolysis**- ossification union failure of the pars interarticularis of the vertebra resulting in the separation of the vertebra into two parts, a ventral and dorsal part. Age and microtrauma are possible causes; however an underlying congenital malformation could predispose an individual towards this condition (Aufderheide and Rodríguez-Martín 1998).
- **Spondylolisthesis**- a consequence of spondylolysis with anterior slippage of the superior vertebra on the inferior one. Usually occurs on the fifth lumbar, but has also been observed in the third and fourth lumbar as well (Aufderheide and

Rodríguez-Martín 1998). It may be due to arthropathy of the facet joints, trauma, or defects of the pars interarticularis. Acute fractures of the pars interarticularis are always secondary to severe trauma, usually that relate to a hyperextension injury (Resnick and Niwayama 1995).

- **Osteochondritis dissecans (OD)**- indicates fragmentation and possible separation of a portion of the articular surface. It can be caused by direct trauma or repetitive microtrauma (Waldron 2009). OD occurs in adolescence most frequently. While trauma is undeniable in most locations, a family history of OD of the knee is evident in some cases (Resnick and Niwayama 1995). The medial femoral condyle is affected most commonly, but other joints also affected are elbow, ankle, hip, shoulder, and wrist (Waldron 2009).

3.1.8.4 Metabolic

Metabolic diseases are disturbances to bone caused by either dietary or hormonal imbalances (Ortner 2003).

- **Cribra orbitalia-** pitting on the superior wall of the orbit from an expansion in hematopoietic bone marrow due to iron deficiency (Ortner 2003). Lesions are primarily bilateral and are most often found in infants and younger children; however healed lesions can still be present in adulthood (Aufderheide and Rodríguez-Martín 1998). Iron depletion occurs either as a result of a deficiency in the diet, chronic diarrhea, blood loss, or parasitic infection (Larsen 2000).

- **Porotic Hyperostosis-** similar to cribra orbitalia, expansion of hematopoietic bone marrow is seen in diploe enlargement at the expense of the outer table (Ortner 2003). Cranial lesions most often involve the frontal and parietal bones (Aufderheide and Rodríguez-Martín 1998). Lesions tend to develop in infancy; however healed lesions can still be present in adults. Stuart-Macadam and Kent (1992) argue that porotic hyperostosis should be considered an adaptive response to bacteria, whereas Roberts and Manchester (2007) argue it is maladaptive since there is an increase in mortality in individuals with lesions of related cribra orbitalia.

- **Osteopenia and Osteoporosis-** generalized, regional, or localized loss of bone density (Resnick and Niwayama 1995). Osteopenia occurs when bone resorption exceeds bone formation regardless of the specific pathogenesis. The term *osteopenia* refers to a translucency in radiographs, however in this study is identified by relatively light bones. Osteoporosis is established when the decrease in bone mass is greater than expected for a person of a given age, sex, and race which then results in fractures. Fractures are most often found in the spine, proximal femur, and distal radius. Women are affected more than men. Osteoporosis most commonly is related to postmenopause. Back pain and lack of height due to vertebral compression and increased thoracic kyphosis is often apparent (Resnick and Niwayama 1995). Definite diagnoses of osteopenia are difficult in analysis of archaeological bone since post mortem damage can also destroy trabecular bone resulting in relatively light bones (Weaver 1998). In this study, relatively light bones are identified as probable osteopenia whereas individuals with relatively light bones that also have one or more fractures are diagnosed with osteoporosis.
- **Rickets**- an interruption in orderly development and mineralization of the growth plate (Resnick and Niwayama 1995). Rickets is caused by vitamin D deficiency, either from diet, lack of ultraviolet light exposure, or disrupted absorption (Aufderheide and Rodríguez-Martín 1998, Ortner 2003, Resnick and Niwayama 1995). The long bones show the greatest deformity due to the effects of weight-bearing, both at the cartilage-shaft junctions and in the diaphyses (Resnick and Niwayama 1995). The stress of the bones leads to the bowing often from sitting with the legs crossed. The weight bearing effects often lead to scoliosis and a decrease in height with the appearance of dwarfing (Resnick and Niwayama 1995).

3.1.8.5 Joint Disease

Degenerative joint disease and osteoarthritis are included in the broad category of ‘arthropathy’ in this study. Arthropathies out-with the spine are referred to as *extra-spinal arthropathies*. Spinal joint disease is considered separately.

- **Extra-Spinal Arthropathies-** chronic and progressive condition characterized by the loss of joint cartilage and the subsequent lesions from direct bone on bone contact. Features include bone loss of cartilage, bone remodeling most often with osteophytes, bony sclerosis evident with porosity and pitting of bone, and eburnation (smooth, shiny and polished surface from bone-to-bone contact) (Aufderheide and Rodríguez-Martín 1998).
- **Spinal Joint Disease-** alterations produced by intervertebral disk degeneration, spinal osteophytosis, spinal ligament disturbances and degenerative joint disease of the articular facets (Aufderheide and Rodríguez-Martín 1998). Cervical, thoracic, and lumbar alterations are considered separately in this study to allow for prevalence of disease by region of the spine.
- **Schmorl's nodes**- lesions in the intervertebral surface of the vertebra from herniation of the vertebral disk (Aufderheide and Rodríguez-Martín 1998). Lesions form from the pressure of the herniated material that causes resorption of bone (Ortner 2003). In this study Schmorl's nodes are recorded as presence or absence on each vertebral body present.
- **Ankylosing Spondylitis (AS)**- a chronic inflammatory disorder of unknown cause that predominantly affects the axial skeleton (Resnick and Niwayama 1995). Alterations occur in synovial and cartilaginous joints and in sites of tendon and ligament attachment to bone. Erosions and bony ankylosis are common, particularly in the spine where spinal fusion with no skip lesions is present (Waldron 2009). Bilateral and symmetrical sacroiliitis (fusion of the sacroiliac joint) is also common. HLA antigen related genetic causes appear to be the cause. AS is often misdiagnosed as DISH.
- **Diffuse Idiopathic Skeletal Hyperostosis (DISH)-** ossification of the anterior longitudinal ligament (located on the right side of the vertebrae), which often resembles melted candle wax (Aufderheide and Rodríguez-Martín 1998, Resnick and Niwayama 1995, Waldron 2009). For a diagnosis of DISH, the spine must have at least four contiguous thoracic vertebral bodies affected (Waldron 2009). This disorder affects the middle-aged and elderly, though the disorder probably starts earlier and takes a long time to develop. Clinical symptoms include

backache, stiffness, reduced mobility, and tendinitis (Resnick and Niwayama 1995). Extra-spinal ossification of other ligaments is also common; therefore pain in ankles, elbows, knees, and hips is common. Hyperostosis can occur at other ligament attachment sites such as the pelvis, trochanters, calcaneus, olecranon, and patella. The cause is unknown but may be related to diabetes mellitus and an increased level of serum uric acid and growth hormones (IGF-I) (Waldron 2009). Obesity is common in DISH patients. Differential diagnosis could be hypoparathyroidism, fluorosis, or ankylosing spondylitis (Resnick and Niwayama 1995). If fewer than four contiguous vertebrae are fused and ossification of extra-spinal entheses and ligaments is present eDISH (early or incipient DISH) is diagnosed in this study.

- **Scheuermann's Disease (juvenile kyphosis)-** pathologic aberrations in the region of the growth areas between the vertebral bodies and the ring-like epiphyses, analogous with Schmorl's nodes (Ortner 2003, Resnick and Niwayama 1995). Between one and five vertebrae can be affected and will often have a wedging of five degrees or more. The degree of thoracic kyphosis is variable. Most affected are males between 13-17 years old and many cases are asymptomatic (Resnick and Niwayama 1995). Other symptoms are fatigue and pain at affected sites. The etiology could be hereditary in nature.
- **Psoriatic Arthritis**- a seronegative spondyloarthropathy associated with the chronic autoimmune skin disease psoriasis (Ortner 2003, Waldron 2009). Features of this condition are asymmetric articular cartilage destruction, erosions dips of the hands and feet, sacroiliitis, spinal fusion with skip lesions, and bony erosion with adjacent proliferation (Waldron 2009). It is likely to result from a genetic predisposition for the disease in which an infectious agent triggers an autoimmune response (Ortner 2003). There is also a link with HLA-B27 (Waldron 2009). Differential diagnoses include ankylosing spondylitis, and Reiter's syndrome (Resnick and Niwayama 1995).

3.1.8.6 Dental Disease

A separate dentition chart was recorded for each individual with dentition present (Appendix 4).

For each tooth a status was first recorded on either an adult or deciduous dental chart:

0. Not know/unclear
1. Unerupted
2. Erupting
3. Present
4. Present but damaged
5. Missing post mortem
6. Missing ante mortem
7. Congenitally absent

a. Dental abscess
c. Carious lesion
h. Socket healing

- **Dental Caries-** progressive demineralization of the enamel, dentine and cement caused by acids formed during the fermentation of carbohydrates by plaque bacteria (Hillson 2005). Carious lesions were assigned a location on the tooth:

    1. occlusal
    2. interproximal
    3. buccal/labial or lingual
    4. cervical
    5. gross

    According to guidelines presented by Waldron (2009), dental caries were presented in two ways, the number of dental caries as a proportion of the teeth present, as well as the number of individuals with dental caries as a proportion of the population. The majority of skeletal reports that were compared in this study contained only the number of individuals with dental caries rather than the number of teeth with carious lesions.

- **Dental Abscess-** a fistula or broad pit around the root apex, also called periapical lesion (Hillson 1996, 2005). In this study the tooth socket location was recorded. According to Waldron (2009), dental abscesses should be reported as number of individuals in whom they are present as a proportion of the total number of individuals with teeth present. The number of dental abscesses as a proportion of the tooth sockets present was also recorded, however the majority of skeletal reports did not present their data this way, and therefore were compared by individual and not by tooth socket.

- **Antemortem Tooth Loss** – tooth loss during life indicated by a remodeled or remodeling tooth crypt (Waldron 2009)

- **Dental Enamel Hypoplasia-** a deficiency in enamel thickness of the crown, which is normally smooth, white, and translucent (Hillson 1996). Since enamel hypoplasia can be caused from multiple factors including infectious disease, under and over nutrition, and hormonal changes (Goodman and Armelagos 1985b) it has been included in the broader category of dental disease rather than metabolic disease. Which teeth had enamel hypoplasia was recorded as was the type of defect (Hillson 1996):

  1. Linear horizontal grooves
  2. Linear vertical grooves
  3. Linear horizontal pits
  4. Nonlinear pits
  5. Single pits

  Enamel hypoplasia was recorded as a proportion of teeth present, as well as a proportion of individuals present. Nearly all studies used for comparison reported dental hypoplasia as a proportion of the individuals present; therefore that is what is compared in this study. The recording of the location of enamel hypoplasia on each tooth to establish the age at which the insult occurred was conducted for this research. However, the majority of reports on other populations did not contain this information and so this could not be used for comparative purposes.

- **Calculus-** the mineralization of plaque deposits on the tooth that can loosen after burial and often becomes detached (Waldron 2009). In view of this, prevalence rates will not likely represent deposits present during life and is therefore not included in this study.

3.1.8.7 Miscellaneous Pathological Conditions

- **Legg- Calvé-Perthes**- a condition that affects children between the age of two and twelve and rarely older adolescents (Resnick and Niwayama 1995). This condition generally affects males more than females. According to Waldron (2009), the disease passes through four stages: 1) the onset of avascular necrosis, 2) fragmentation of the femoral head, 3) revascularization and regeneration, and 4) healing. While the condition occurs in children, residual changes are often visible in healed adults, such as: a smooth flattening of the femoral head that resembles a mushroom cap, an enlarged femoral head, a shallow acetabulum, and a shortening and widening of the femoral neck (Waldron 2009). Either hip can be affected; if both are altered one hip is affected first, and then the other hip, however they are generally not affected simultaneously. Bilateral symmetric fragmentation of the capital femoral epiphyses could suggest other diseases such as hypothyroidism and epiphyseal dysplasias that affect the hip (Resnick and Niwayama 1995). The cause of the condition is a deficiency of blood supply but aetiology is debateable; potential reasons are genetic or trauma. Bilateral femoral head necrosis is more often seen in sickle cell anemia, Gaucher's disease and in multiple epiphyseal and spondyloepiphyseal dysplasias (Resnick and Niwayama 1995).

- **Dermoid Cyst-** a cystic form of teratoma. Teratomas are tumors containing structures composed of all three germ layers (endoterm, mesoderm, and ectoderm) (Aufderheide and Rodríguez-Martín 1998). If dermoid cysts are found outwith the ovary, they are malignant, however if found within the ovary they are benign (Aufderheide and Rodríguez-Martín 1998). The dermal elements may produce hair and calcified masses that resemble malformed teeth (Aufderheide and Rodríguez-Martín 1998).
- **Chondroblastoma-** uncommon, benign, cartilaginous neoplasm originating in bone (Resnick and Niwayama 1995). It mainly occurs in adolescents and young adults, with a predominance for males (Ortner 2003, Resnick and Niwayama 1995). The tumor occurs in the long bones, and most often in the epiphyses. The most frequent sites of involvement are the femur, humerus, and tibia (Resnick and Niwayama 1995). The tumor is lytic, usually several centimeters in diameter, and can extend into the adjacent metaphysis (Ortner 2003).
- **Meningioma-** tumors arising from the meninges in the skull. Can produce either lytic or blastic lesions (Ortner 2003). Meningiomas can project from

the inner through to the outer table of the skull, similar to an osteosarcoma. Can be asymptomatic or symptomatic (Resnick and Niwayama 1995).

- **Metastatic tumor**- a tumor that has spread from a primary location through the bloodstream. Metastatic carcinoma can be expressed with both blastic or lytic lesions, and occasionally a mixture of both (Ortner 2003, Tkocz and Bierring 1984). The majority of metastatic bone tumors involve more than one bone (Ortner 2003). Cancer metastasis to bone from other organs is the most common cause of tumors (Ortner 2003).
- **Osteoma**- benign lesions usually arise from membranous bones and are comprised of dense, compact osseous tissue (Resnick and Niwayama 1995). The most common lesion is the button osteoma of the cranial vault (Ortner 2003). Lesions are not more than two centimeters in maximal diameter and are found in at least 1% of all autopsies (Ortner 2003).
- **Hyperostosis frontalis interna**- hyperostosis in the inner table of the frontal squama. Thickening of the internal table can be bilateral or unilateral. The condition is found most often in older women. It is possible the individual could have headaches, hypertension, and depression (Resnick and Niwayama 1995). However, Waldron (2009) argues it is generally asymptomatic. It should not be confused with Paget's disease or acromegaly. The etiology is unknown, but is suggested to be related to an endocrine imbalance (Aufderheide and Rodríguez-Martín 1998, Mann and Hunt 2005).

3.1.9 Isotope Analysis

Isotope tests including ^{13}C, ^{14}C, ^{15}N, ^{88}Sr, and ^{18}O were performed on five skeletons from the Isle of May; 155, 814, 859, 972, 997. All tests including collagen and enamel extraction were performed by Scottish Universities Environmental Research Centre, laboratory code SUERC-38050 (GU26087). Details on methods used on stable isotope analysis will not be reviewed here, instead questions should be referred to SUERC.

Strontium ($^{87}Sr/^{86}Sr$) and oxygen ($^{18}O/^{16}O$) are fixed in tooth enamel at the time of tooth formation. Strontium comes from the underlying soil and bedrock and when plant foods are ingested, the strontium is then fixed in the tooth enamel (Lamb et al.

2012, Schoeninger 1995). The 'signature' retained in the tooth enamel reveals where an individual resided during their childhood (Bentley et al. 2004, Budd et al. 2004, Evans et al. 2010, Evans et al. 2012, Lamb et al. 2012). $\delta^{18}O$ (the ratio of ^{18}O to ^{16}O) in tooth enamel reflects the isotopic value of available meteoric water. Water from around the world varies in $\delta^{18}O$, therefore $\delta^{18}O$ values from an individual can aid in determining where the water they drank came from, and in turn where they originated (Budd et al. 2004, Evans et al. 2010, 2012, Lamb et al. 2012, Müldner et al. 2011). For this thesis, maps were used from Evans et al. (2010) that illustrates biosphere strontium isotope variation across Britain (Figure 18) and Darling et al. (2003) that shows variances of oxygen in UK water (Figure 19).

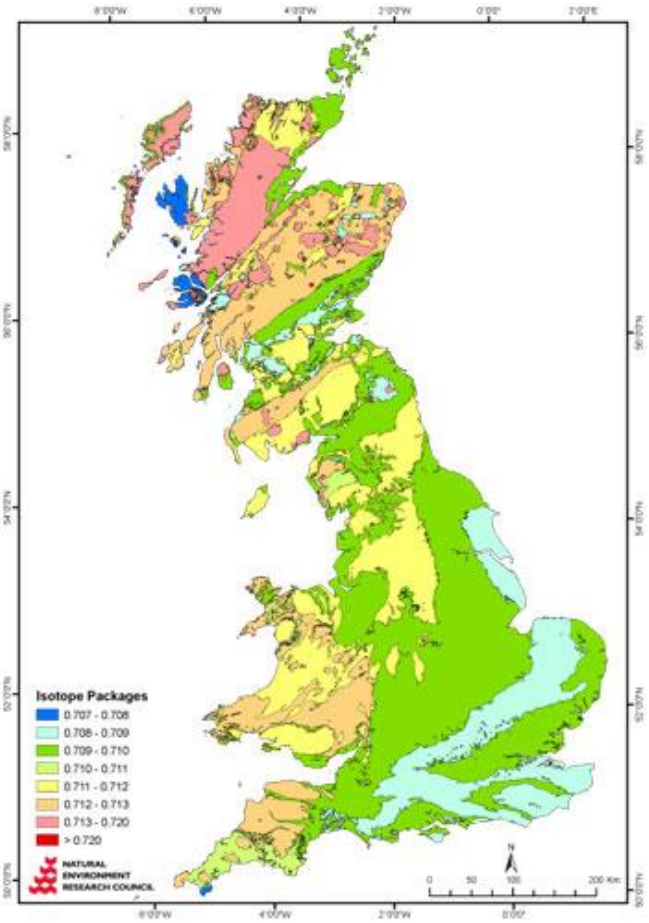


Figure 18 $^{87}Sr/^{86}Sr$ biosphere map
(from Evans et al. 2010)

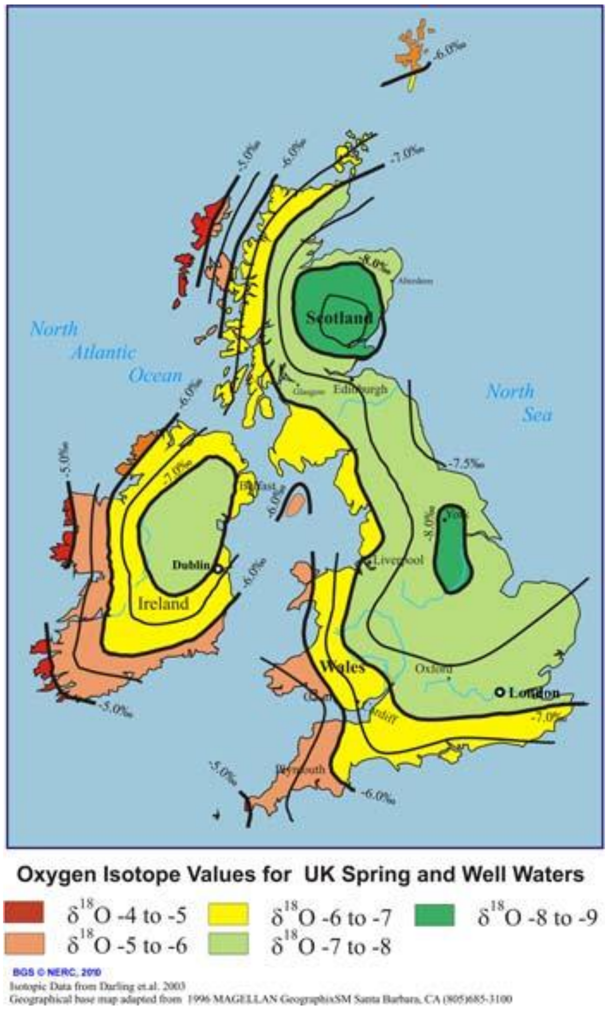


Figure 19 δ^{18}O Map

Compiled from Darling et al. 2003

Carbon (^{13}C/^{12}C) and nitrogen (^{15}N/^{14}N) analyses were also performed for paleodietary reconstruction. δ^{13}C and δ^{15}N essentially reflect where the protein ingested by that individual came from, whether from terrestrial, freshwater, or marine resources (Mays 2000, Kellner and Schoeninger 2007, Schoeninger 1995). The ratio of ^{13}C to ^{12}C in plants varies with their photosynthetic pathway (C_3 or C_4); this ratio (δ^{13}C) is passed up the food chain to consumers. δ^{13}C values in human bone collagen can therefore be used to determine the main plant foods (C_3 or C_4) being consumed by herbivores and humans (Budd et al. 2004, Katzenberg 2008, Mays 2000, Schoeninger 1995). In northwest Europe δ^{13}C values of c. -20‰ indicate that an individual received the majority of their protein from a diet based on C_3 plants (e.g. most cereal crops and vegetables) and their consumers such as cattle, sheep, pigs (Kellner and Schoeninger 2007, Schoeninger 1995). On the other end of the scale, $\delta^{13}C$ values that are c. -12‰ suggest a diet based on C_4 plants (e.g. millet, sugarcane and maize) (Kellner and Schoeninger 2007).

$\delta^{15}N$ values increase by 3-5‰ at each trophic level within a food chain (Cook et al. 2001, Kellner and Schoeninger 2007). $\delta^{15}N$ values of diets based on marine resources are generally higher than those of terrestrial diets. Therefore, an individual with a solely marine diet could have a $\delta^{15}N$ value of up to 20‰ (Schoeninger et al. 1983), while $\delta^{15}N$ values around 7-9‰ would indicate a predominantly terrestrial diet. One caveat is that low trophic level marine species (e.g. shellfish such as mussels and oysters) can mimic terrestrial values (Cook et al. 2001).

Combining C and N isotope data helps to differentiate between terrestrial and marine diets. Higher $\delta^{13}C$ but with 'terrestrial' $\delta^{15}N$ values may suggest consumption of C_4 plants (Schoeninger et al. 1983); higher $\delta^{13}C$ and $\delta^{15}N$ values are more likely to indicate marine resource consumption (Kellner and Schoeninger 2007, Schoeninger 1995). If only $\delta^{15}N$ is elevated, consumption of freshwater resources and/or omnivores (i.e. pigs) is suggested. Using linear mixing models can help estimate the percentage of marine resources in each individual's diet. The theoretical endpoints used here were: -21.5 for a diet of 0% marine resources, and -12.5 for a diet of 100% marine resources (Cook et al. 2001, Fischer et al. 2007, Richards et al. 2006). Linear mixing models for carbon assume that all marine resources have very similar $\delta^{13}C$ values, which does depend on the type of resources consumed.

3.1.10 Statistical Analysis

In this study, choice of statistical tests was based on guidelines presented by Mays et al. (2004). Both crude and true prevalence rates are employed (Waldron 1994) (see section 1.2.2.2). The chi-square test was used to test for differences in the paleopathological prevalence rates both between the four study populations, and between the age and sex categories within each population. Chi-square tests were also employed to test for differences in pathology prevalence rates in different burial locations, and also for differences between preservation between the populations. If counts were less than five in any category, the results were not included to prevent bias in small sample sizes (Fletcher and Lock 1994). The level of significance was set at 5%, a p-value less than 0.05 indicates a 95% probability that any difference between samples is not due to chance. For statistical accuracy, chi square tests that examined relationships between disease, age at death, and sex were only carried out on skeletons that could be sexed or aged. Therefore skeletons placed into the categories of undetermined adults, unsexed non-adults, or into the general age category of adult, were not included in the above tests. A one-way ANOVA was performed to test the differences between stature for males in the four study populations and also for females. Bivariate correlations were also employed to test for correlations in the data (e.g. correlation between the rates of dental caries per tooth in urban locations). An independent-samples t-test was conducted to compare the diet between two groups at Ballumbie. All tests were performed with the statistical package SPSS version 19.

3.1.11 Comparisons with other Medieval populations

A compilation of disease prevalence rates for twenty-three other medieval Scottish populations was also created to provide contextualized comparisons of health within rural, urban, monastic, and lay environments. Scottish populations used for comparisons were chosen if there were more than eight articulated inhumations in the sample size. In excavations where there are multiple time periods present, if the medieval burials could be separated out, the remainder of the inhumations were not included here. Excavations at the Holy Trinity Church in St Andrews produced two excavations; Logies Lane in 1991 and St Andrews Library in 2003 (this study). The urban Carmelite friary at Aberdeen on the Green, with monastic and lay burials dating from the fourteenth to seventeenth centuries, was excavated twice, in 1980 and 1994. The report by Cardy (unpublished) combines results from both excavations, which is used in this study. The lay cemetery in urban Dunbar dating from the ninth to the thirteenth centuries also produced two excavations, Castle Park in 1993 and Captain's Cabin in 1998. For Castle Park, the burials from the layers DB09 and DB10 will be used here. Period II-IV of Jedburgh Abbey represent the twelfth to sixteenth centuries of an urban monastic assemblage. Focusing only on the monastic burials at Jedburgh Abbey allows for a better comparison with other heavily monastic sites like the Isle of May. Since methods vary between the sites compared here, only data recorded with similar methods were included. Skeletal reports present data with prevalence rates and generally do not include raw data, therefore chi-square tests were not used in comparisons with inhumations not analyzed by the author. Table 8 lists all the populations used for comparison in this study as well as the reference to the skeletal reports. Appendix 10 provides a map of all Scottish medieval sites used to contextualize discussions and Appendix 12 provides more information on the compiled sites.

Table 8 Scottish sites used for comparative purposes

Study populations are in red.

Site Name	Date cents. AD	Sample Size	Location	Reference
Ballumbie	**6th-17th**	**197**	**Rural, Angus**	**This Study**
Isle of May	**5th-16th**	**58**	**Island, Forth River**	**This Study**
St Andrews Library	**15th-16th**	**72**	**Urban, St Andrews**	**This Study**
Whitefriars	**14th-17th**	**58**	**Urban, Perth**	**This Study**
Kinnoull Street	13th-16th	23	Urban, Perth	Bruce 1995
St. John's Kirk	12th-16th	33	Urban, Perth	Roberts 2005
Horse Cross	12th-16th	10	Urban, Perth	Roberts 2007
Dundee City Churches	12th-15th	35	Urban, Dundee	Roberts 2000
Kirk Ness	12th-17th	24	Urban, North Berwick	Henderson unpublished
The Hirsel	11th-13th	331	Rural, Berwickshire	Anderson 2014
Whithorn (Period V)	13th-15th	1605	Urban, Galloway	Cardy 1997a
Chapelhall	10th	8	Rural, Argyll	Roberts 2000b.
St. Mary's Church, Kirkhill	5th-12th	282	Urban, St Andrews	Bruce 1997
Logies Lane	15th-16th	121	Urban, St Andrews	Cardy 1997b
Hallow Hill	6th-9th	145	Rural, Fife	Young 1996
Aberdeen on the Green (both excavations)	14th-17th	193	Urban, Aberdeen	Cardy unpublished
St. Nicholas Church (Phase A)	12th-15th	478	Urban, Aberdeen	Duffy unpublished
Castle Park, Dunbar	Early Christian-13th	27	Urban, East Lothian	Bruce 2000
Captain's Cabin, Dunbar	9th-11th	76	Urban, East Lothian	Roberts 2001
Longniddry, Four Winds	5th-8th	8	Rural, East Lothian	Lorimer 1992
Linlithgow	13th-17th	201	Urban, Linlithgow	Cross and Bruce 1989
Isle of Ensay	16th-19th	416	Island, Hebrides	Miles 1989
Glasgow Cathedral	14th-19th	79	Urban, Glasgow	King 2002
St. Giles (Period 2)	12th-14th	78	Urban, Edinburgh	Henderson 2006
St. Trolla's Chapel	11th-17th	13	Rural, Sutherland	Roberts 2003
Jedburgh (Period II-IV)	12th-16th	23	Urban, Jedburgh	Grove 1995
Auldhame	7th-17th	242	Rural, East Lothian	Melikian and Ives forthcoming

4. Results

4.1 Ballumbie

4.1.1 Age at death

Of the 197 articulated skeletons in the Ballumbie assemblage the age breakdown is as follows: four infants (2%), five young juveniles (2.5%), 12 old juveniles (6.1%), 15 adolescents (7.6%), 17 young adults (8.6%), 39 young middle adults (19.8%), 44 middle adults (22.3%), and 26 old adults (13.2%). Thirty-five skeletons cannot be aged specifically, and are placed into the broad category of adult. Comparing adults to non-adults; 82% of the assemblage are adults (aged 18 and over) and 18% are non-adults (aged 17 and younger) (Table 9; Figure 20).

Table 9 Ballumbie age at death

Category	Age Range	n	Percentage
Neonate	0-2 mo	0	0
Infant	2 mo-2yr	4	2.0
Young Juvenile	2-6	5	2.5
Old Juvenile	7-12	12	6.1
Adolescent	13-17	15	7.6
Young Adult	18-24	17	8.6
Young Middle Adult	25-34	39	19.8
Middle Adult	35-44	44	22.3
Old Adult	45+	26	13.2
Adult	18+	35	17.8

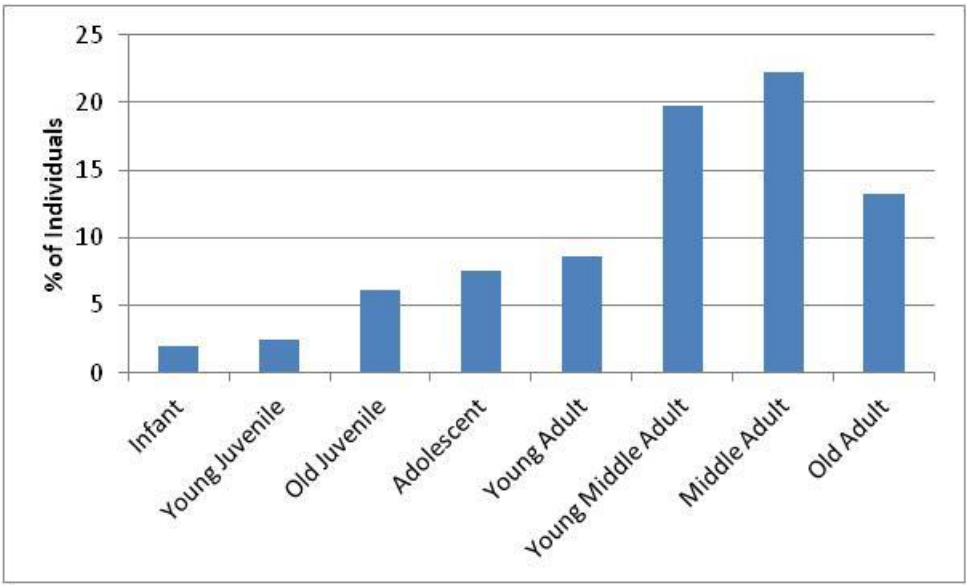


Figure 20 Ballumbie age at death profile

4.1.2 Sex

In the Ballumbie assemblage 147 of the 169 adult skeletons could be sexed. There are 61 males, nine probable males, 61 females, and 16 probable females. The biological sex for 22 adult skeletons could not be determined, and 28 are unsexed non-adults. Males and probable males make up 41% of the population, females and probable females 45%, undetermined adults 13%. Among the 147 sexed skeletons, males make up 48% and females 52%. Therefore the male to female ratio is 0.91:1 (Table 10; Figure 21).

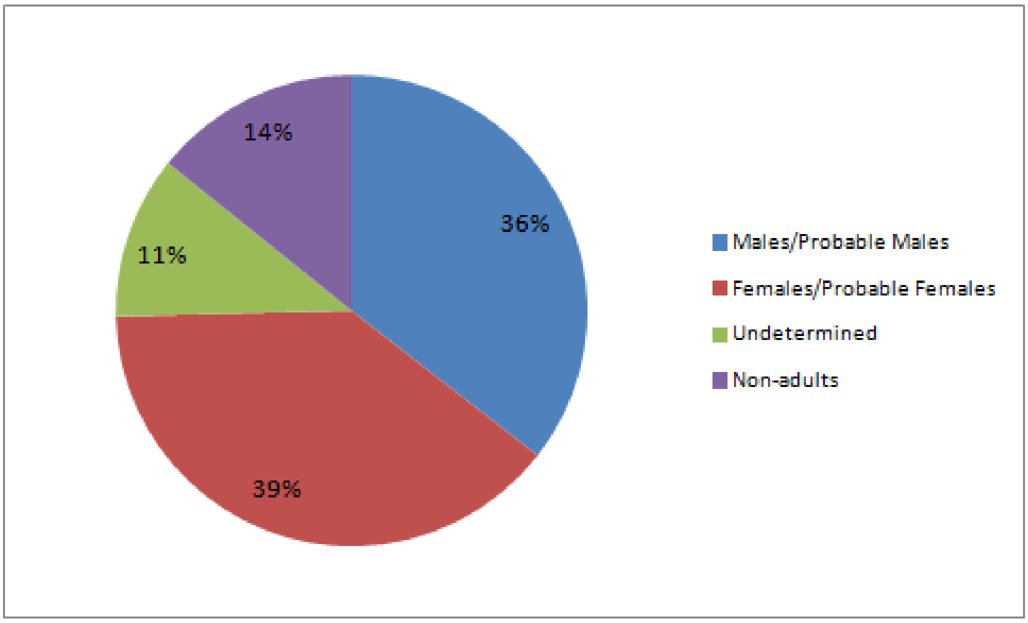


Figure 21 Ballumbie sex profile

Table 10 Ballumbie sex profile

Sex	N	Percentage
Male/Probable Male	70	35.5
Female/Probable Female	77	39.1
Undetermined Adults	22	11.2
Non-Adults	28	14.2
Total	197	100

4.1.3 Stature Estimation

Of the sexed adult individuals at Ballumbie, stature could be estimated for 112: 52 males or probable males and 60 females or probable females. For males, stature ranged from 148.40 cm to 178.60 cm with a mean of 168.47 cm and a standard deviation of 6.01 cm. Skeleton 623 (148.40 cm) and Skeleton 225 (178.60 cm) are both outliers belonging below the 5th percentile for height due to pathology, which will be discussed further in section 4.1.6.3. When the outliers are removed the stature range changed to 158.80 cm to 178.60 cm with a mean of 169.16 cm and a standard deviation of 4.96 cm. The range without outliers is more statistically accurate and will be used to compare with other populations. For females, stature ranged from 142.10 cm to 168.70 cm with a mean of 157.27 cm and a standard deviation of 5.09 cm. Skeleton 790 is an outlier above the normal range for females in this population most likely due to pathology, which will be discussed further in section 4.1.6.3. Skeleton 728 is also an outlier, though due to the bad condition of the skeleton and since only legs were present, it is difficult to say whether this was a normal skeleton or whether there was also a pathology which affected its height. In order to attain statistical accuracy SK 790 was removed. The new stature range for females is 142.10 cm to 166.80 cm with a mean of 157.07 cm and a standard deviation of 4.9 cm. This more accurate mean will be used to compare stature with other populations.

4.1.4 Pathological Conditions

In the Ballumbie assemblage, 124 individuals, or 62.9% of the total population, have at least one type of pathological condition. There are 73 individuals (37.1%), with no pathology that could be discerned from the skeleton. Eleven individuals (5.6%), have pathology that could be placed into the category of infectious disease. In the category of congenital disorders there are 21 individuals (10.7%). Twenty-six individuals (13.2%) could be placed into the category of trauma. In the category of metabolic disease there are 33 individuals (16.8%). Eighty individuals (40.6%) have joint disease. Eighty-four individuals (42.6%) have dental disease and 13 individuals (6.6%) have miscellaneous lesions that could not be included in the previous categories and instead are placed into a broad category of other disease (Figure 22).

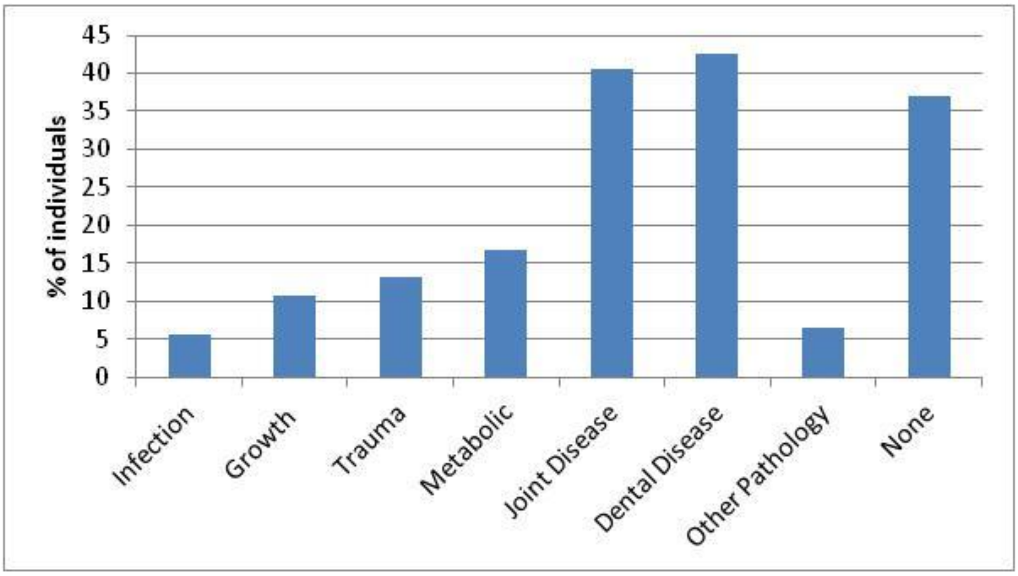


Figure 22 Ballumbie pathology profile

4.1.5 Infectious Disease

Out of the 11 individuals that had evidence of infectious disease in the Ballumbie assemblage, 10 had evidence of non-specific infection.

4.1.5.1 Non-Specific Infections

4.1.5.1.1 Periostitis and Osteomyelitis

There are seven individuals in Ballumbie that have periostitic lesions, or inflammation of the periosteal bone represented by new woven bone formation. The lesions in SK 501, SK 682, SK 749, and SK 848 are associated with fractures on the same bone which indicates a localized infection associated with the trauma. Six out of seven skeletons with periostitic lesions have them on their tibiae. All the tibiae in these cases, except for in SK 749, have periostitic lesions that are unrelated to fractures. Table 11 lists the skeletons and bones that are affected by periostitic lesions and those that have periostitic lesions due to fractures.

Table 11 Cases of periostitis in Ballumbie

Skeleton	**Bones Affected by Periostitis**	**Fractured Bones**
SK 13	Radius, Femur, Tibia	
SK 501	Tibia, Fibula	Fibula
SK 659	Tibia	
SK 682	Zygomatic	Zygomatic
SK 749	Fibula, Tibia	Fibula, possibly Tibia
SK 751	Tibia	
SK 848	Tibia, Maxilla	Maxilla

There are five individuals with osteomyelitis, an infection of the bone and marrow: SK 172, SK 623, SK 749, and SK 751 (Table 12). SK 172 and SK 749 have osteomyelitis associated with fractured bones. SK 751, a young-middle adult male, has osteomyelitis on the right fibula and periostitic lesions on the right tibia which indicates a localized infection of the right leg. The right ankle of SK 764, a middle adult female, including the distal tibia and talus, has osteomyelitis. The distal tibial joint surface is misshapen, with sinuses at the lateral and anterior edges. There is no involucrum, which is a new layer of bone often seen in cases of osteomyelitis, but instead is a purely lytic lesion. The left femur is also swollen and distorted and there are deep vessel tracks on the surface which are probably associated with the osteomyelitis of the right ankle. The left second proximal phalanx of the hand also has osteomyelitis at the distal end. A possible diagnosis for this individual is septic arthritis.

Table 12 Cases of osteomyelitis in Ballumbie

Skeleton	Bones Affected by Osteomyelitis	Fractured Bones
SK 172	Ulna	Ulna
SK 623	Radius, Carpals	
SK 749	Tibia	Tibia
SK 751	Fibula	
SK 764	Tibia, Talus, Hand Phalanx	

4.1.5.1.2 Septic Arthritis

As mentioned in the previous section, SK 764 has a possible case of septic arthritis (section 3.1.8.1). SK 761, a middle adult male, is another individual with a possible diagnosis of septic arthritis. SK 761 has cervical spinal degenerative disease with fusion of the 6th and 7th cervical vertebrae. Cervical vertebrae 3-7 have severe osteophytosis and disc degeneration on their bodies. The thoracic vertebrae 8-11 have bony bridging, but are not fused. There is also localized osteoarthritis of the elbows with eburnation on the capitulum. There are many bony spurs throughout the skeleton that indicate, along with the bridging of thoracic vertebrae, this individual may be a bone former (Waldron 2009). There is an erosive lesion on the acetabulum with an associated deep *fovea capitis* with much destructive changes. The most viable diagnosis is septic arthritis, a bacterial infection that spreads to the joints and commonly involves the hip joint (Ortner 2003). However, another possible diagnosis could be incipient DISH. Cervical vertebrae 6 and 7 are fused, which can occur with DISH, although the fusion here may be related to mechanical loading. The presence of many bone spurs throughout the skeleton is another indication of incipient DISH, however the erosive lesions on the acetabulum are suggestive of some sort of degenerative inflammatory disease such as septic arthritis. Differential diagnosis could also include tuberculosis, which resembles septic arthritis (Ortner 2003), however tuberculosis generally involves further bone destruction than is seen in SK 761.

4.1.6 Congenital Disorders

In Ballumbie there are 21 individuals with pathological lesions that could be placed in the category of congenital or growth disorders. Of the skeletons with congenital disorders 14 (61%) have a congenital anomaly of the spine and nine (39%) have an extra-spinal anomaly, discussed below.

4.1.6.1 Spina Bifida and Spina Bifida Occulta

Of the 21 individuals with congenital disorders, five of these have spina bifida, or spina bifida occulta. Spina bifida occulta is more common and is found in SK 225, SK 525, SK 594, and SK 847. SK 628, a young-middle adult male, is the only skeleton with complete spina bifida of sacral bodies 1-5 (Table 13)

Table 13 Spina bifida and spina bifida occulta in Ballumbie

Skeleton	**Anomaly**
SK 225	Spina Bifida Occulta
SK 525	Spina Bifida Occulta
SK 594	Spina Bifida Occulta
SK 628	Spina Bifida
SK 847	Spina Bifida Occulta

4.1.6.2 Spinal Congenital Anomalies (except for Spina Bifida and Spina Bifida Occulta)

Of the 21 skeletons with congenital disorders, 8, or one third have a spinal anomaly other than spina bifida or spina bifida occulta (Table 14). SK 67, SK 601, and SK 630 have lumbar sacralization and SK 419 has partial lumbar sacralization. SK 725 and SK 747 show sacral lumbarization. SK 419, a middle adult male, has six lumbar vertebrae and SK 633, a young-middle adult male, has a transitional 12th

thoracic vertebra. SK 501, a middle adult female, has a cleft posterior arch of the atlas.

Table 14 Spinal anomalies in Ballumbie other than spina bifida or spina bifida occulta

Skeleton	**Anomaly**
SK 67	Lumbar Sacralization
SK 419	6 Lumbar Vertebrae and Partial Lumbar Sacralization
SK 501	Cleft Atlas
SK 601	Lumbar Sacralization
SK 630	Lumbar Sacralization
SK 633	T12 Transitional
SK 725	Sacral Lumbarization
SK 749	Part Sacral Lumbarizaton

4.1.6.3 Extra-Spinal Congenital Anomalies

There are eight skeletons in Ballumbie that display an extra-spinal congenital anomaly. SK 153 has an abnormal auricular surface along with an unfused ischio-pubic ramus and bi-lateral accessory facets, which is seemingly common (Mann and Hunt 2005) and sometimes listed as a nonmetric variation (Buikstra and Ubelaker 1994). SK 432 has different lengths of right and left arms, with as much as 6 cm in difference between right and left ulnae. SK 447A has a mesiodens in the left maxilla composed of enamel approximately 6mm x 8mm in size. SK 467 has the right deciduous lateral incisor of the maxilla retained into adulthood. SK 527 has bi-lateral maxillary tori, which is sometimes considered a developmental anomaly (Mann and Hunt 2005) or nonmetric variation (Buikstra and Ubelaker 1994).

SK 623, a young-middle adult male, has multiple congenital anomalies. In the maxilla, the central incisors and left lateral incisor appear to be missing congenitally from the lack of resorbed alveolar bone and no available space for the tooth crypts. Instead, the left canine is in the position of the lateral incisor. Where the canine should be in position is congenitally missing a tooth. The left 1st and second premolar and 2nd and 3rd molars are rotated toward each other (premolars rotated toward molars, molars rotated toward premolars). The 1st molar is congenitally missing. The right 2nd premolar is rotated toward the 1st premolar. The third right molar is also rotated. In the mandible the left 2nd molar is the only molar present. The left 1st molar is missing antemortem, however it appears that the left 3rd molar never erupted from the lack of changes to the alveolar bone, including remodelling. The right 1st molar is possibly congenitally missing. There is a right 1st premolar in the position of where the 1st molar should be. The right 2nd molar is in position but the right 3rd molar is congenitally absent. The os coxae are hypoplastic, or underdeveloped. The lower segments of the limbs are shortened compared to the upper segments; radii and ulnae, and tibiae and fibulae are all shortened compared to the humeri and femora. The radial/humeral index (brachial) is 68.9 and the tibia/femur index (crural) is 74.86, which are the lowest indices for all Ballumbie males. The stature for this individual is estimated at 148 cm which, as mentioned earlier, is an outlier belonging below the 5th percentile for height within this assemblage. This individual also has the shortest femora, tibiae, humeri, and radii in comparison with all males in the Ballumbie assemblage. The femora and tibiae measurements for SK 623 are outliers among males in Ballumbie, though the test for normality proved these outliers are not statistically significant. A possible diagnosis for this skeleton is chondroectodermal dysplasia which features acromesomelic dwarfism and dental anomalies (Aufderheide and Rodríguez-Martín 1998) (section 3.1.8.2). Figure 23 demonstrates the drastic reduction in size of tibiae in SK 623, which is pictured on the far right. The tibia on the far left is from SK 790, the old adult probable female with possible acromegaly, which is also the longest tibia in Ballumbie. The middle tibia is from SK 725, an old adult male with average stature.

Figure 23 Right Tibiae of SK 623 (far right) compared to SK 790 (far left) and SK 725 (middle); anterior view

Figure 24 SK 623 (bottom) left humerus, radius, ulna compared to SK 725 (bottom) average statured male right humerus, radius, ulna; anterior and lateral views

SK 701 is a young-middle adult male that has several dental anomalies, including agenesis of the right and left maxillary and mandibular 2nd pre-molars. Also, the deciduous mandibular 2nd molars are retained, and the permanent 1st mandibular molars had probably never erupted. The right maxillary canine remains unerupted, and the deciduous canine is retained. The cause for these dental anomalies is unclear.

SK 790 is an old adult female that has an abnormally large mandible with a bigonial breadth about 10% larger than any other female and 7% larger than any male in the Ballumbie assemblage. The skull is very robust and thickened. The cranial sutures have fused abnormally. There are two frontal bones (metopic suture present) which extend very far back, which shifts the parietals even further back. The sutures do not line up properly at the bregma. The post-cranial skeleton is very large, presuming that the skeleton is female (168.7 cm). The phalanges are quite broad with irregular new-bone growth on the shafts. Hand and foot bones are long and the 1st metatarsal is especially large. The auricular area of the ilium is distorted in shape and very concave. The ribs have expanded sternal ends and extreme ossification of the costal cartilage. The clavicles are unusually large, as are the scapulae. The long bones are long, thick, and heavy. It was extremely difficult to determine the sex of this skeleton. The skull has female traits: small mastoid processes, high frontal, no supraorbital tori, and a nuchal area that was not very pronounced. The pelvis has a narrow greater sciatic notch associated with male skeletons; however the abnormal auricular surface may be affecting this. The oval shape of the obturator foramen is associated with female skeletons. The long bones have a mix of male and female measurements (femoral midshaft- male, distal tibia- female, proximal tibia- indeterminate). The glenoid fossa is in the range for female skeletons. Other abnormities include palatine and mandibular tori. A possible diagnosis is acromegaly; although the mandible is not as severely protruding as is usual for skeletons with acromegaly, there is malocclusion with an underbite. If the skeleton is female, as I have determined, then at 168.7 cm it is above the 95th percentile in height and the tallest female in the Ballumbie assemblage (Figure 23). If the skeleton is male, however, then another diagnosis could be possible. This skeleton was removed from calculations of mean stature for Ballumbie for more statistical accuracy. Table 15 lists the skeletons with extra-spinal anomalies in the Ballumbie assemblage.

Table 15 Extra-spinal anomalies in Ballumbie

Skeleton	Anomaly
SK 153	Pelvic Anomaly
SK 432	Different Arm Length
SK 447A	Mesiodens
SK 467	Dental Anomaly
SK 527	Maxillary Tori
SK 623	Dental Anomaly and Form of Dysplasia
SK 701	Dental Anomaly
SK 790	Form of Dysplasia

4.1.7 Trauma

In the Ballumbie assemblage 26 individuals, or 13.2% of the population, suffered from trauma and 19, or two thirds, of those individuals have one or more fractured bones (Table 16).

Table 16 Ballumbie fractures

N = total number of individuals with bone present, n = number of individuals with fracture, CPR= percentage of individuals with fractured bones

Bone	**N**	**n**	**CPR**
Cranium	103	2	1.9
Mandible	78	0	0
Clavicle	82	2	2.4
Scapula	98	0	0
Rib	78	4	5.1
Vertebra	74	5	6.8
Innominate	125	0	0
Humerus	125	1	0.8
Radius	109	1	0.9
Ulna	135	4	3
Metacarpal	57	0	0
Hand Phalanx	89	0	0
Patella	60	0	0
Femur	161	1	.6
Tibia	131	4	3.1
Fibula	96	6	6.3
Metatarsal	57	2	3.5
Foot Phalanx	109	2	1.8

4.1.7.1 Post-cranial Fractures

There are 18 individuals with fractures in the post-cranial skeleton. Fractures are reported by bone element in separate sections below.

4.1.7.1.1 Long Bone Fractures

Only one individual (SK 397), out of 125 with at least one humerus present has a fractured humerus. Again, only one individual (SK 606), out of 109 individuals with a radius has a fractured radius. Along with a fracture to the right radius, SK 606, a middle adult male, also has fractures to right and left ribs, the right ulna, left fibula, and right foot. Another traumatic lesion found in this individual was a medial epicondyle avulsion fracture in the left humerus. Four individuals out of 135 individuals with at least one ulna present have a fractured ulna. One individual out of 161 with at least one femur present has a fracture of the femur (SK 706). SK 706 also has a tibial fracture; both the femoral and tibial fractures appear to be perimortem. Four individuals out of 131 with at least one tibia present have a tibial fracture. Six individuals out of 96 with at least one fibula present have fibular fractures. Two individuals (SK 501, SK 599) had fractures of both the tibia and fibula from the same side of the body. Out of the long bones, the fibula has the highest percentage of fractures at 6.3% of individuals with a fibula present. Out of 82 individuals with at least one clavicle present, two individuals have a fractured clavicle. SK 682, a middle adult male, has multiple fractures including at the left clavicle, the left ulna, the left fibula, right and left ribs, nasals, and vertebrae (Figure 25). Figure 26 illustrates the percent of individuals with long bone fractures in Ballumbie.

Figure 25 SK 682 Parry fracture to the left distal ulna; lateral view

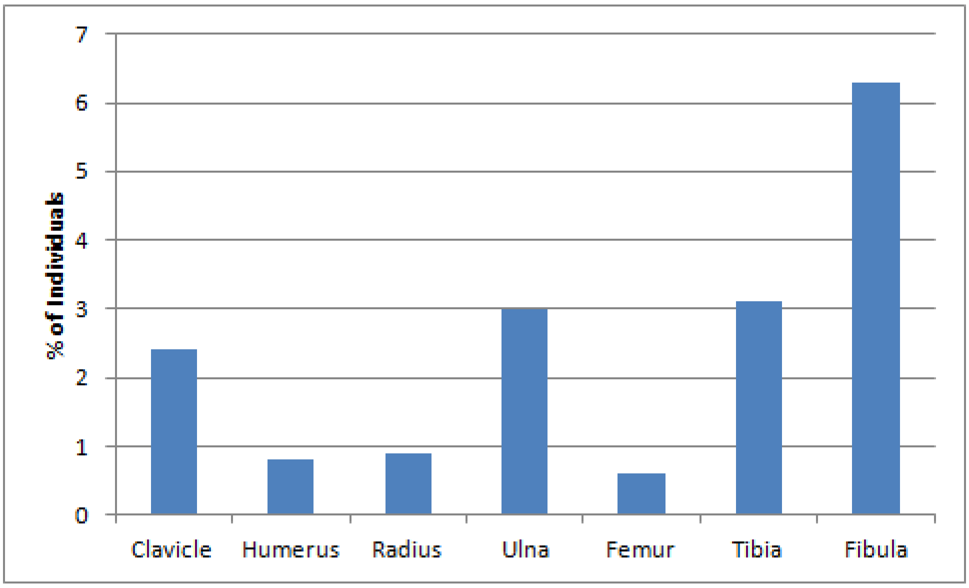


Figure 26 Ballumbie long bone fractures by bone category

Of the adult individuals, males and females have similar percentages of fractures of the clavicle and ulna (Table 17; Figure 27). Only females have humeral fractures in the Ballumbie assemblage, however only males have radial fractures. Only females have femoral fractures. Females have twice as many tibial fractures (5.8%) than males do (2.2%), however males have twice as many fibular fractures (male 11.4%, females 5.6).

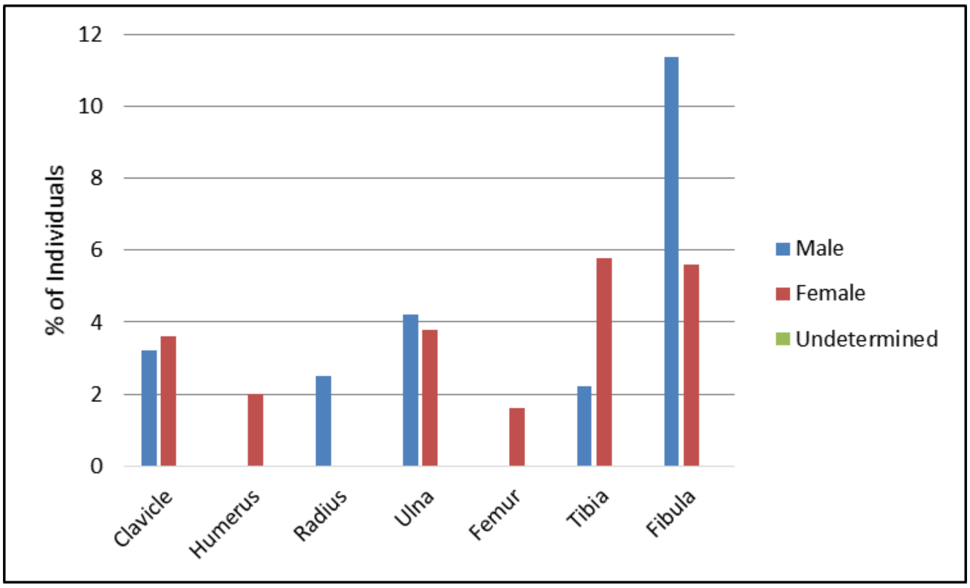


Figure 27 Ballumbie long bone fractures by sex

Table 17 Ballumbie long bone fractures by sex

Bone	Male			Female			Undetermined		
	N	n	CPR	N	n	CPR	N	n	CPR
Clavicle	31	1	3.2	28	1	3.6	10	0	0
Humerus	42	0	0	50	1	2	13	0	0
Radius	40	1	2.5	42	0	0	12	0	0
Ulna	48	2	4.2	53	2	3.8	13	0	0
Femur	55	0	0	62	1	1.6	18	0	0
Tibia	45	1	2.2	52	3	5.8	13	0	0
Fibula	35	4	11.4	36	2	5.6	11	0	0

4.1.7.2 Non- Long Bone Fractures

There are no scapular fractures in the Ballumbie assemblage. There are two individuals, out of 78 individuals with at least one rib present, with a rib fracture. Five individuals, out of 74 with at least one vertebra present, had vertebral fractures. There are no metacarpal or hand phalanx fractures in the Ballumbie assemblage, nor are there any patellar fractures. Out of 57 individuals with at least one metatarsal present, two individuals have a metatarsal fracture. Out of 109 individuals with at least one foot phalanx present, two had a foot phalanx fracture (Figure 28).

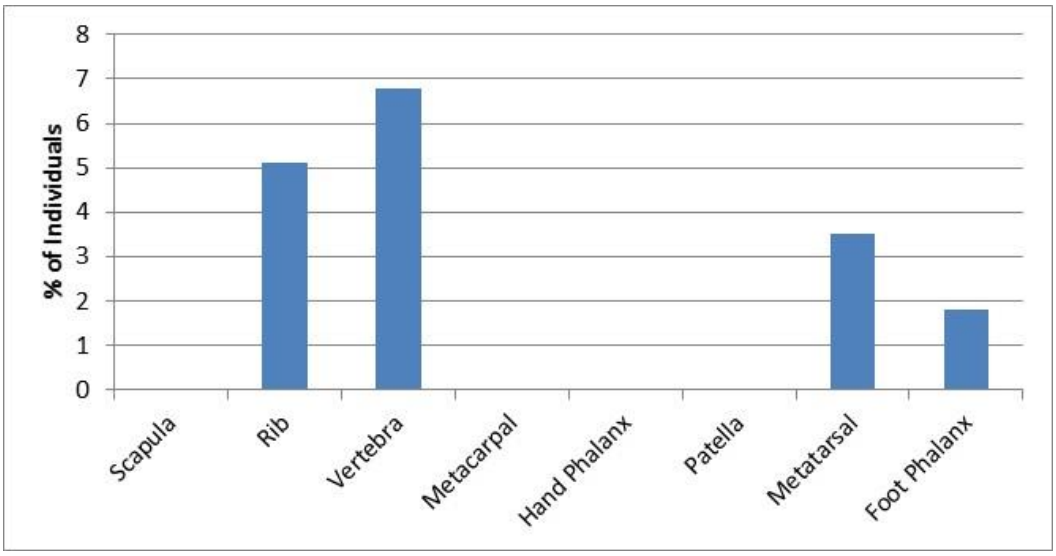


Figure 28 Ballumbie non-long bone fractures

Of the individuals with rib fractures, all were male. Males have more vertebral fractures than females (males 10.7%, females 6.5%). Males and females have similar frequencies of metatarsal fractures (males 4.8%, females 4.5%), however only males have foot phalanx fractures (Table 18; Figure 29).

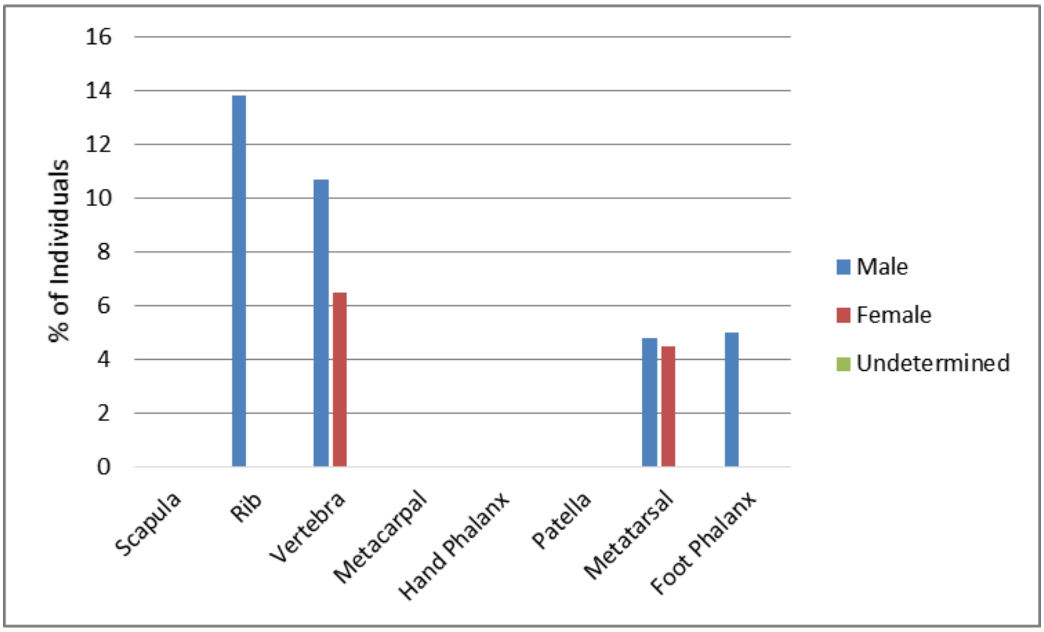


Figure 29 Ballumbie non-long bone fractures by sex

Table 18 Ballumbie counts and crude prevalence rates for non-long bone fractures by sex

Bone	Male			Female			Undetermined		
	N	n	CPR	N	n	CPR	N	n	CPR
Scapula	34	0	0	42	0	0	9	0	0
Rib	29	4	13.8	32	0	0	6	0	0
Vertebra	28	3	10.7	31	2	6.5	7	0	0
Metacarpal	21	0	0	22	0	0	6	0	0
Hand Phalanx	32	0	0	34	0	0	10	0	0
Patella	21	0	0	23	0	0	6	0	0
Metatarsal	21	1	4.8	22	1	4.5	6	0	0
Foot Phalanx	40	2	5	42	0	0	12	0	0

4.1.7.3 Cranial Trauma

Out of 103 individuals with cranial bones present, only two individuals had trauma to the skull. SK 630, an old adult male, has a healed depression fracture at the lambda landmark. SK 682, a middle adult male, has multiple fractures including his nasals. Since most of his fractures are focused on his left side, it is possible his injuries were from interpersonal violence.

4.1.7.4 Spondylolysis and Spondylolisthesis

There are six cases of spondylolysis and spondylolisthesis in the Ballumbie assemblage out of 66 individuals with at least one vertebra present (Table 19).

Table 19 Spondylolysis and spondylolisthesis at Ballumbie

Skeleton	Trauma	Vertebrae Affected
SK 75	Spondylolysis	5th Lumbar
SK 225	Hemi-Spondylolysis	12th Thoracic
SK 234	Spondylolisthesis	5th Lumbar
SK 525	Spondylolisthesis	3rd Lumbar
SK 628	Spondylolisthesis	5th Lumbar
SK 717	Possible Spondylolisthesis	4th Lumbar

4.1.7.5 Osteochondritis Dissecans

There are three cases of osteochondritis dissecans in the Ballumbie assemblage; SK 172, SK 341, and SK 541 (Table 20).

Table 20 Osteochondritis dissecans in Ballumbie

Skeleton	Joint(s) Affected
SK 172	Knee
SK 341	Hip
SK 599	Knee, Foot

4.1.7.6 Other Trauma

There are five individuals with other types of trauma (Table 21). SK 234, a young adult male, has a lumbarization of the first sacral body as a result of trauma. SK 510, an old adult male, has a Pott's fracture comprising of exostosis of the interosseous crest on both tibiae and fibulae, which suggests a probable dislocation of the ankle. SK 567, an old adult male, has a slight femur subluxation. SK 606, a middle adult male, has an avulsion fracture of the medial epicondyle of the left humerus. SK 630, an old adult male, has a fused sacroiliac joint from a possible injury.

Table 21 Other trauma in Ballumbie

Skeleton	Trauma
SK 234	S1 Lumbarized
SK 510	Ankle Dislocation
SK 567	Femur Dislocation
SK 606	Humerus Medial Epicondyle Avulsion
SK 630	Sacroiliac Joint Fusion

4.1.8 Metabolic Disease

There are 33 individuals, or 16.8% of the population, showing symptoms of metabolic disease.

4.1.8.1 Cribra Orbitalia and Porotic Hyperostosis

There are 15, out of 74 individuals with at least one orbit present, with cribra orbitalia (20.3%) (Figure 30). Out of 101 individuals with the skull or part of the skull present, 11 (10.9%), have porotic hyperostosis. In the Ballumbie assemblage, no individuals have both cribra orbitalia and porotic hyperostosis.

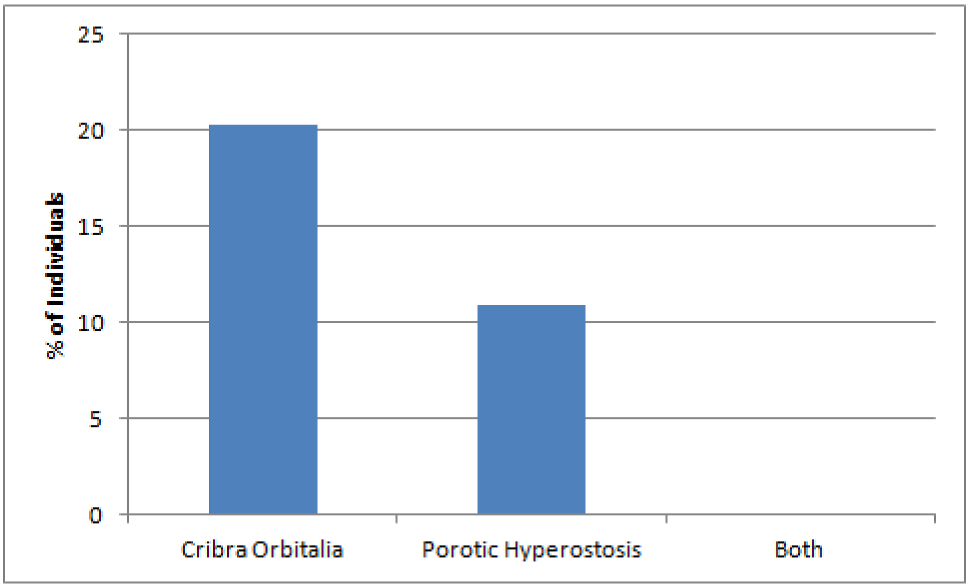


Figure 30 Cribra orbitalia and porotic hyperostosis in Ballumbie

4.1.8.2 Rickets

There are four individuals with probable rickets in the Ballumbie assemblage. SK 144, an adult, has bowing of the femora, tibiae, fibulae, and radius, with a confident diagnosis of rickets (Figure 31). SK 491, a young-middle adult female, has slight bowing of the right femur, which may indicate rickets. SK 579, an old juvenile, also has bowing of the right femur, which could indicate rickets. Both in SK 491 and SK 579 the left femora were unaffected. SK 832, an old adult male, has slight bowing of both of the tibiae and fibulae, which probably indicates healed childhood rickets.

Figure 31 SK 144 bowed right femur and tibia; lateral view

4.1.8.3 Osteopenia and Osteoporosis

There are seven individuals in the Ballumbie assemblage with probable osteopenia: SK 254, SK 276, SK 325, SK 437, SK 501, SK 827, and SK 845. Two of these individuals, SK 501 and SK 827 (both females) also have bone fractures, and bones of individuals with osteoporosis have lower bone density and therefore are easily susceptible to fracture. Therefore, these two cases are good candidates for osteoporosis. SK 501 has fractures in her right tibia and fibula and SK 827 has compression fractures in the 1^{st} and 2^{nd} lumbar vertebrae.

4.1.9 Joint Disease

There are 80 individuals, or 40.6% of the population who suffered from joint disease. Joint disease is broken down further into extra-spinal arthropathies and spinal joint disease. These categories are not mutually exclusive; individuals can have both types of joint disease.

4.1.9.1 Extra-Spinal Arthropathies

There are 61 individuals, or 31% of the population, with extra-spinal arthropathies. Table 22 lists the numbers and percentages of arthropic changes by joint. The highest percentage of arthropic changes is in the hand joints, at 28% of the population with at least one hand joint present. The joint with the lowest percentage of arthropathies is the ankle (Figure 32).

Table 22 Extra-spinal arthropathies at Ballumbie

Joint(s)	N	N	CPR
Shoulder	92	14	15.2
Sterno-clavicular	74	9	12.2
Acromio-clavicular	84	19	22.6
Elbow	106	17	16.0
Wrist	88	22	25.0
Hand	92	26	28.0
Hip	137	33	24.0
Knee	139	20	14.4
Ankle	119	13	10.9
Foot	81	15	18.5

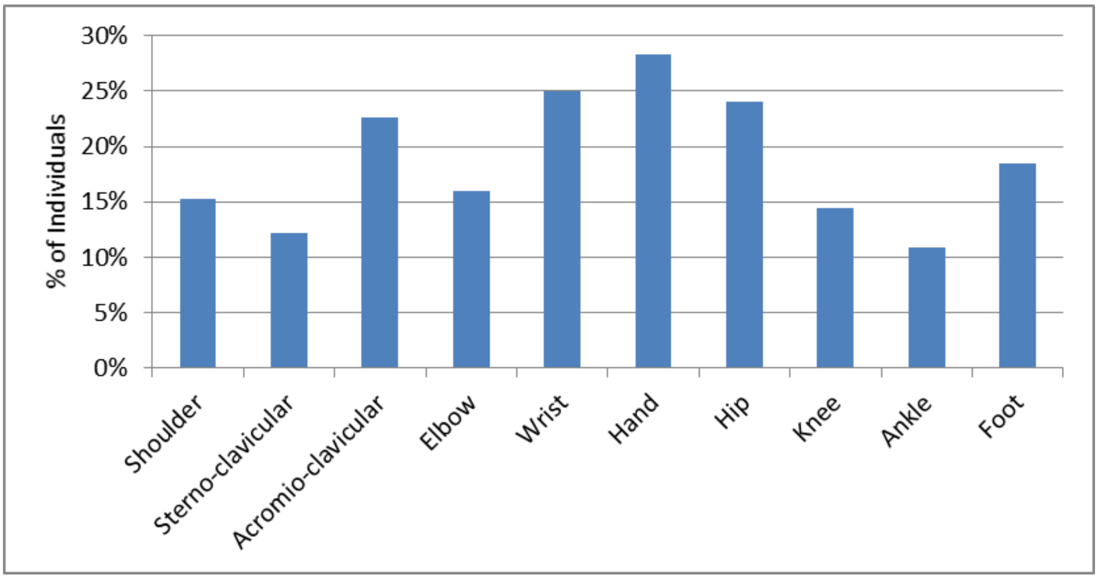


Figure 32 Extra-spinal arthropathies at Ballumbie

Figure 30 demonstrates the differences in percentages of arthropathies in each joint for males and females. Males have more arthropathies than females in every joint examined, and in many cases twice more than females, however none of the differences are statistically significant (Table 23).

Table 23 Ballumbie crude prevalence rates of extra-spinal arthropathies in adult skeletons

Joint (s)	Male			Female			Undetermined		
	N	n	CPR	N	n	CPR	N	n	CPR
Shoulder	42	8	19	41	6	14.6	0	0	0
Sterno-clavicular	31	6	19.4	34	3	8.8	0	0	0
Acromio-clavicular	39	11	28.2	37	8	21.6	0	0	0
Elbow	47	11	23.4	49	6	12.2	0	0	0
Wrist	42	15	35.7	38	7	18.4	1	0	0
Hand	41	15	36.6	42	11	26.2	1	0	0
Hip	56	16	28.6	60	16	26.7	6	0	0
Knee	56	11	19.6	64	6	9.4	6	3	50
Ankle	50	7	14	55	5	9.1	3	1	33.3
Foot	36	7	19.4	37	7	18.9	2	1	50

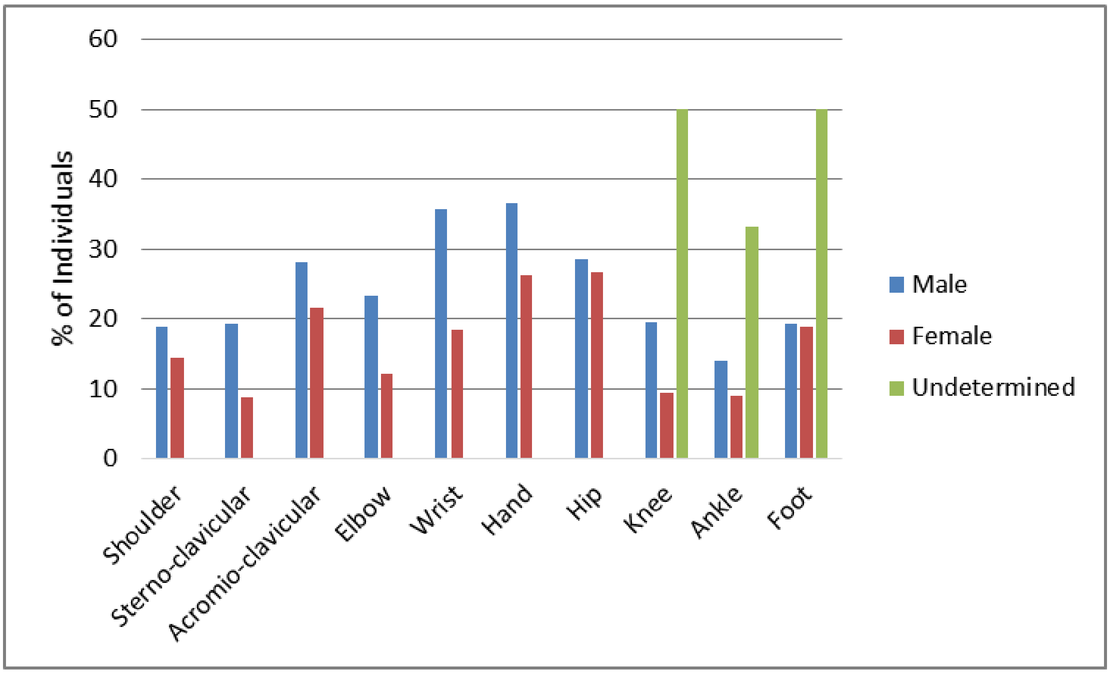


Figure 33 Ballumbie extra-spinal arthropathies by sex

4.1.9.2 Spinal Joint Disease

Forty-six percent, or 29 individuals out of 63 with at least one cervical vertebra present, have cervical joint disease (Figure 34). Out of 60 individuals with at least one thoracic vertebra present, 41, or 68.3%, have thoracic vertebrae affected. Out of 69 individuals with at least one lumbar vertebra present, 34, or 49.3%, have lumbar spinal joint disease. Out of the individuals that had cervical and thoracic vertebrae present, 43% had both cervical and thoracic joint disease (Figure 35).

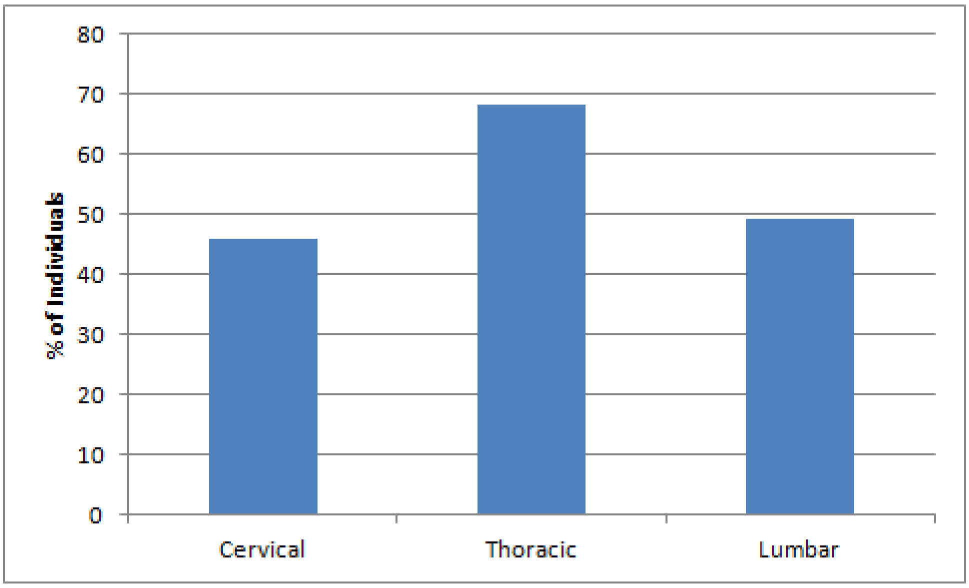


Figure 34 Ballumbie spinal joint disease by spinal section

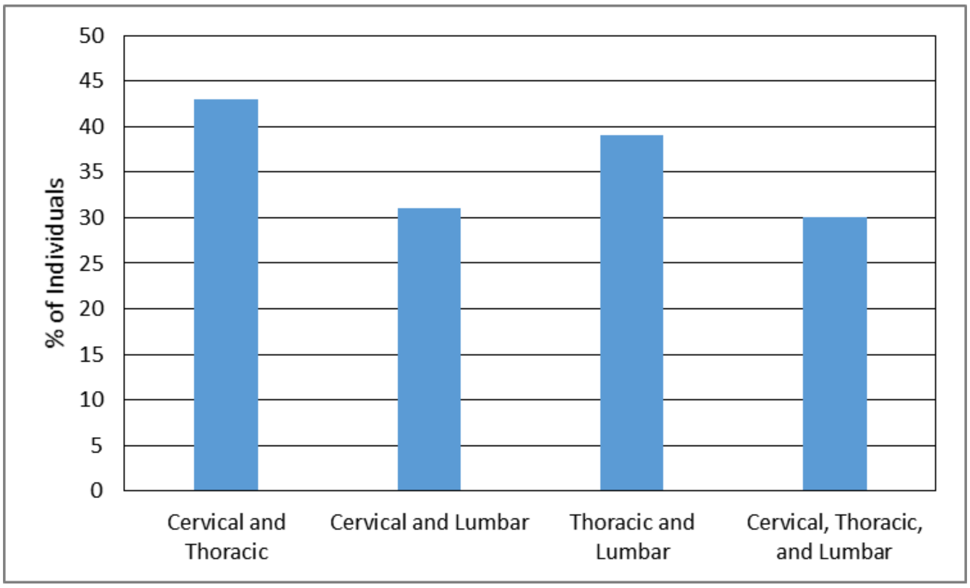


Figure 35 Ballumbie spinal joint disease in multiple spinal sections

4.1.9.3 Ankylosing Spondylitis

One skeleton, SK 567, an old adult male, has a probable diagnosis of ankylosing spondylitis (section 3.1.8.5). The sacroiliac joint is bi-laterally fused (Figure 36). Cervical vertebrae 3 and 4 are fused together on the left articular facets and all other cervical vertebrae have disc degeneration. The changes on the cervical vertebrae could be related to the diagnosis or could also be due to trauma and therefore unrelated to the other changes in the spine. The eighth through to twelfth thoracic vertebrae have osteophytic bridging on the right side and the bridges consist of smooth bone, which could be indicative of incipient DISH. The lumbar vertebrae also have several bony spurs, but the lipping is not restricted to the right side. There are marked enthesopathies and bony spurs and growths on many joints. The left femur has a slight dislocation with an associated additional facet. While the bridging in the thoracic vertebrae occurs on the right side, as it does in DISH, the bilateral sacroiliitis is a diagnostic trait in ankylosing spondylitis (Waldron 2009). Other than the probable diagnosis of ankylosing spondylitis, other possible diagnoses could be incipient DISH or Reiter’s Syndrome.

Figure 36 SK 567 Bilateral sacroiliitis

4.1.9.4 DISH and eDISH

There are no clearly diagnosed cases of DISH or incipient DISH in the Ballumbie assemblage. As mentioned earlier, SK 761 and SK 567 could have possible diagnoses of incipient DISH; however other diagnoses such as septic arthritis and ankylosing spondylitis are more likely.

4.1.10 Dental Disease

The highest percentage of disease in the Ballumbie collection falls into the category of dental disease. Out of the total population at Ballumbie, 84 individuals (43%) have dental disease. There are 36%, or 42 out of 114 individuals with at least one tooth present, with dental caries (Table 24). Twenty-three percent, or 26 individuals, have a dental abscess. There are 33%, or 38 individuals, with antemortem tooth loss. There is 17.5%, or 20 individuals, with enamel hypoplasia.

Table 24 Dental disease in Ballumbie by individual

Disease	**N**	**n**	**CPR**
Caries	114	42	36.8
Abscesses	114	26	22.8
Antemortem Tooth Loss	114	38	33.8
Enamel Hypoplasia	114	20	17.5

Prevalence of dental disease by tooth was also assessed. Out of 2,310 teeth present, 129 (5.6%) have caries, 84 (3.6%) have abscesses, and 128 (5.5%) have enamel hypoplasia. Table 25 lists the counts and percentages of dental disease in Ballumbie by tooth.

Table 25 Dental disease in Ballumbie by tooth

Disease	N	N	TPR
Caries	2310	129	5.6
Abscesses	2310	84	3.6
Enamel Hypoplasia	2310	128	5.5

4.1.11 Other Disease

There are 13 individuals, or 6.6% of the population, with diseases that could not be placed into any of the above categories. Instead, they are assigned to the general category of 'other' disease (Table 26).

SK 501 is a middle adult female who has multiple disease processes present including a cleft posterior arch of the atlas, tibia and fibula fractures with healed infections, possible osteopenia, and osteoarthritis at the apophyseal joints on the cervical and thoracic vertebrae. However, a pathological lesion that could not be placed into another category is ossified plaque found in the thorax where the lung would have been (Figure 37). It is possible this plaque is the result of ossified pleura from tuberculosis.

Figure 37 SK 501 Ossified plaque found in thorax

SK 521 is a young adult probable male with a sclerotic lesion on the left tibia superior to the medial malleolus. The lesion is 24.5mm long, 14.4mm wide, and 7.3mm deep. The most likely diagnosis is a chondroblastoma, a benign bone tumor, most often found in young males at the epiphysis of long bones (Ortner 2003) (section 3.1.8.7). There are rough edges around most of the lesion, which indicates the tumor was present at the time of death. Another possible diagnosis is a dermoid cyst, a benign tumor that can contain mature tissue such as hair, nails, teeth, and bone.

SK 616 is a middle adult female that also has a dermoid cyst (Figure 38). This cyst appears to have been in the ovaries due to its location in the body cavity. The cyst is also termed an ovarian benign teratoma and consists of calcified tissue that resembles malformed teeth, a feature in 25-30% of dermoid cysts (Aufderheide and Rodríguez-Martín 1998: 292) (section 3.1.8.7). She has a minimum of 16 ‘enamel crowns’, eight of which are fused together. The largest ‘crown’ is 10.9mm by 8.4mm and the smallest is conical in shape with a maximum dimension of 4.5mm. These malformed ‘teeth’ resemble two adult lower molars, two deciduous 2nd molars, one lower molar, and one upper central incisor. The other ‘teeth’ appear to contain a small bulb of enamel resting on a withered root. This female also has a small blastic lesion on the endocranium lateral to the frontal crest (Figure 39). Possible diagnoses are hyperostosis frontalis interna that only occurs in women, 90% of the time in women over 30, and is thought to be a type of pituitary disorder (Aufderheide and Rodríguez-Martín 1998: 419) (3.1.8.7). Other possible diagnoses are a benign osteoma or a fibro-osseous tumor which is also most often benign.

Figure 38 SK 616 Ovarian benign teratoma

Figure 39 SK 616 Possible hyperostosis frontalis interna; inferior view

Figure 40 SK 706 Possible Legg-Perthes

Table 26 Other disease in Ballumbie

Skeleton	**Disease Process**
SK 501	Ossified Plaque in Thorax
SK 521	Chondroblastoma
SK 525	Lytic Lesion on Talus
SK 606	Ossified Tongue
SK 616	Dermoid Cyst and Blastic Endocranial Lesion
SK 630	Possible Healed Skull Fracture
SK 633	Possible Legg-Perthes
SK 659	Possible Childbirth Death
SK 682	Abnormal Bone Growth on Zygomatic
SK 706	Possible Legg-Perthes
SK 721	Rib Ossified Hematoma
SK 764	Swollen Left Femur
SK 844	Proliferative Lesion on Right Femur

4.1.12 Burial Location

4.1.12.1 Sex and Age by Burial Location

Burial location is often related to social status, and therefore a useful variable to consider. The age and sex breakdown in the different burial locations can be seen in Table 27. The differences in demography between the various burial locations are not statistically significant.

Table 27 Burial location demography at Ballumbie

Burial Location			Sex: Male	Sex: Female	Total
Aisle	Age	YA	1	0	1
		YMA	1	1	2
		MA	1	1	2
		OA	1	1	2
	Total		4	3	7
Burial ground	Age	ADL	4	3	7
		YA	2	5	7
		YMA	11	10	21
		MA	9	11	20
		OA	4	6	10
		AD	3	7	10
	Total		33	42	75
Cist	Age	YA	0	1	1
		YMA	1	0	1
		MA	5	1	6
		OA	0	1	1
		AD	2	1	3
	Total		8	4	12
Inside church	Age	ADL	1	0	1
		YA	2	2	4
		YMA	7	6	13
		MA	4	8	12
		OA	6	5	11
		AD	2	2	4
	Total		22	23	45
Non-cist but pre-church	Age	YMA	1	1	2
		MA	1	0	1
		OA	0	1	1
	Total		2	2	4

4.1.12.2 Burial Location and Pathology

Chi-square tests were run to see if there is a difference between the types of disease an individual had during their lifetime and where they were buried. Chi-square tests were also run for several specific diseases. There is no significant relationship between where an individual is buried and whether they have infectious disease, a congenital disorder, joint disease, dental disease, or other disease. Categories of disease and specific diseases that did have differences and were statistically significant are explained further below.

Chi-square tests could only be run for categories where the count is greater than five. Therefore, only the burials in the burial ground and inside the church could be tested when assessing skeletons with traumatic lesions. In the burial ground, eight individuals had a traumatic lesion on their skeleton, however 95 individuals had none. Among the burials inside the church, 16 individuals had traumatic lesions, and 36 individuals did not. There is a significant relationship between where individuals are buried and whether they had trauma during their life (χ^2=13.971, p=.000185, df=1).

Table 28 Burial location and trauma at Ballumbie

			Trauma		
			no	**yes**	**Total**
Burial Location	burial ground	Count	95	8	103
		% within Burial Location	92.2%	7.8%	100.0%
	inside church	Count	36	16	52
		% within Burial Location	73.1%	26.9%	100.0%
Total		Count	131	24	155
		% within Burial Location	84.5%	15.5%	100.0%

Again, due to low counts, only the burials in the burial ground and inside the church could be tested when assessing skeletons with metabolic disease (Table 29). In the burial ground, there are twelve individuals that had metabolic disease, while 91 individuals did not. Among the burials inside the church, fourteen individuals had metabolic disease, while 38 individuals did not. There is a significant relationship between where individuals are buried and whether they had metabolic disease during their life (χ^2=5.773, p=.016, df=1).

Table 29 Burial location and metabolic disease at Ballumbie

			Metabolic		
			no	yes	Total
Burial Location	burial ground	Count	91	12	103
		% within Burial Location	88.3%	11.7%	100.0%
	inside church	Count	38	14	52
		% within Burial Location	73.1%	26.9%	100.0%
Total		Count	129	26	155
		% within Burial Location	83.2%	16.7%	100.0%

Due to low counts, only individuals with no pathological lesions in the burial ground, cist cemetery, and inside the church could be statistically tested (Table 30). In the burial ground, there are 43 individuals without any noticeable pathological lesions, and 60 individuals did have pathological lesions. In the cist cemetery, eight individuals were without pathological lesions, and ten individuals did have pathological lesions. Nine individuals buried inside the church had no pathological lesions and 43 individuals did. There is a significant relationship between where individuals are buried and whether they had pathological lesions (χ^2=9.956, p=.00068, df=2). The majority of individuals with no pathological lesions on their skeletons were buried in the churchyard rather than below or inside the church. It is important to remember that many diseases do not affect the skeleton, so individuals with no pathological lesions on their skeleton does not signify their soft tissue was disease free.

Table 30 Burial location and no disease at Ballumbie

			No Disease		Total
			no	yes	
	burial ground	Count	60	43	103
		% within Burial Location	58.3%	41.7%	100.0%
	Cist	Count	10	8	18
		% within Burial Location	55.6%	44.4%	100.0%
	inside church	Count	43	9	52
		% within Burial Location	82.7%	17.3%	100.0%
Total		Count	113	60	173
		% within Burial Location	65.3%	34.6%	100.0%

To determine whether there was a pattern of disease across time, burials were split into two groups; Pre-Church which dates from around 500 AD until 1000 AD, and the Ballumbie Church, which dates from around 1000 AD until 1500 AD. When chi-square tests were run between these two groups and the types of disease any differences were not statistically significant.

4.2 Isle of May

4.2.1 Age at Death

Of the 58 articulated skeletons in the Isle of May assemblage the age breakdown is as follows: two old juveniles, three adolescents, eight young adults, eleven young-middle adults, sixteen middle adults, and eleven old adults (Table 31; Figure 41). Seven individuals could not be aged more specifically, and are placed into the broad adult category. Of the population as a whole, old juveniles account for 3.4%, adolescents 5.2%, young adults 13.8%, young-middle adults 19%, middle adults 27.6%, old adults 19%, and 12.1% are in the broad category of adults. Comparing adults to non-adults; 91% of the assemblage are adults (aged 18 and over) and 9% of the assemblage are non-adults (aged 17 and younger).

Table 31 Isle of May age at death

Category	Age Range	n	% of Total Population
Neonate	0-2 mo	0	0
Infant	2 mo-2yr	0	0
Young Juvenile	2-6	0	0
Old Juvenile	7-12	2	3.4
Adolescent	13-17	3	5.2
Young Adult	18-24	8	13.8
Young-Middle Adult	25-34	11	19.0
Middle Adult	35-44	16	27.6
Old Adult	45+	11	19.0
Adult	18+	7	12.1

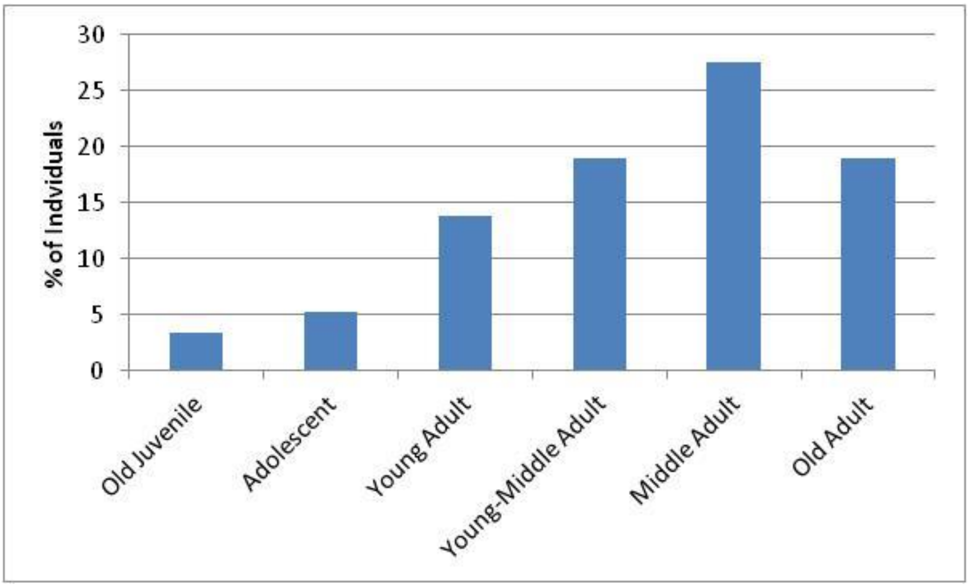


Figure 41 Isle of May age at death profile

4.2.2 Sex

In the Isle of May assemblage 51 of 58 skeletons could be sexed. There are 47 males, two probable males, one female, and one probable female. Sex for four adults could not be determined and three skeletons are unsexed non-adults. In the total population, males and probable males make up 85% of the population, females and probable females 3%, sexually indeterminate adults 7%, and unsexed non-adults 5%.

Among the 52 sexed skeletons, males make up 94.2% of the population and females make up 3.8%. Therefore the male to female ratio is 16.3:1 (Table 32; Figure 42).

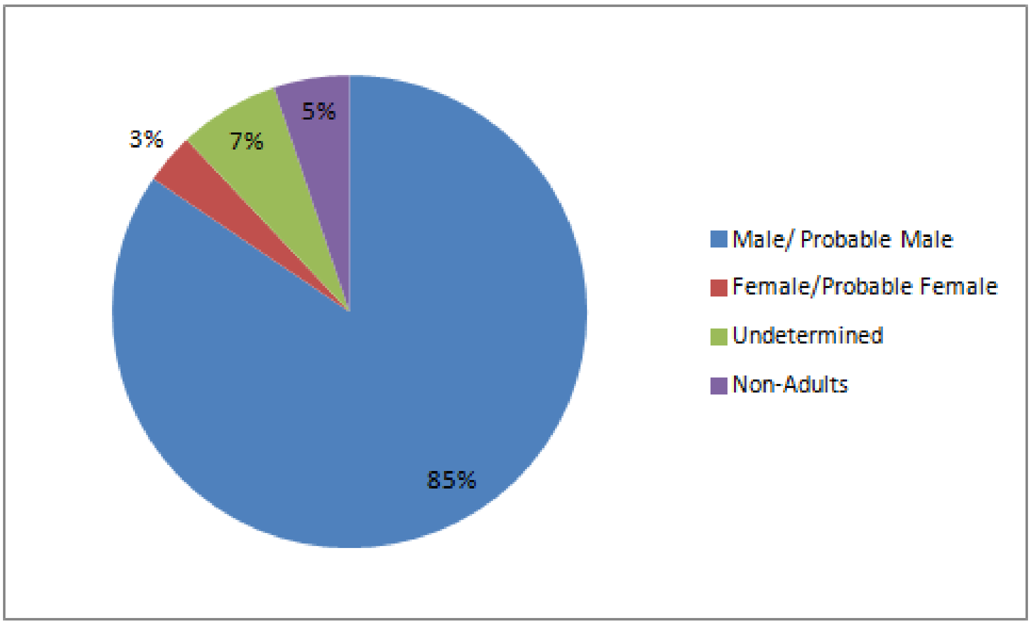


Figure 42 Isle of May sex profile

Table 32 Isle of May sex profile

Sex	n	Percentage
Male/Probable Male	49	84.5
Female/Probable Female	2	3.4
Undetermined	4	6.9
Non-Adults	3	5.2
Total	58	100

4.2.3 Stature Estimation

Of the sexed individuals, stature could be estimated for 46 skeletons; 45 males, or probable males, and one female, or probable female. For males, stature ranged from 158.51 cm to 183.74 cm with a mean of 170.68 cm and a standard deviation of 5.9 cm. There are no outliers, or individuals with stature outside the normal distribution. The stature for the one female that it could be estimated for was 162.77 +/- 3.66 cm. Since there is only one stature for females, a mean could not be calculated.

4.2.4 Pathological Conditions

In the Isle of May collection, 56 individuals (96.6%), have at least one type of pathological condition. Two individuals, or 3.4% of the total population, have no pathology that could be discerned from the skeleton. Twenty-eight individuals (49%) have pathology that could be placed into the category of infectious disease. Seven individuals (12%) have pathology that could be placed into the category of congenital disorders. Twenty-two individuals (37.9%) have lesions that could be placed into the category of trauma. There are 23 individuals (39.7%) that have pathological lesions in the category of metabolic disease. Forty-seven individuals (81%) have joint disease. Twenty-six individuals (44.8%) have dental disease. Seventeen individuals (29.3%) have pathology that could not be included into the previous categories and instead are pooled into a broad category of 'other' disease (Figure 43).

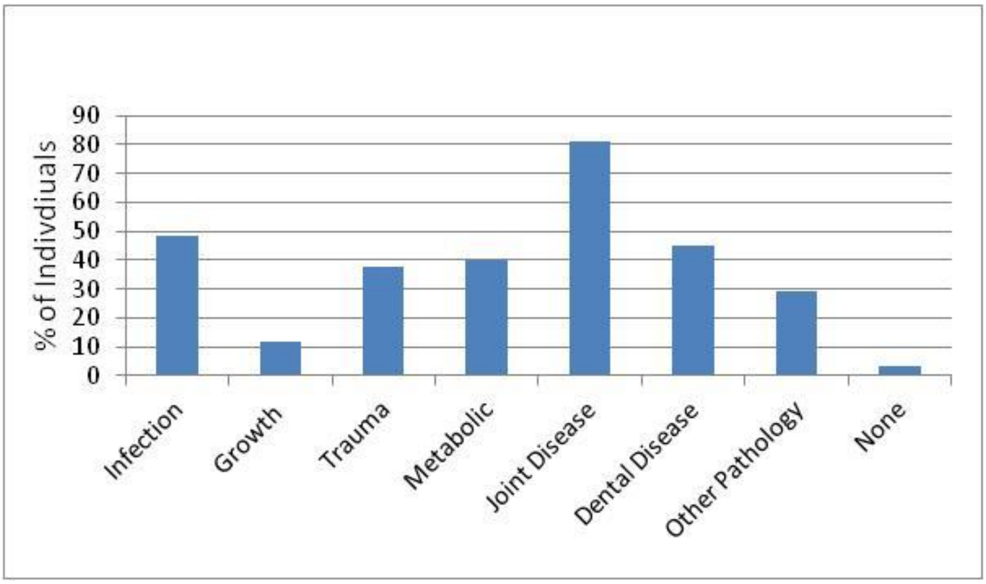


Figure 43 Isle of May pathology profile

4.2.5 Infection

Out of the 28 individuals that showed symptoms of infection in the Isle of May assemblage, 21 (75%) had a non-specific infection.

4.2.5.1 Non-Specific Infections

4.2.5.1.1 Periostitis and Osteomyelitis

There are 21 individuals in Isle of May that have periostitic lesions. The lesions in SK 379 (AD male), SK 967 (YMA male), SK 1042 (MA male), and SK 1137 (MA male) are associated with trauma on the same bone. Fourteen out of twenty-one skeletons (two-thirds) with periostitic lesions have them on their tibiae. Table 33 lists the skeletons and bones that are affected by periostitic lesions and the bones that have periostitic lesions due to trauma. There are two individuals with osteomyelitis in the Isle of May assemblage, SK 848, an old adult male, has possible osteomyelitis of the sternum, and SK 997, an adolescent male, has osteomyelitis of the lower leg and foot associated with either tuberculosis or congenital syphilis, which will be discussed further in the following section. SK 982, an adult male, has active and healed periostitis on the fibula, femur, and tibia. The distal end of the fibula is swollen and also appears to have a healed cloaca. This is possibly a case of osteomyelitis or could also be periostitis with a chronic infection due to both active and healed lesions. The trabeculae of both fibula and femur are striated, indicating quick bone repair possibly from infection. Another possible diagnosis could be septic arthritis or a ligament infection due to healed periostitis at the linea aspera. There may have been more abnormal bone growth on the tibia, however it is too fragmented to make a certain diagnosis.

Table 33 Cases of periostitis in Isle of May

Skeleton	Bones Affected by Periostitis	Bones with Trauma
SK 379	Tibia, Fibula	Fibula
SK 435	Ulna, Carpal, Metacarpal	
SK 832	Tibia, Fibula, Calcaneus	
SK 833	Femur	
SK 837	Femur, Tibia, Fibula	
SK 848	Mandible	
SK 853	Femur, Tibia	
SK 859	Femur, Tibia, Calcaneus, Talus	
SK 959	Tibia	
SK 967	Rib	Rib
SK 970	Radius, Ulna, Ribs, Femur, Tibia, Fibula	
SK 980	Femur, Tibia	
SK 982	Femur, Tibia, Fibula	
SK 993	Femur	
SK 995	Tibia	
SK 1022	Femur	
SK 1025	Femur	
SK 1042	Rib, Femur, Tibia, Fibula	Tibia and Fibula Dislocation
SK 1137	Femur, Tibia, Fibula	Tibia and Fibula Dislocation
SK 1138	Femur, Tibia, Fibula	
SK 1211	Femur, Tibia, Fibula	

4.2.5.1.2 Tuberculosis

Two individuals have possible tuberculosis. SK 972, an old juvenile, has many affected bones. The 6th and 7th cervical vertebrae are fused together and the 2nd cervical vertebrae through the 7th cervical vertebrae have resorbed bodies (Figure 44). The 1st through the 3rd thoracic vertebrae and the 4th through the 9th thoracic vertebrae are fused together at the spinous processes and the bodies have been resorbed almost completely (Figure 45). The spine has both scoliosis and kyphosis. The pathology on the spine indicates tuberculosis that led to resorption of the vertebral bodies, resulting in kyphosis of those vertebrae and a severe curvature of the spine commonly referred to as 'Pott's Disease' (Aufderheide and Rodríguez-Martín 1998, Resnick 2002) (section 3.1.8.1). It is possible this child was paralyzed or had other neurological complications due to the severe curvature of the spine (Lewis 2011, Turgut 2001, Waldron 2009). Related to the curvature of the spine are the clavicles that have an abnormal curvature and the medial articular surfaces have abnormal shapes, possibly due to resorption. The scapulae are also affected with new bone growth. The unfused head of the humerus appears partly resorbed. The ribs also have an abnormal curvature and the sternal articular surfaces are abnormal.

Figure 44 SK 972 'Pott's disease'-tuberculosis; lateral view of cervical and thoracic vertebrae

Figure 45 SK 972 Resorption of cervical vertebrae- tuberculosis; superior view

SK 997 has a possible diagnosis of either tuberculosis or congenital syphilis but will be discussed in the following section under syphilis, the more likely diagnosis.

4.2.5.1.3 Possible Syphilis

As mentioned previously, SK 997, an adolescent male, has a possible diagnosis of either tuberculosis or congenital syphilis. SK 997 is the only skeleton in the Isle of May collection with a possible diagnosis of syphilis. There is widespread periostitis affecting the mandible, right clavicle, eight right and left ribs, sacrum, and right and left innominates. The femora are extremely light and thin most likely due to atrophy from disuse. Both tibiae have severe osteomyelitis with cloacae and the trabecular bone has been mostly resorbed. Both fibulae are swollen at the distal ends with osteomyelitis and also have no trabecular bone from resorption. There are six foot bones present and they lack any trabecular bone; the bones appear to have formed osteomyelitic sheaths (Figure 46), referred to as dactylitis or spina ventosa and common in both childhood tuberculosis and congenital syphilis (Ortner 2003) (section 3.1.8.1). There are periostitic lesions on three ribs. This skeleton has both osteomyelitis and possible osteoporosis but which condition is primary is not clear or if there is an underlying cause of both. Other possibilities are haematogenous osteomyelitis, tuberculosis, or brucellosis.

Figure 46 Metatarsals of SK 997

4.2.5.1.4 Hypertrophic Pulmonary Osteoarthropathy

SK 814, an adolescent male, and SK 1030, also an adolescent, appear to have Hypertrophic Pulmonary Osteoarthropathy, or HPO (section 3.1.8.1). SK 814 has widespread periostitis on the humerus and radius; the lesions are bi-lateral on the ulnae, os coxae, and femora (Figure 47). The largest areas of periostitis are on the femora, right humerus, and right ulna. The periostitis on the innominates might be healing or healed from an earlier episode of the infection. The bilateral periostitis is a diagnostic feature of HPO, making this a likely candidate (Aufderheide and Rodríguez-Martín 1998, Ortner 2003, Resnick 2002). SK 1030 has small amounts of active periostitis on the right femur, a moderate degree of periostitis on the left femur, small amounts of healed and active periostitis on the right tibia, and healed periostitis on the left tibia. The periostitis is for the most part bilateral, which could indicate HPO, although with less severity than SK 814.

Figure 47 SK 814 Bilateral periostitis of the left and right femora; lateral views

4.2.5.1.5 Labyrinthitis

There are three skeletons with labyrinthitis, or inner ear infection. SK 924, a middle adult male, SK 955, a young-middle adult male, and SK 957, a young-middle adult male, all have lytic lesions on the endocranium of both temporals, consistent with ear infections. The infections were not active at the time of death.

4.2.6 Congenital Disorders

In the Isle of May collection there are seven skeletons, or 12% of the population, with pathology that could be placed into the category of congenital or growth disorder. Four (57%) of these have a congenital anomaly of the spine and three (43%) have an extra-spinal anomaly.

4.2.6.1 Spina Bifida and Spina Bifida Occulta

Of the seven skeletons with congenital disorders, three have spina bifida or spina bifida occulta. Spina bifida is only diagnosed in the sacrum if all five neural arches in the sacral bodies are unfused. Spina bifida occulta, is found in SK 888 and SK 980. SK 971, a young adult male, is the only skeleton with complete spina bifida of sacral bodies 1-5 (Table 34).

Table 34 Spina bifida and spina bifida occulta in The Isle of May

Skeleton	Anomaly
SK 888	Spina Bifida Occulta
SK 971	Spina Bifida
SK 980	Spina Bifida Occulta

4.2.6.2 Spinal Congenital Anomalies (except for Spina Bifida and Spina Bifida Occulta)

Of the seven skeletons with congenital disorders, three have a spinal anomaly other than spina bifida or spina bifida occulta. SK 971, a young adult male, has lumbarization of the 1st sacral vertebra as well as an unfused neural arch in the 1st cervical vertebra. SK 980, a young adult male, has the 9th and 10th thoracic vertebrae fused together at the spinous processes. SK 1138, a young adult male, has partial lumbar sacralization of the 5th lumbar vertebra.

4.2.6.3 Extra-Spinal Congenital Anomalies

There are five skeletons in the Isle of May that have an extra-spinal congenital anomaly (Table 35). The right and left first metatarsals on SK 385 appear to be dislocated but the abnormality appears to be congenital. There are extra articular facets on the 1st and 2nd metatarsals and the navicular is also affected with possible extra attachment to cartilage. SK 971 has an abnormally large head that is most likely due to hydrocephaly (Figures 50, 51), possibly connected to the unfused neural arch of C1 mentioned previously (Daroff et al. 2012) (section 3.1.8.2). When skull metrics are compared between all Isle of May skulls SK 971 has the longest maximum length, the widest maximum breadth, the longest basion to bregma measurement, the widest minimum frontal breadth, and the longest total facial height. SK 971 is also an outlier for the minimum frontal breadth measurement, although the difference is not statistically significant. The deviation from normal basion-bregma measurements is also substantial, however the trend is likewise not statistically significant (Figure 48). The lumbarization of the first sacral vertebra and spina bifida from the 1st to the 5th sacral vertebra have already been mentioned in earlier sections, but are most likely related to the other congenital deformities this individual has. The right and left naviculars are fused onto the calcanei, a condition often referred to as tarsal coalition (Figure 49 and section 3.1.8.2). According to Zimmerman and Kelley (1982:31) spina bifida can be associated with hydrocephalus and clubfoot, therefore it seems that this individual's skeletal deformities may all be related. A possible diagnosis is an acrocephalopolysyndactyly disorder such as Apert's Syndrome, which includes hydrocephaly and tarsal fusion, or Carpenter's Syndrome, which includes hydrocephaly and spina bifida occulta, where the sacrum laminae are unfused (Aufderheide and Rodríguez-Martín 1998, Daroff et al. 2012) (section 3.1.8.2). Both of these diagnoses would have been associated with mental retardation (Aufderheide and Rodríguez-Martín 1998).

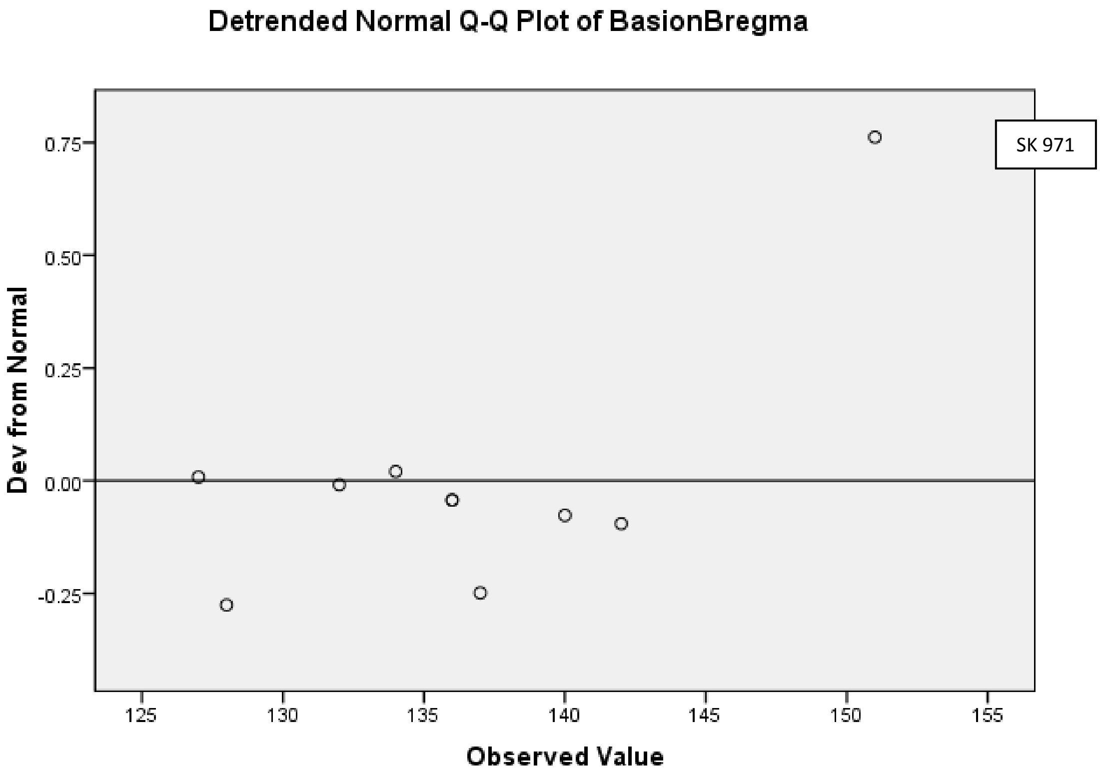


Figure 48 Isle of May basion-bregma measurement

Figure 49 SK 971 Tarsal coalition of left and right calcanei and naviculars; lateral view

Figure 50 SK 971 (left) compared to SK 1120 (an average male skull); anterior view

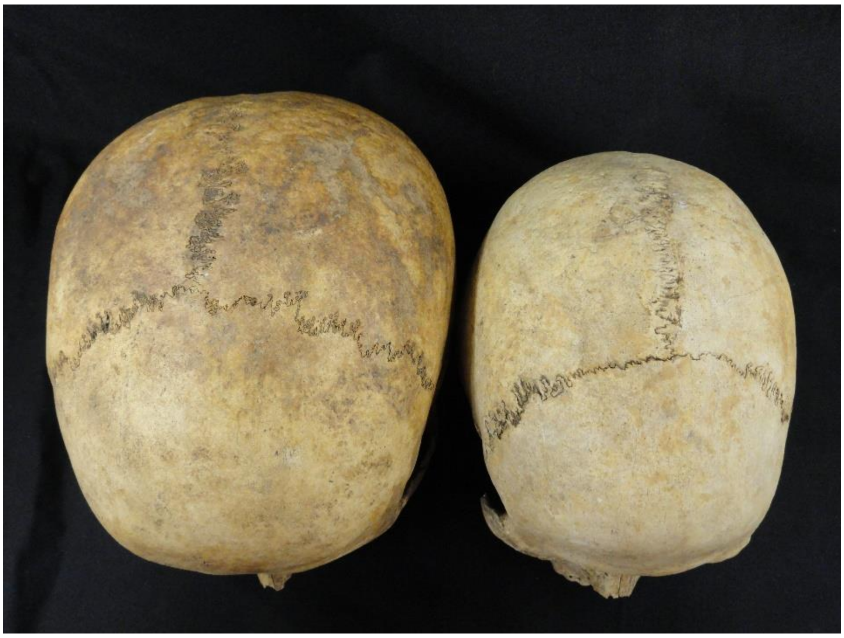


Figure 51 SK 971 (left) compared to SK 1120 (average male skull); superior view

SK 980, a young adult male, has an abnormal head shape head due to premature cranial suture fusion. SK 1022, a young adult male, has a slight posterior twisting of the proximal ends of humerii. In SK 1025, a young-middle adult male, both clavicles are twisted anteriorly at the lateral ends. The distal left radius is twisted posteriorly and the proximal right radius is twisted laterally. While the twisting in the left radius appears to be due to a healed fracture, the twisting in the clavicles and right radius appear to be congenital in nature, however they could also be due to activity.

Table 35 Extra-spinal anomalies in The Isle of May

Skeleton	**Anomaly**
SK 385	1st Metatarsal Dislocated Congenitally
SK 971	Hydrocephaly, Fusion of Metatarsals
SK 980	Abnormal Cranial Suture Fusion
SK 1022	Twisted Humerus
SK 1025	Twisted Clavicles and Radii

4.2.7 Trauma

In the Isle of May assemblage 22 individuals, or 38%, suffered from trauma and 10, or 45%, of those individuals have one or more healed fractures. Table 36 lists the number and percentage of individuals with fractured bones by bone element.

Table 36 Isle of May fractures

N = total number of individuals with bone present, n = number of individuals with fracture, CPR= percentage of individuals with fractures

Bone	N	n	CPR
Cranium	37	1	2.7
Mandible	32	0	0
Clavicle	34	0	0
Scapula	41	2	4.9
Rib	41	3	7.3
Vertebra	47	5	10.6
Innominate	45	1	2.2
Humerus	40	0	0
Radius	44	1	2.3
Ulna	46	1	2.2
Metacarpal	47	2	4.3
Hand Phalanx	49	0	0
Patella	38	0	0
Femur	47	0	0
Tibia	41	0	0
Fibula	38	1	2.6
Metatarsal	38	0	0
Foot Phalanx	37	0	0

4.2.7.1 Post-cranial Fractures

There are nine individuals with healed fractures in the post-cranial skeleton. Fractures are reported by bone element in separate sections below.

4.2.7.1.1 Long Bone Fractures

One individual (SK 1025), out of forty-four individuals with at least one radius present has a fractured radius. One individual out of forty-six individuals with at least one ulna present has a fractured ulna. SK 815, a middle adult male, has a parry fracture on the right ulna. A parry fracture is a fracture located on the distal ulna and is often sustained from a defensive motion or from breaking a fall. One individual, out of thirty-eight individuals with at least one fibula present, has a fibula fracture. SK 379, an adult male, has a healed fracture at the proximal end of the right fibula. Of all the long bones, the fibula has the highest percentage of fractures at 2.6% of individuals with a fibula present (Figure 52). Males are the only ones with long bone fractures in the Isle of May, but this is not significant as the majority of the remains belong to males.

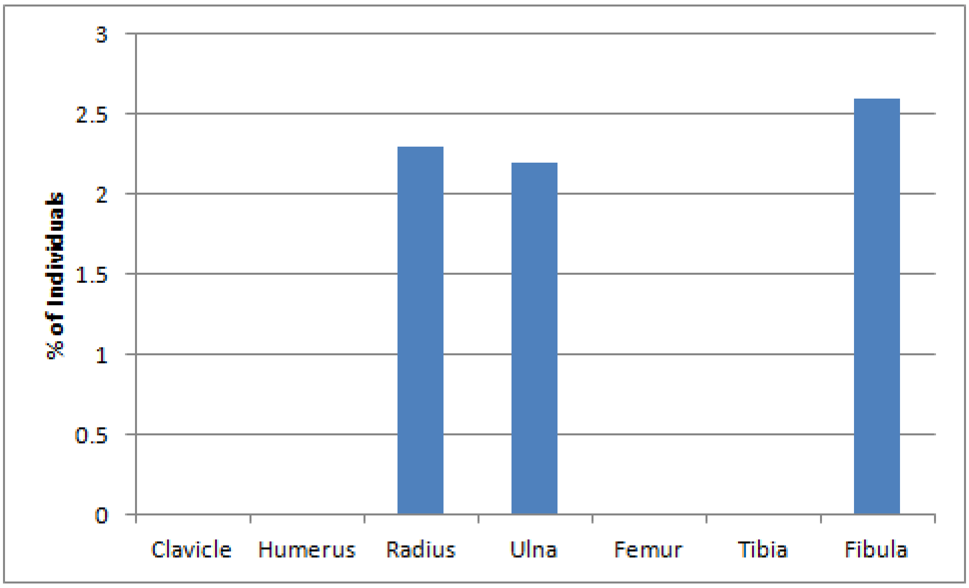


Figure 52 Isle of May long bone fractures

4.2.7.1.2 Non-Long Bone Fractures

Two out of forty-one individuals with at least one scapula present have trauma to the scapula in the Isle of May assemblage. There are three individuals, out of forty-one individuals with at least one rib present, with a rib fracture. Five individuals, out of 47 with at least one vertebra present, have a vertebra fracture. Fractures to the vertebrae are the most common in the Isle of May assemblage with 10.6% of the population with at least one vertebra present (Figure 53). There are two individuals, out of forty-seven with at least one metacarpal present, with a metacarpal fracture. All non-long bone fractures are in male individuals.

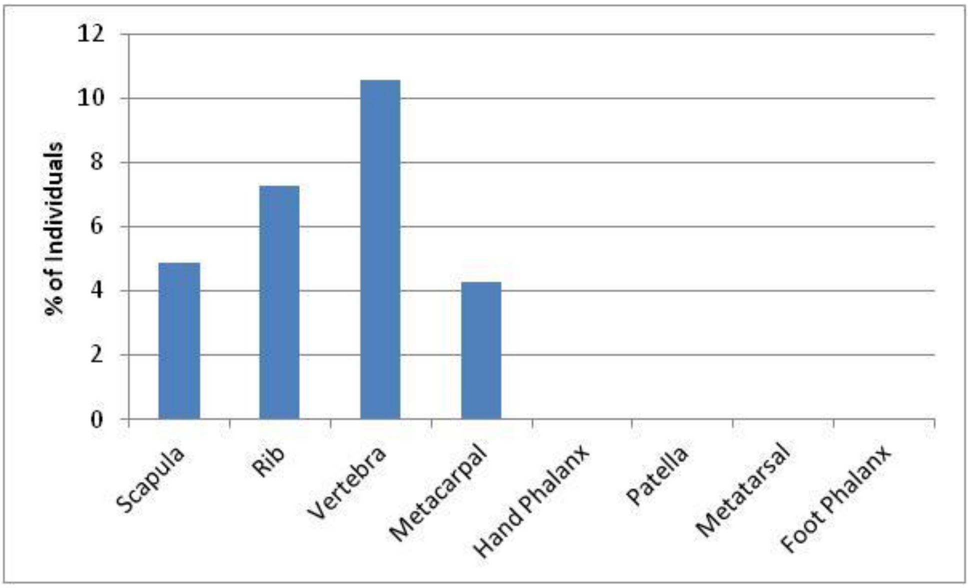


Figure 53 Isle of May non-long bone fractures

4.2.7.2 Cranial Trauma

Out of thirty-seven individuals with a skull present, one had trauma to the skull. SK 1211, a young-middle adult male, has a possible depressed fracture or healed lytic lesion on the right parietal. The right supraorbital torus has a depression that is 15.3mm long and 3.5mm wide that appears to be indicative of healed trauma, such as an accidental or deliberate blow to the head.

4.2.7.3 Spondylolysis and Spondylolisthesis

There is one case of spondylolisthesis, SK 815, a middle adult male, in the Isle of May assemblage out of forty-three individuals with at least one vertebra present.

4.2.7.4 Osteochondritis Dissecans

There are nine cases of osteochondritis dissecans in the Isle of May assemblage (Table 37).

Table 37 Osteochondritis dissecans in Isle of May

Skeleton	Joint(s) Affected
SK 440	Foot
SK 832	Foot
SK 853	Wrist
SK 887	Foot
SK 971	Foot
SK 1030	Spine
SK 1042	Foot
SK 1120	Hand
SK 1137	Knee

4.2.7.5 Other Trauma

There are six individuals with other types of healed trauma in the Isle of May assemblage (Table 38). Related to the 1st lumbar compression that SK 868, an old adult male, has is a possible fusion of the 2nd lumbar to the 1st or 3rd lumbar vertebrae. There was most likely kyphosis at the fused area. Unfortunately, there was too much post mortem damage to be able to make a more accurate diagnosis. The proximal end of the left fibula in SK 957, a young adult male, has ossified cartilage that might indicate a dislocated or twisted knee and tendons tore and reformed. There are enthesophytes on the patella that corresponds to a possible knee dislocation. In SK 985, a young-middle adult male, the styloid processes on the right and left 5th metatarsals have been resorbed. A possible diagnosis could be osteochondritis dissecans, but other disease processes could be possible, such as avulsion fractures. SK 987, an old adult male, has a healed fracture of the ilium that could have been caused by a high impact collision of a cart or other heavy object hitting the side of his body (Simon Mays pers. comm.) (Figure 54). SK 1042 and SK

1137, both middle adult males, have Pott's fractures comprising of exostoses of interosseous crest on both tibiae and fibulae that are indicative of a probable dislocation.

Figure 54 SK 987 Healed fracture of the left ilium

Table 38 Trauma other than fractures in Isle of May

Skeleton	**Trauma**
SK 868	Possible Vertebrae Fusion and Kyphosis
SK 957	Knee Dislocation
SK 985	Metatarsal Styloid Process Resorption
SK 1042	Ankle Dislocation
SK 1137	Ankle Dislocation

4.2.8 Metabolic Disease

There are 23 individuals, or 39.7% of the population, with metabolic disease.

4.2.8.1 Cribra Orbitalia and Porotic Hyperostosis

There are ten individuals, out of thirty-five individuals with at least one orbit present, with cribra orbitalia. Out of 38 individuals with a skull or part of a skull present, 14 individuals have porotic hyperostosis. Five individuals have both cribra orbitalia and porotic hyperostosis in the Isle of May (Figure 55).

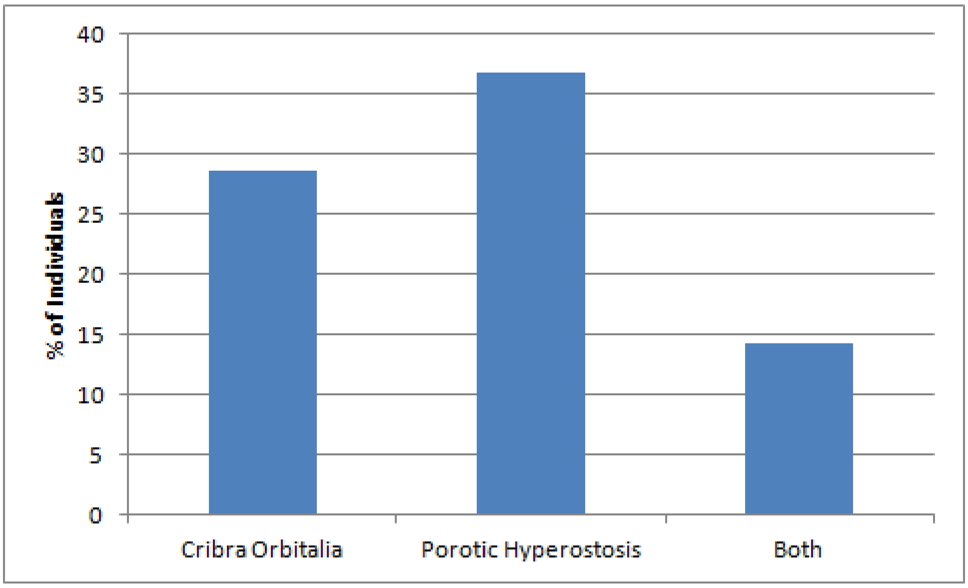


Figure 55 Isle of May cribra orbitalia and porotic hyperostosis

4.2.8.2 Rickets

There are no individuals identified with rickets in the Isle of May assemblage.

4.2.8.3 Osteopenia and Osteoporosis

There are four individuals in the Isle of May assemblage with probable osteopenia and all were male. No individuals with osteopenia have bone fractures; therefore there are no cases of osteoporosis.

4.2.9 Joint Disease

The highest percentage of disease in the Isle of May falls into the category of joint disease. There are 47 individuals (81%) with joint disease.

4.2.9.1 Extra-Spinal Arthropathies

There are 38 individuals (65.5%) with extra-spinal arthropathies. Table 39 lists the counts and percentages of arthropic changes by joint. The highest percentage of arthropic changes is in the shoulder joints, at 52.3% of the population with at least one shoulder joint surface present (Figure 56). The joint with the lowest percentage of arthropathies is the ankle, with 19.5% of the population with at least one ankle joint surface present.

Table 39 Extra-spinal arthropathies at Isle of May

Joint(s)	**N**	**N**	**CPR**
Shoulder	44	23	52.3
Sterno-clavicular	33	11	33.3
Acromio-clavicular	32	15	46.8
Elbow	45	19	42.2
Wrist	45	16	35.5
Hand	48	12	25.0
Hip	48	16	33.3
Knee	48	21	43.7
Ankle	41	8	19.5
Foot	41	15	36.5

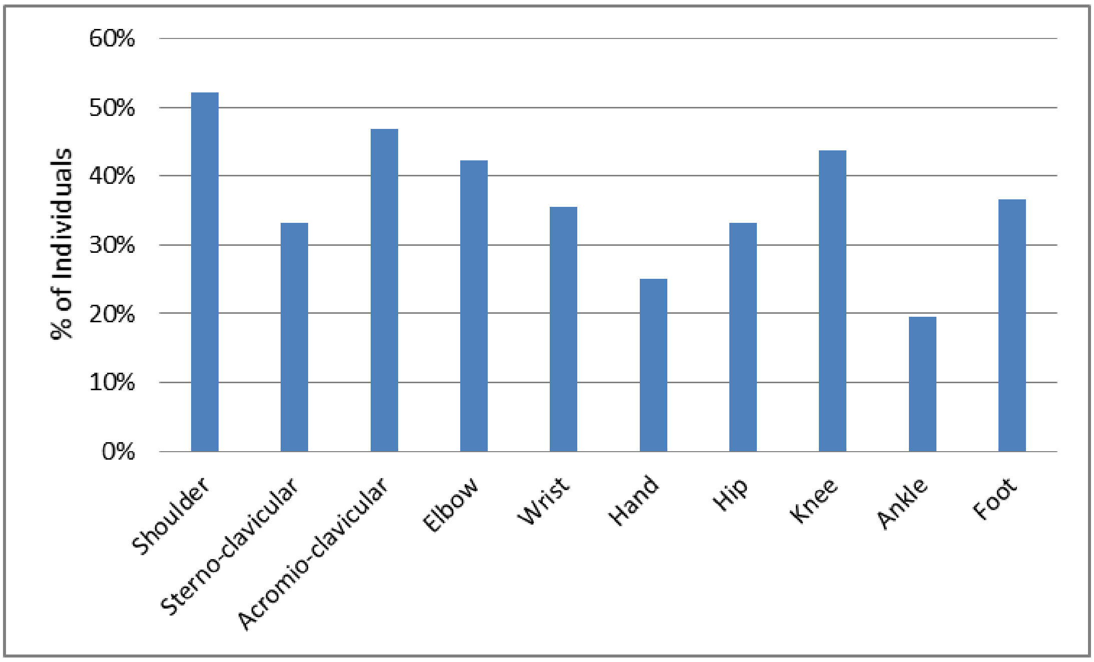


Figure 56 Extra-spinal arthropathies by bone type at Isle of May

Figure 57 demonstrates the differences in percentages of arthropathies in each joint for males and females. Since the Isle of May population is almost all male, most of the arthropathies are in male skeletons (Table 40).

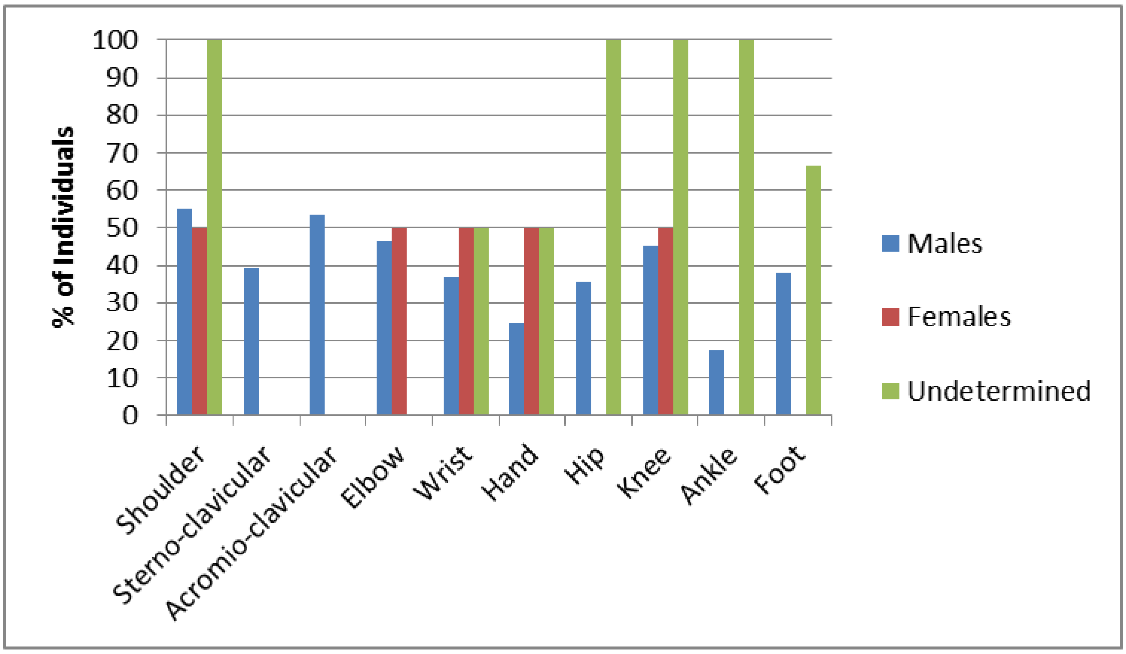


Figure 57 Isle of May extra-spinal arthropathies by sex

Table 40 Isle of May crude prevalence rates of extra-spinal arthropathies in adult skeletons

Joint (s)	Male			Female			Undetermined		
	N	n	CPR	N	n	CPR	N	n	CPR
Shoulder	38	21	55.3	2	1	50	1	1	100
Sterno-clavicular	28	11	39.3	1	0	0	1	0	0
Acromio-clavicular	28	15	53.6	1	0	0	1	0	0
Elbow	39	18	46.2	2	1	50	1	0	0
Wrist	38	14	36.8	2	1	50	2	1	50
Hand	41	10	24.4	2	1	50	2	1	50
Hip	42	15	35.7	2	0	0	1	1	100
Knee	42	19	45.2	2	1	50	1	1	100
Ankle	34	6	17.6	2	0	0	2	2	100
Foot	34	13	38.2	1	0	0	3	2	66.7

4.2.9.2 Spinal Joint Disease

Seventeen individuals out of 42 with at least one cervical vertebra present, have cervical spinal joint disease (Figure 58). Out of 44 individuals with at least one thoracic vertebra present, 34 individuals (77.3%) have thoracic spinal joint disease. Out of 42 individuals with at least one lumbar vertebra present, 33 individuals (78.6%) have lumbar spinal joint disease.

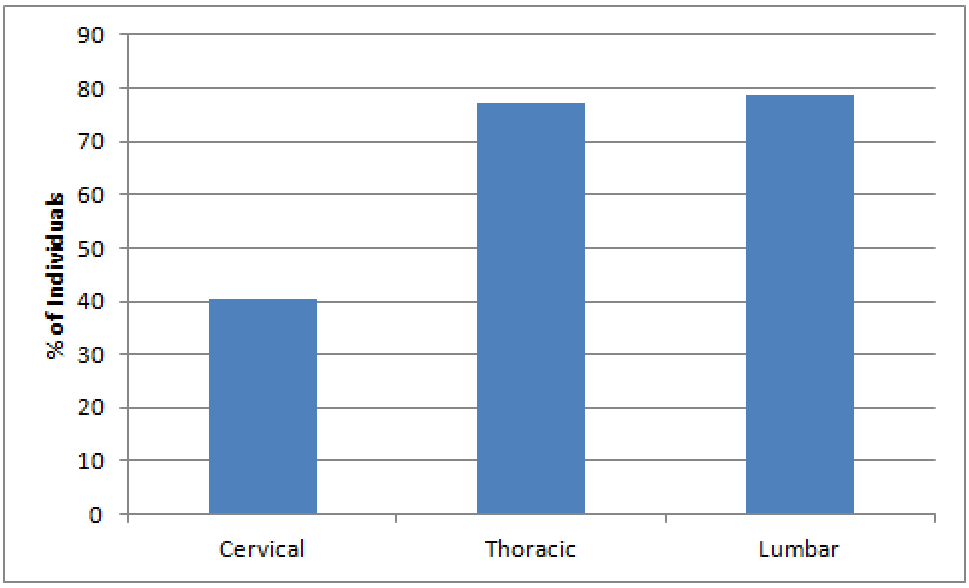


Figure 58 Spinal joint disease in Isle of May

4.2.10 DISH and eDISH

There are two possible cases of incipient DISH (or eDISH) in the Isle of May assemblage, SK 848 and SK 987. SK 848 is an old adult male likely between the ages of 45 and 64. There are exostoses and strong enthesophytes on many bones. Bony lipping and spurs are indicative of osteoarthritis. However, the 3rd and 4th lumbar vertebrae are fused, which could indicate eDISH or other ankylosing disorders (section 3.1.8.5). There are also many bony spurs throughout the skeleton, therefore eDISH would be supported. For a diagnosis of DISH, fusion of four contiguous vertebrae is required (Waldron 2009). SK 987 is another extreme bone former. This individual is an old adult male likely over the age of 45. This skeleton possibly has DISH or eDISH based on fusion of the 8th and 9th thoracic vertebrae with candle-wax looking bone (Figure 59). There is osteophytic bridging on most of the spine and fusion of the right sacro-iliac joint. There is hyperostosis on most of the skeletal elements present including the scapula, ulna, trapezium, sternum, vertebra, sacrum, innominates, patella, calcaneus, femur, and tibia. The hand phalanges have strong enthesophytes, related to the rest of bone forming but could also mean this individual used his hands extensively producing strong muscles. Lumbar vertebrae have ossification of the anterior ligament especially at the 3rd and 4th lumbar vertebrae. The 5th lumbar vertebra is sacralized from ossification. Again, for a conclusive diagnosis of DISH, the skeleton requires four contiguous vertebrae to be fused, and this skeleton has only two. Nevertheless, with the fusion of the sacroiliac joint and the sacralization, this skeleton is a strong candidate of either eDISH, or another ankylosing disorder such as ankylosing spondylitis.

Figure 59 SK 987 incipient DISH; lateral view

4.2.11 Dental Disease

Out of the total population at the Isle of May 26 individuals (44.8%) have dental disease. There are 18.6%, or eight individuals out of 43 individuals with at least one tooth present, with dental caries (Table 41). There are 20.9%, or nine individuals, with a dental abscess. There are 13 individuals (30.2%) with antemortem tooth loss. Eleven individuals (25.6%) have enamel hypoplasia. There is no significant relationship between age or sex and any of the dental diseases.

Table 41 Dental disease in Isle of May by individual

Disease	**N**	**n**	**CPR**
Caries	43	8	18.6
Abscesses	43	9	20.9
Antemortem Tooth Loss	43	13	30.2
Enamel Hypoplasia	43	11	25.6

Prevalence of dental disease by tooth was also assessed. Out of 778 teeth present, 17 (2.2%) have caries, 16 (2.1%) have abscesses, and 172 (22.1%) have enamel hypoplasia. Table 42 lists the counts and percentages of dental disease in Isle of May by tooth.

Table 42 Dental disease in Isle of May by tooth

Disease	N	n	TPR
Caries	778	17	2.2
Abscesses	778	16	2.1
Enamel Hypoplasia	778	172	22.1

4.2.12 Other Disease

There are 17 individuals (29.3%) of the population with disease that could not be placed into one of the above categories (Table 43).

SK 831, a middle adult male, has a large abscess at the right 2nd maxillary molar. It appears the abscess led to an infection that spread throughout the skeleton. SK 832 is a young adult male likely between the ages of 18 and 25. The 11th and 12th thoracic vertebrae and the 1st lumbar vertebra are square in shape. The irregular shape and amount of disc degeneration indicates a probable case of Scheuermann's Disease, which typically affects adolescent males (Aufderheide and Rodríguez-Martín 1998) (section 3.1.8.5). SK 859, an old adult male, has multiple lesions on its skeleton including proliferative lesions on the right and left innominates that appear mossy and nodular. The right innominate has a 23.2mm x 17.1mm proliferative lesion on the iliac fossa which penetrated the bone to the other side (Figures 60 and 61). There are proliferative lesions on much of the ischium and superior to the auricular surface on both the medial and lateral ilia. The osteoblastic lesions are suggestive of metastatic carcinoma of the prostate, which often have a mossy appearance (Ortner 2003). There are also lytic lesions on the distal humerus, axis, 12th thoracic vertebra, distal femur, and right 1st metatarsal. There are enlarged foramina on many bones, suggesting the elements are hypervascular, which along with the lesions indicates the cancer was likely spreading throughout the body (Ortner 2003). Other possible diagnoses include Ewing’s sarcoma and osteochondroma. However, the diagnosis of metastatic carcinoma of the prostate is more likely, a diagnosis that was also deemed probable by paleopathology expert Simon Mays (pers. comm.).

Figure 60 SK 859 Blastic lesion on right innominate; lateral view

Figure 61 SK 859 Blastic lesion zoom

SK 971, a young adult male, was mentioned previously for its congenital deformities. This skeleton also has hydrocephaly, which although could also be a congenital condition, is mentioned here because it has extensive etiology that potentially also includes trauma, infections, or tumors (Aufderheide and Rodríguez-Martín 1998). SK 993, a middle adult female, has a hydatid cyst 12.2 mm x 9.4 mm in size which is caused by ingesting the fertilized ova of a tape worm from the genus *Echinococcus*. The parasite affects the liver or lungs by causing extreme necrosis of the tissue (Figure 62). Chronic conditions calcify the originally water filled cysts, which is the case in SK 993 (Aufderheide and Rodríguez-Martín 1998).

Figure 62 SK 993 Hydatid cyst

SK 1025, a young-middle adult male, has a small blastic lesion of unknown origin on the anterior surface of the body of L3.

Table 43 Other disease in Isle of May

Skeleton	Disease Process
SK 386	Lytic Lesion on Zygomatic
SK 815	Lytic Lesion on Ulna
SK 830	Lytic Lesion on Calcaneus
SK 831	Possible Blood Poisoning from Tooth Abscess
SK 832	Scheuermann's Disease
SK 837	Lytic Lesion on Foot Phalanx
SK 859	Metastatic Tumor, Prostate Cancer
SK869	Lytic Lesion on Hand Phalanx
SK 957	Lytic Lesion on Atlas
SK 970	Lytic Lesion on Maxilla
SK 971	Hydrocephaly
SK 981	Lytic Lesion on Carpals
SK 993	Hydatid Cyst
SK 1022	Lytic Lesion on Tibia
SK 1025	Blastic Lesion on Lumbar Vertebra
SK 1137	Lytic Lesion on Cervical Vertebra
SK 1211	Lytic Lesion on Humerus

4.2.13 Burial Location

4.2.13.1 Sex and Age by Burial Group

For the Isle of May assemblage there are six burial groups that were determined by the archaeologist of the excavation by stratigraphic evidence and radiocarbon dating. These six burial groups were combined into two assemblages, A and B, to make statistical tests more accurate due to larger counts (Table 44). In Assemblage A there are 29 males and one female. In Assemblage B there are 14 males and one female. Assemblage A includes: two adolescents, three young adults, seven young-middle adults, nine middle adults, and nine old adults. Assemblage B includes: four young adults, three young-middle adults, six middle adults, and two old adults. There is no statistical significance to where an individual was buried or their age or sex.

Table 44 Burial location demography at the Isle of May

				Sex		
				Male	Female	Total
Assemblage A	Age	ADL	Count	2	0	2
			% within Age	100.0%	.0%	100.0%
		YA	Count	3	0	3
			% within Age	100.0%	.0%	100.0%
		YMA	Count	7	0	7
			% within Age	100.0%	.0%	100.0%
		MA	Count	8	1	9
			% within Age	88.9%	11.1%	100.0%
		OA	Count	9	0	9
			% within Age	100.0%	.0%	100.0%
	Total		Count	29	1	30
			% within Age	96.7%	3.3%	100.0%
Assemblage B	Age	YA	Count	4	0	4
			% within Age	100.0%	.0%	100.0%
		YMA	Count	2	1	3
			% within Age	66.7%	33.3%	100.0%
		MA	Count	6	0	6
			% within Age	100.0%	.0%	100.0%
		OA	Count	2	0	2
			% within Age	100.0%	.0%	100.0%
	Total		Count	14	1	15
			% within Age	93.3%	6.7%	100.0%

4.2.13.2 Burial Location and Pathology

When chi-square tests were run between Assemblage A and Assemblage B and each category of disease it was determined there were no statistically significant differences.

4.3 St Andrews Library

4.3.1 Age at death

Of the 72 articulated skeletons in the St Andrews Library assemblage the age breakdown is as follows: one neonate, three infants, seven young juveniles, two old juveniles, six adolescents, four young adults, nine young-middle adults, 14 middle adults, and seven old adults (Table 45; Figure 63). Nineteen skeletons cannot be aged more specifically, and are placed into the broad adult category. Of the population, neonates account for 1.4%, infants 4.2%, young juveniles 9.7%, old juveniles 2.8%, adolescents 8.3%, young adults 5.6%, young-middle adults 12.5%, middle adults 19.4%, old adults 9.7%, and 26.4% in the broad category for adults. Comparing adults to non-adults; 72% of the assemblage are adults (aged 18 and over) and 28% of the assemblage are non-adults (aged 17 and younger).

Table 45 St Andrews Library age at death

Category	**Age Range**	**n**	**Percentage**
Neonate	0-2 mo	1	1.4
Infant	2 mo-2yr	3	4.2
Young Juvenile	2-6	7	9.7
Old Juvenile	7-12	2	2.8
Adolescent	13-17	6	8.3
Young Adult	18-24	4	5.6
Young-Middle Adult	25-34	9	12.5
Middle Adult	35-44	14	19.4
Old Adult	45+	7	9.7
Adult	18+	19	26.4

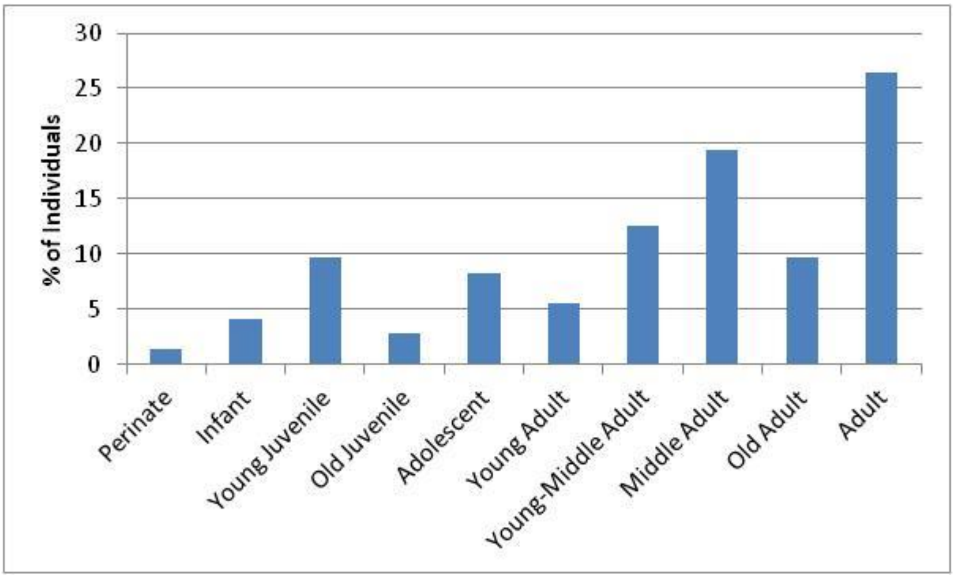


Figure 63 St Andrews Library age at death profile

4.3.2 Sex

In the St Andrews Library assemblage 46 of the 72 adult skeletons could be sexed. There are 27 males, three probable males, 14 females, and two probable females. Sex for 12 adult skeletons could not be determined and 14 skeletons are unsexed non-adults. Males and probable males make up 41.7% of the population, females and probable females 22.2%, undetermined adults 16.7% and unsexed non-adults 19.4%. On average, males at St Andrews Library were gracile, which made sex determination extremely difficult. Many skeletons showed both male and female traits, making sex determination impossible resulting in a high percentage of undetermined adults. Among the 46 sexed skeletons, males make up 65% of the population and females make up 35%. Therefore the male to female ratio is 1.9:1 (Table 46; Figure 64).

Table 46 St Andrews Library sex profile

Sex	N	Percentage
Male/Probable Male	30	41.7
Female/Probable Female	16	22.2
Undetermined	12	16.7
Non-Adults	14	19.4
Total	72	100

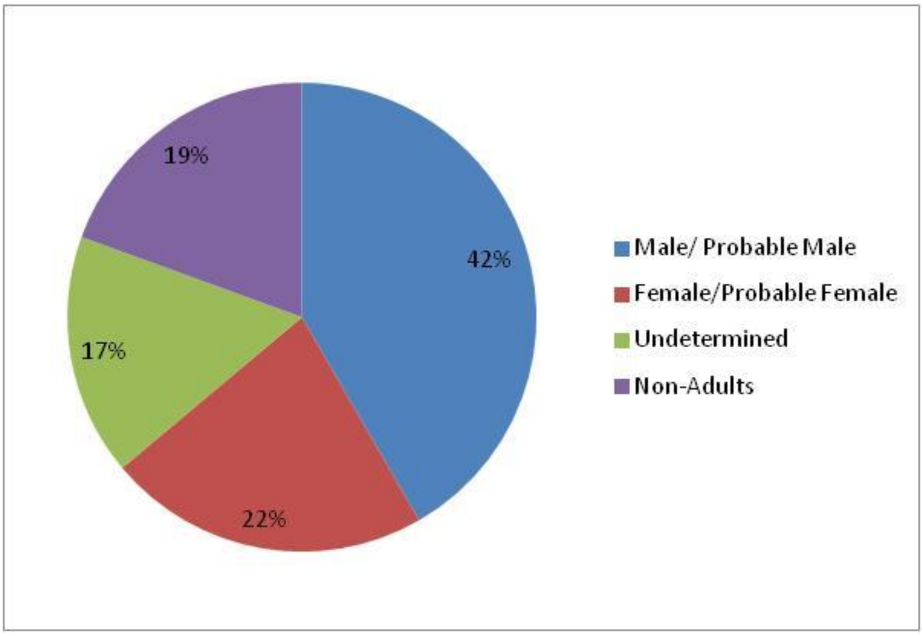


Figure 64 St Andrews Library sex profile

4.3.3 Stature Estimation

Of the sexed individuals in the St Andrews Library assemblage, stature could be estimated for 36 skeletons, 24 males or probable males and 12 females or probable females. For males, stature ranged from 148.52 cm to 176.71 cm with a mean of 165.28 cm and a standard deviation of 6.89 cm. For females, stature ranged from 145.89 cm to 162.93 cm with a mean of 158.65 cm and a standard deviation of 5.73 cm. There were no male or female outliers for stature.

4.3.4 Pathological Conditions

For the St Andrews Library assemblage 65 individuals (90.3%) have at least one type of pathological condition. Only seven individuals (9.7%) have no pathology that could be discerned from the skeleton. Forty-four individuals (61%) have pathological lesions consistent with infectious disease. Six individuals (8%) have pathology that could be placed into the category of congenital disorders. Twelve individuals (16%) have traumatic lesions. Twenty individuals (28%) have pathological lesions in the category of metabolic disease. Forty-seven individuals (65%) have pathology have joint disease. Twenty-seven individuals (37.5%) have dental disease. Seven individuals (10%) have pathology that could not be included in the previous categories and instead are placed into a broad category of 'other disease' (Figure 65).

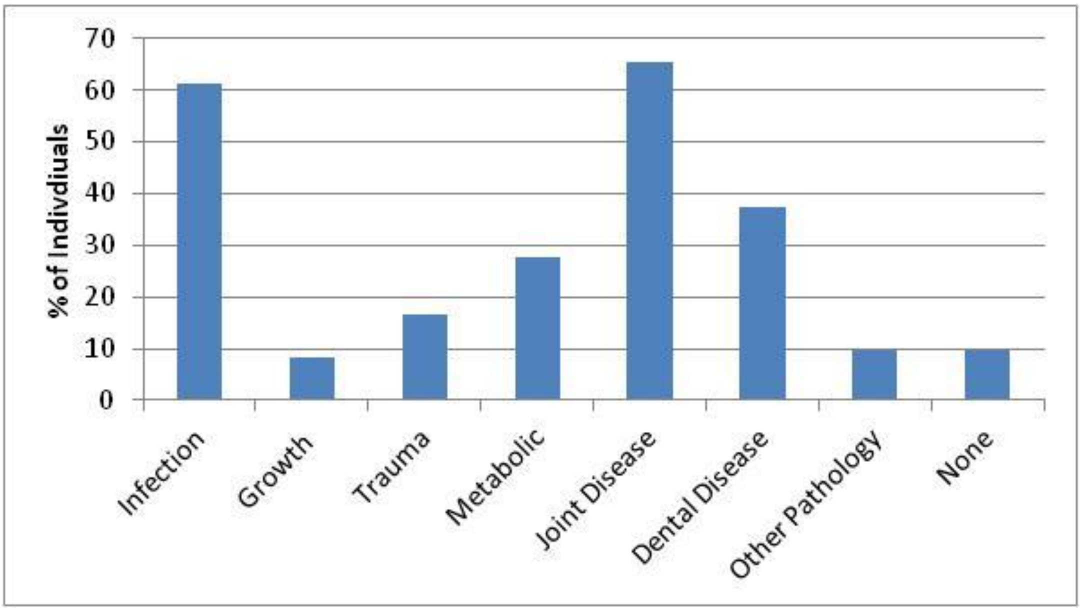


Figure 65 St Andrews Library pathology profile

4.3.5 Infection

Out of the 44 individuals that had infection in the St Andrews Library assemblage, 40 had a non-specific infection.

4.3.5.1 Non-Specific Infections

4.3.5.1.1 Periostitis and Osteomyelitis

There are 43 individuals in St Andrews Library material who have periostitic lesions (Table 47). The lesions in SK 31 are associated with trauma at the same bone. Thirty-six out of 43 (84%) with periostitic lesions have them on their tibiae (Figure 63). Twenty out of 43 (47%) with periostitic lesions have them on their femora. Eleven out of 43 (26%) with periostitic lesions have them on their fibulae. SK 53, a middle adult female, had both periostitis and osteomyelitis. SK 13, a young-middle adult female, and SK 62, a middle adult male have periostitis that is attributed to syphilis, therefore is represented in both sections for periostitis and syphilis. SK 63, an adult, has periostitic lesions that are associated with skin ulcers.

Table 47 Cases of periostitis in St Andrews Library

Skeleton	Bones Affected by Periostitis	Bones with Trauma
SK 10	Tibia, Fibula	
SK 11	Tibia	
SK 13	Zygomatic, Scapula, Ulna, Humerus, Femur, Tibia, Fibula	
SK 17	Femur	
SK 18	Femur, Tibia, Fibula	
SK 19	Humerus	
SK 20	Femur, Tibia	
SK 22	Femur, Tibia	
SK 23	Temporal	
SK 26	Femur, Tibia	
SK 28	Innominate	

Skeleton	**Bones Affected by Periostitis**	**Bones with Trauma**
SK 29	Tibia, Fibula	
SK 30	Femur, Tibia	
SK 31	Tibia, Fibula	Tibia and Fibula Dislocation
SK 36	Femur, Tibia	
SK 41	Tibia	
SK 43	Tibia	
SK 45a	Tibia	
SK 45b	Tibia	
SK 46	Tibia	
SK 47	Tibia, Fibula	
SK 48	Tibia, Fibula, Calcaneus	
SK 49	Femur, Tibia	
SK 50	Femur, Tibia	
SK 53	Tibia, Fibula	
SK 54	Femur, Tibia	
SK 55	Femur, Tibia	
SK 56	1st Maxillary Molar	
SK 57	Femur, Tibia	
SK 59	Femur, Tibia	
SK 60	Femur, Tibia, Fibula	
SK 61	Femur, Tibia	
SK 62	Humerus, Clavicle, Hand Phalanx, Ribs, Femur, Tibia, Fibula, Calcaneus, Metatarsals	
SK 63	Tibia, Fibula	
SK 64	Femur, Tibia	

Skeleton	Bones Affected by Periostitis	Bones with Trauma
SK 69	Femur, Tibia	
SK 70	Tibia	
SK 71	Tibia	
SK 73	Femur, Tibia	
SK 74	Tibia	
SK 79	Radius	
SK 80	Tibia	
SK 85	Radius	

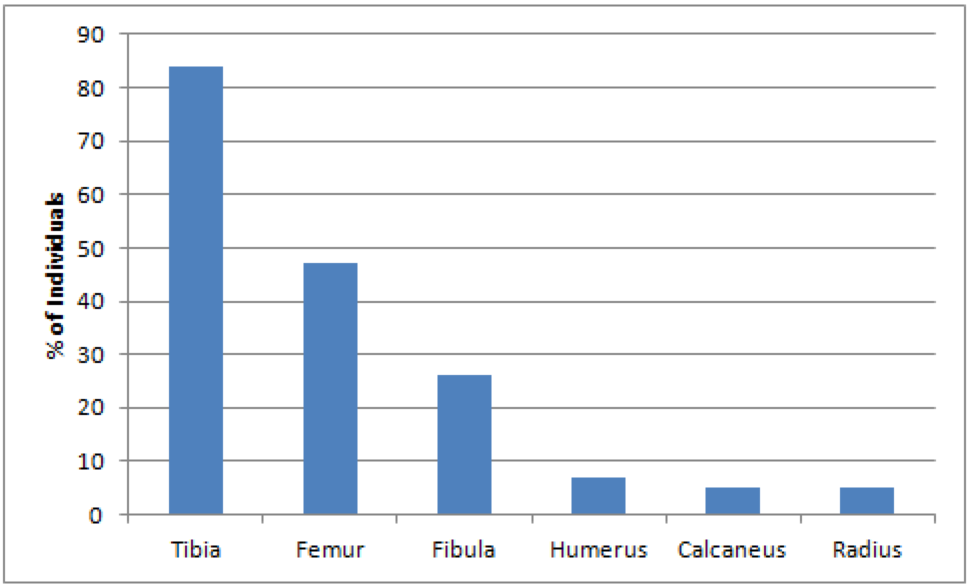


Figure 66 Distribution of periostitic lesions

There are two individuals with osteomyelitis: SK 15 and SK 53 (Table 48). SK 15, an adolescent, may represent a case of syphilis; therefore it is discussed in the following section. SK 53, a middle adult female, has a proximal hand phalanx with a lytic lesion on the palmar surface which may be a tumor. At the site of the lesion there is osteomyelitis.

Table 48 Cases of osteomyelitis in St Andrews Library

Skeleton	Bones Affected by Osteomyelitis	Fractured bones
SK 15	Tibia, Tarsals	
SK 53	Hand Phalanx	

4.3.5.1.2 Possible Syphilis

The St Andrews Library assemblage has three possible cases of syphilis: SK 13, SK 15, and SK 62. SK 13 is a young-middle adult female likely between the ages of 25 and 30. There are widespread healed and active periostitic lesions on the zygomatic, scapula, ulnae, left humerus, femora, tibiae, and fibulae. The thoracic vertebrae have enlarged foramina on their anterior bodies: "The periosteal involvement usually leads to hypervascularity, which is noticeable on the dry bone by the increased number and size of vascular channels and foramina" (Ortner 2003:320). There is also a small lytic lesion on the femoral head. The extensive periostitis on the legs may indicate a case of syphilis. The skull may have lesions present, however since there is only a small part of a parietal present a final diagnosis is uncertain.

SK 15 is an adolescent likely between the ages of 15 and 16. The skeleton has osteomyelitis on the tibia, ankles, and feet. The tibia has 7+ cloacae and is extremely swollen (Figure 67). This skeleton is a possible case of syphilis; however it is only 10% complete and does not have a skull present, so a diagnosis is ambiguous.

Figure 67 SK 15 Tibia with cloacae

SK 62 is a middle adult male likely between the ages of 35 and 45. This skeleton has healed periostitis on the left femur. There are active periostitic lesions on the humerus, clavicle, one proximal phalanx, sternum, right and left ribs, both tibiae and fibulae, both calcanei, right 1st and 5th metatarsals, and left 4th and 5th metatarsals. The amount of periostitis and the distribution of lesions, which worsens at the lower legs and ankles is consistent with syphilis, however, since the skull is not present it is difficult to attain a definite diagnosis. Since there are periostitic lesions on the sternum and ribs, tuberculosis could be another possible diagnosis.

4.3.5.1.3 Infected Skin Ulcers

SK 63, an adult, has lesions that suggest infected leg ulcers on the right and left tibiae both on the anterior surface of the distal end of the diaphysis (Figure 68). The ulcers are quite defined and protruding from the rest of the shaft. Along with the ulcers, both shafts are swollen with periostitis as well as the fibulae, and on the tibiae and fibulae there are bony outgrowths of bone related to ossification of periostitis (Ortner 2003).

Figure 68 SK 63 right tibia showing infected skin ulcers; lateral view

4.3.6 Congenital Disorders

In St Andrews Library there are six skeletons (8%) that have pathology that could be placed into the category of congenital or growth disorder. Three (50%) of these have a congenital anomaly of the spine, two (33%) have an extra-spinal anomaly, and one (17%) has both types of anomalies.

4.3.6.1 Spina Bifida and Spina Bifida Occulta

There are no cases of spina bifida or spina bifida occulta in the St Andrews assemblage.

4.3.6.2 Spinal Congenital Anomalies (except for Spina Bifida and Spina Bifida Occulta)

Of the six skeletons with congenital disorders, four have a spinal anomaly other than spina bifida or spina bifida occulta (Table 49). SK 24, a middle adult male, has six sacral vertebrae, SK 28, a young-middle adult male, has a hypoplastic sacrum, SK 73, young-middle adult male, has six lumbar and four sacral vertebrae, and SK 74, a young juvenile, has partial lumbar sacralization.

Table 49 Spinal anomalies in St Andrews Library other than spina bifida or spina bifida occulta

Skeleton	**Anomaly**
SK 24	6 Sacral Vertebrae
SK 28	Hypoplastic Sacrum
SK 73	6 Lumbars and 4 Sacral Vertebrae
SK 74	L5 Partial Sacralization

4.3.6.3 Extra-Spinal Congenital Anomalies

There are three skeletons in the St Andrews Library assemblage that have an extra-spinal congenital anomaly (Table 50). SK 31, a middle adult male, has fused 1st and 2nd right ribs at the bodies, suggestive of a developmental disorder or could be related to the clavicle fracture that will be discussed in the following section. SK 26 is a young adult female likely between the ages of 18-20. The skull has an abnormal shape, the parietals appear swollen and flat frontal bone. SK 28 is a young-middle adult male likely between the ages of 25 and 35 with several congenital abnormalities. Stature is estimated to 148.52 cm +/- 3.27 using the femur, which is the shortest male in the St Andrews Library assemblage. The right radius is bowed. The innominates are hypoplastic and the pubic symphysis has abnormal bowing. The right femur is severely shortened, is bowed and has slightly flaring metaphyses. The femoral head has coxa vara and is enlarged. The right tibia appears very gracile compared to the femur. The bowing of the radius and the abnormal femur and innominates are consistent with a skeletal dysplasia disorder, possibly dyschondrosteosis, which is a short-limb form of dwarfism, however it usually occurs with coxa valga and ankle deformities (Aufderheide and Rodríguez-Martín 1998). Another possible diagnosis is hyperphosphatasia which has bowed long bones and coxa vara. However, this condition also occurs with thickened cranial bones, kyphoscoliosis, and thick bones of the hands and feet (Aufderheide and Rodríguez-Martín 1998).

Table 50 Extra-spinal anomalies in St Andrews Library

Skeleton	**Anomaly**
SK 26	Abnormal Skull Shape
SK 28	Form of Dysplasia
SK 31	Rib Fusion

4.3.7 Trauma

In the St Andrews Library assemblage 12 individuals (16%) had healed trauma and eight of those individuals (two-thirds) have one or more fractured bones. Table 51 lists the number and percentage of individuals with fractured bones by bone element.

Table 51 St Andrews Library fractures

N = total number of individuals with bone present, n = number of individuals with fracture, CPR= percentage of individuals with fractures

Bone	**N**	**N**	**CPR**
Cranium	33	0	0
Mandible	27	0	0
Clavicle	40	3	7.5
Scapula	44	0	0
Rib	54	2	3.7
Vertebra	54	2	3.7
Innominate	40	0	0
Humerus	42	0	0
Radius	41	0	0
Ulna	42	0	0
Metacarpal	38	1	2.6
Hand Phalanx	40	1	2.5
Patella	25	0	0
Femur	45	0	0
Tibia	45	0	0
Fibula	38	0	0
Metatarsal	30	1	3.5
Foot Phalanx	34	0	0

4.3.7.1 Post-cranial Fractures

There are eight individuals with healed fractures in the post-cranial skeleton. Fractures are reported by bone element in separate sections below.

4.3.7.1.1 Long Bone Fractures

The only long bone fractures in the St Andrews collection are of clavicles. Out of 40 individuals with at least one clavicle present, three individuals (7.5%) have a fractured clavicle and all are male. SK 23, a young-middle adult male, has a healed left clavicle fracture that has shortened the bone. SK 31, a middle adult male, has pseudoarthrosis of the right clavicle. SK 47, a middle adult male, has a mal-united healed fracture of the right clavicle.

4.3.7.1.2 Non-Long Bone Fractures

There are two individuals, out of 54 adult individuals with at least one rib present, with a rib fracture (Figure 69). There are two individuals, out of 54 with at least one vertebra present, with a vertebra fracture. There is one individual, out of 38 with at least one metacarpal present, with a metacarpal fracture. There is one individual, out of 40 with at least one hand phalanx present, with a hand phalanx fracture. There are no patellar fractures in St Andrews Library. Out of 30 individuals with at least one metatarsal present, one individual, or 3.3% have a metatarsal fracture. There are no individuals with a foot phalanx fracture in St Andrews Library. Males are the only ones with vertebra, metacarpal, hand phalanx, and metatarsal fractures. In fact, the only female with healed fractures at St Andrews Library has them on her ribs (Figure 70). There is one male and one female with a rib fracture.

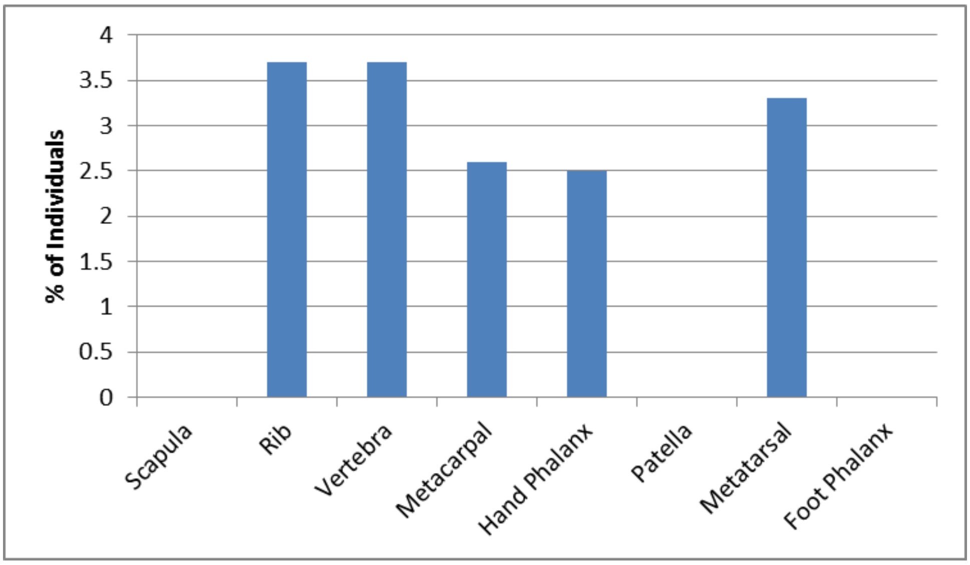


Figure 69 St Andrews Library non-long bone fractures

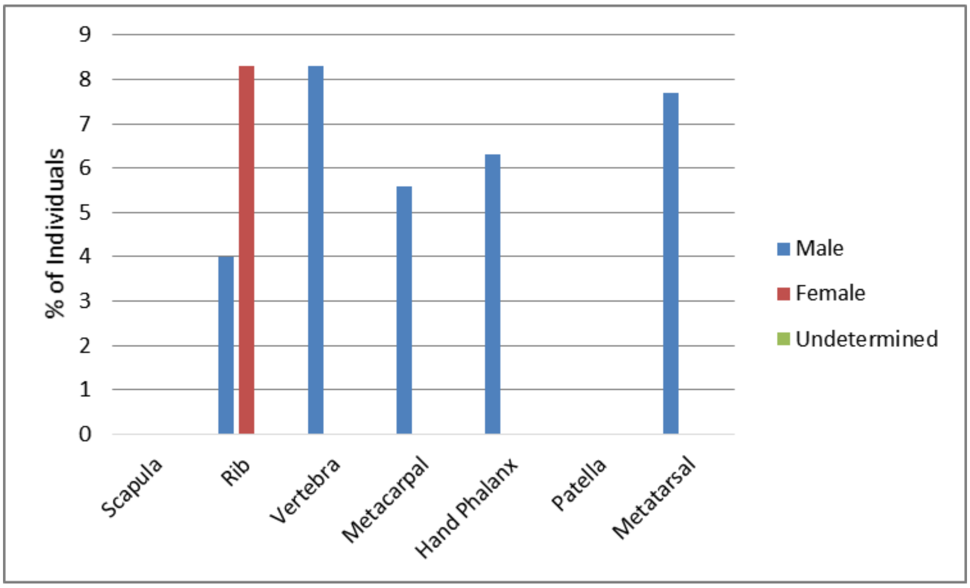


Figure 70 St Andrews Library non-long bone fractures by sex

Table 52 St Andrews Library non-long bone fractures by sex

Bone	Male			Female			Undetermined		
	N	n	CPR	N	n	CPR	N	n	CPR
Scapula	22	0	0	12	0	0	4	0	0
Rib	25	1	4	12	1	8.3	6	0	0
Vertebra	24	2	8.3	12	0	0	7	0	0
Metacarpal	18	1	5.6	11	0	0	3	0	0
Hand Phalanx	16	1	6.3	11	0	0	6	0	0
Patella	13	0	0	7	0	0	3	0	0
Metatarsal	13	1	7.7	7	0	0	6	0	0
Foot Phalanx	13	0	0	10	0	0	6	0	0

4.3.7.2 Cranial Trauma

There are no cases of cranial trauma in the St Andrews Library assemblage.

4.3.7.3 Spondylolysis and Spondylolisthesis

There are no cases of spondylolysis and spondylolisthesis in the St Andrews Library Assemblage.

4.3.7.4 Osteochondritis Dissecans

There are four cases of osteochondritis dissecans in the St Andrews Library assemblage; SK 19, SK 47, SK 48, and SK 50 (Table 53).

Table 53 Osteochondritis dissecans in St Andrews Library

Skeleton	Bone Affected
SK 19	Proximal Phalanx
SK 47	Proximal Foot Phalanx
SK 48	Proximal Foot Phalanx
SK 50	Proximal Foot Phalanx

4.3.7.5 Other Trauma

There are four individuals with other types of trauma (Table 54). SK 13, a young-middle adult female, has a round sharp force trauma on the mesosternum (Figure 73). In SK 18, an adolescent male, the styloid process on the right 5th metatarsal has been resorbed. A possible diagnosis could be osteochondritis dissecans, but another disease process could be possible, such as an avulsion fracture. SK 31, a middle adult male, has a lot of abnormalities in the ankles and feet including probable dislocation of the ankle due to exostosis on the distal fibula (Figure 71). On the talus there is exostosis inferior to the calcaneal articular surface, which indicates incomplete separation of the posterior talar process, also called Steida's process (Mann and Hunt 2005) (Figure 73). The left navicular has exostosis inferior to where the tubercle is broken off. On the left 1st metatarsal and proximal phalanx there is subchondral sclerosis at the flexor hallucis brevis tendon insertion indicating constant over extension with osteoarthritic changes (Figure 72). SK 55, an adolescent male, has a possible trauma at the left central mandibular incisor which led to an abscess at the site.

Figure 72 SK 31 exostosis on distal fibula; inferior view

Figure 71 SK 31 subchondral sclerosis on proximal phalanx; dorsal view

Figure 73 SK 31 Steida's process on the talus; plantar view

Figure 74 SK 13 Sharp force trauma to mesosternum; superior view

Table 54 Other trauma in St Andrews Library

Skeleton	**Trauma**
SK 13	Sharp Force Trauma to Mesosternum
SK 18	Resorbed Metatarsal Styloid
SK 31	Ankle Dislocation
SK 55	Dental Trauma

4.3.8 Metabolic Disease

There are 20 individuals (28%) in the St Andrews Library assemblage with metabolic disease.

4.3.8.1 Cribra Orbitalia and Porotic Hyperostosis

There are five individuals (17.2%) out of 29 individuals with at least one orbit present with cribra orbitalia (Figure 74). Out of 33 individuals with a skull or part of a skull present 15 individuals (45.5%) have porotic hyperostosis. Out of 29 individuals two have both cribra orbitalia and porotic hyperostosis.

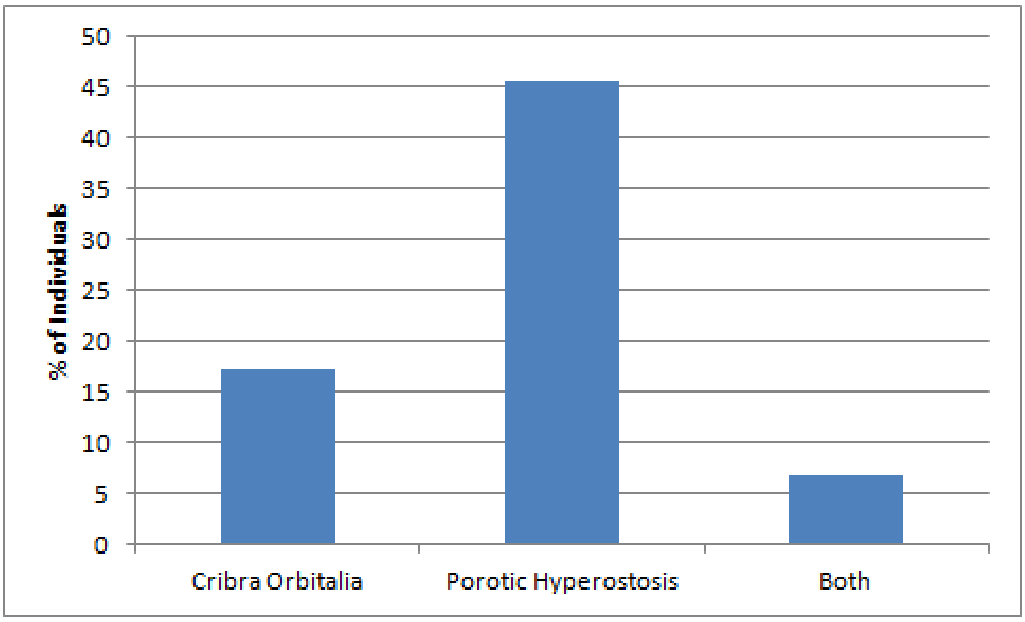


Figure 75 Cribra orbitalia and porotic hyperostosis in St Andrews Library

4.3.8.2 Rickets and Osteopenia

There is one individual (1.4%) in the St Andrews Library assemblage with possible osteopenia. There are three individuals (4%) with possible rickets. SK 12 is a middle adult male likely between the ages of 35 and 45. The skeleton has extremely light bones which might indicate osteopenia, but could also be post mortem damage. This individual also has a bowed left radius which could possibly be healed childhood rickets. SK 48, a middle adult, has bowed femora, possibly indicating childhood rickets; however the tibiae and fibulae appear normal. SK 50, an adolescent male, has bowed fibulae which may indicate healing rickets.

4.3.9 Joint Disease

There are 47 individuals (65.3%) with joint disease. Joint disease is broken down further into extra-spinal arthropathies and spinal joint disease.

4.3.9.1 Extra-Spinal Arthropathies

There are 45 individuals, or 62.5% of the population, with extra-spinal arthropathies. Table 55 lists the counts and percentages of arthropic changes by joint. The highest percentage of arthropic changes is in acromio-clavicular joints, at 51% of the population with at least one acromio-clavicular joint surface present (Figure 75). The joint with the lowest percentage of arthropathies is the wrist, with 12.1% of the population with at least one wrist joint surface present.

Table 55 Extra-spinal arthropathies at St Andrews Library

Joint(s)	**N**	**N**	**CPR**
Shoulder	41	18	43.9
Sterno-clavicular	39	16	41.0
Acromio-clavicular	37	19	51.4
Elbow	42	16	38.1
Wrist	33	4	12.1
Hand	39	9	23.1
Hip	43	11	25.6
Knee	43	12	27.9
Ankle	36	5	13.8
Foot	37	13	35.1

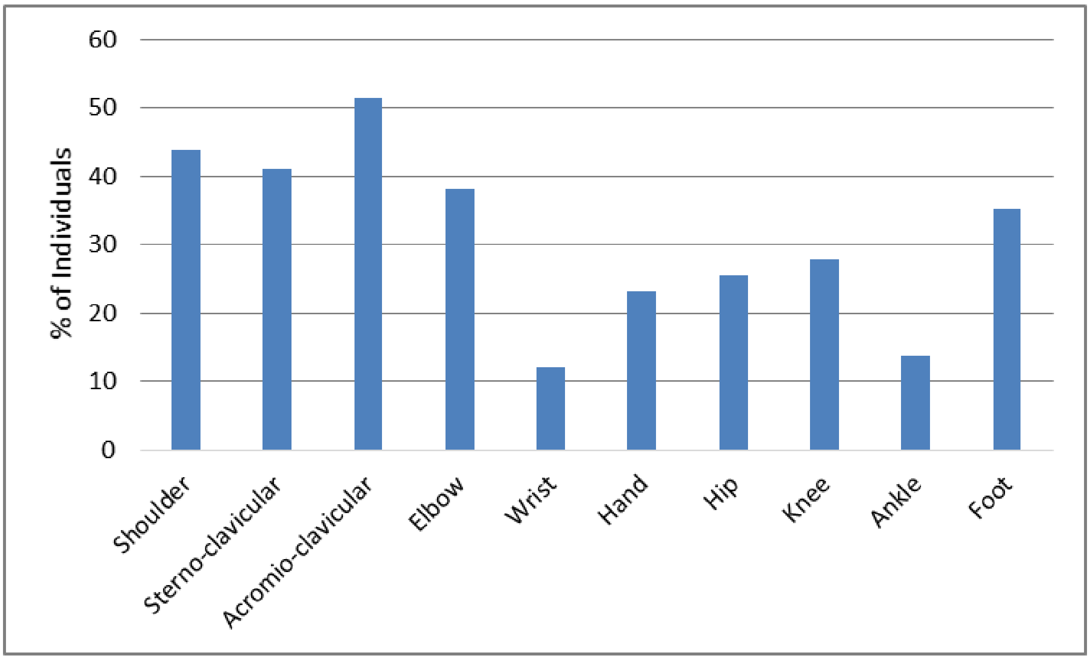


Figure 76 Extra-spinal arthropathies at St Andrews Library

Males have more extraspinal arthropathies than females in the shoulder, wrist, and hand joints (Figure 76). Females have more extraspinal arthropathies than males in the acromio-clavicular, elbow, hip, and knee joints. None of the differences are statistically significant.

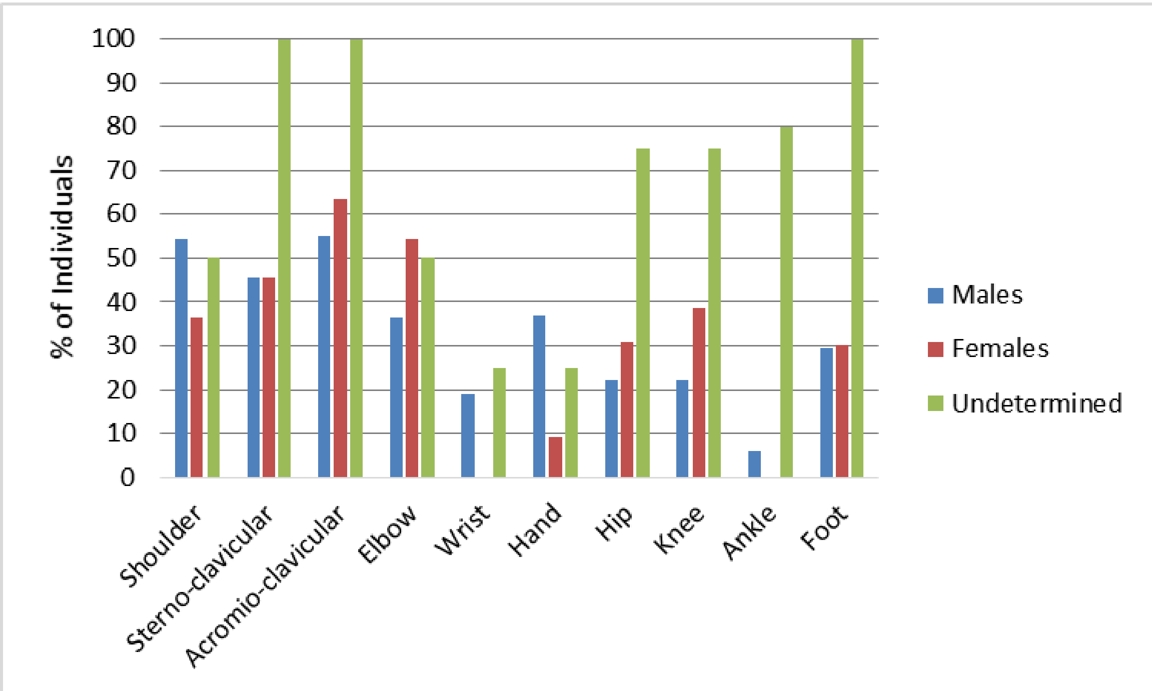


Figure 77 St Andrews Library extra-spinal arthropathies by sex

Table 56 St Andrews Library crude prevalence rates of extra-spinal arthropathies in adult skeletons

Joint (s)	**Male**			**Female**			**Undetermined**		
	N	n	CPR	N	n	CPR	N	n	CPR
Shoulder	22	12	54.5	11	4	36.4	4	2	50
Sterno-clavicular	22	10	45.5	11	5	45.5	1	1	100
Acromio-clavicular	20	11	55	11	7	63.6	1	1	100
Elbow	22	8	36.4	11	6	54.5	4	2	50
Wrist	16	3	18.8	9	0	0	4	1	25
Hand	19	7	36.8	11	1	9.1	4	1	25
Hip	18	4	22.2	13	4	30.8	4	3	75
Knee	18	4	22.2	13	5	38.5	4	3	75
Ankle	17	1	5.9	9	0	0	5	4	80
Foot	17	10	29.4	10	3	30	5	5	100

4.3.9.2 Spinal Joint Disease

Eleven individuals (32.4%) out of 34 with at least one cervical vertebra present, have cervical spinal joint disease (Figure 77). Out of 43 individuals with at least one thoracic vertebra present, 21 individuals (48.8%) have thoracic spinal joint disease. Out of 19 individuals with at least one lumbar vertebra present, all have lumbar spinal joint disease.

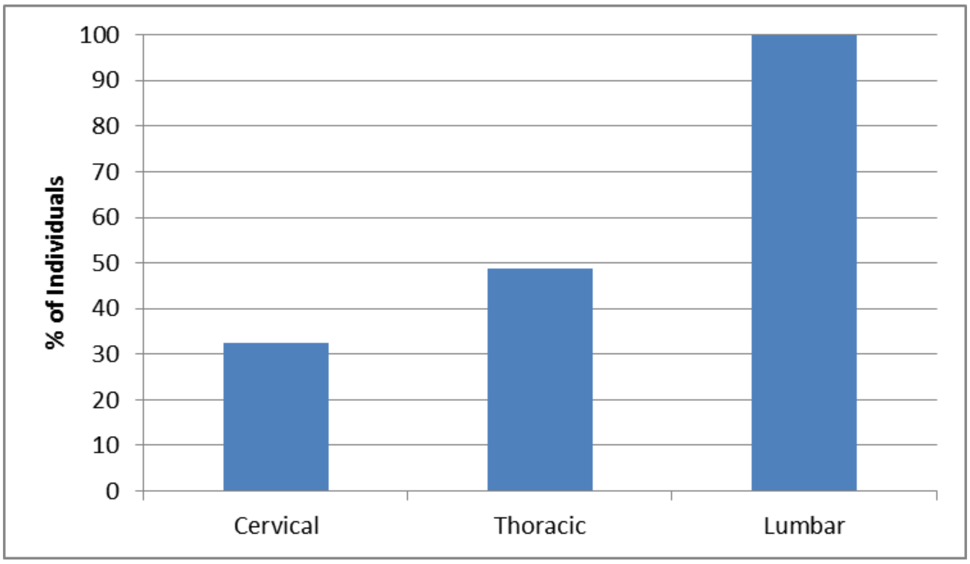


Figure 78 St Andrews spinal joint disease

4.3.9.3 Erosive Arthropathies

On all foot bones and the distal ends of both tibiae and fibulae on SK 45b, an adult, are erosive lesions. These lesions suggest an erosive arthropathy such as rheumatoid arthritis or psoriatic arthritis. Unfortunately, since the skeleton is only 10% complete and is missing the sacroiliac joints and the spine, a more comprehensive diagnosis is not possible.

4.3.9.4 DISH and eDISH

There is one possible case of incipient DISH in the St Andrews Library assemblage. SK 46 is an old adult male likely over the age of 50. There are bone spurs on almost every bone. There are marked enthesophytes on both of the iliac crests and ischial tuberosities. Right and left sacroiliac joints are possibly in the early stages of fusion. There is bony bridging on most lumbar vertebrae and the 5th lumbar is sacralized. There is eburnation at both knees, most extreme on the right. There is marked marginal osteophytes on right and left distal femora, proximal tibiae, and patellas. Due to the extreme amounts of bone spurs on almost every bone along with the spinal bridging, 5th lumbar vertebra sacralisation due to ossification, and partial fusion of the sacroiliac joint, this skeleton is a good candidate for incipient DISH.

4.3.10 Dental Disease

Out of the total population represented at St Andrews Library 27 individuals (37.5%) have dental disease. There are 43.8%, or 14 individuals out of 32 with at least one tooth present, with dental caries (Table 57). There are 21.9%, or seven individuals, with a dental abscess. There are 56.3%, or 18 individuals, with antemortem tooth loss. There is 40.6%, or 13 individuals, with enamel hypoplasia.

Table 57 Dental disease in St Andrews Library by individual

Disease	N	n	CPR
Caries	32	14	43.8
Abscesses	32	7	21.9
Antemortem Tooth Loss	32	18	56.3
Enamel Hypoplasia	32	13	40.6

Out of 473 teeth present, 21 (4.4%) have caries, 12 (2.5%) have abscesses, and 174 (36.8%) have enamel hypoplasia. Table 58 lists the counts and percentages of dental disease in St Andrews Library by tooth.

Table 58 Dental disease in St Andrews Library by tooth

Disease	N	n	TPR
Caries	473	21	4.4
Abscesses	473	12	2.5
Enamel Hypoplasia	473	174	36.8

4.3.11 Other Disease

There are seven individuals (10%) with disease that could not be classified into one of the above categories (Table 59). Most individuals included in this category have lytic lesions on various areas of the skeleton that do not have a noticeable pattern therefore remain undiagnosed. SK 14 is an infant under the age of six months and has pitting over most of the ectocranial surfaces, including the orbits. It is unclear whether this is a disease process, or normal apposition of bone, however if it is a disease it is most likely an infection or metabolic in origin.

Table 59 Other disease in St Andrews Library

Skeleton	Disease Process
SK 13	Lytic Lesion on Femoral Head
SK 14	Possible Infection or Metabolic Disease
SK 17	Button Osteoma on Hand Phalanx
SK 18	Lytic Lesion on Distal Femur
SK 20	Lytic Lesion at Proximal 2nd Metatarsal
SK 55	Lytic Lesion on Distal Tibia
SK 85	Lytic Lesion on Lunate

4.3.12 Burial Location

4.3.12.1 Sex and Age by Burial Group

For the St Andrews Library assemblage there are three burial layers determined by the archaeologist of the excavation by stratigraphic evidence. For individuals that could be aged and sexed in burial layer 1, there are six males and one female (Table 60). In burial layer 2 there are nine males and five females. In burial layer 3 there are seven males and five females. In burial layer 1 there is one adolescent, three young adults, seven young-middle adults, nine middle adults, and nine old adults. In burial layer 2 there are three adolescents, two young adults, two young-middle adults, six middle adults, and one old adult. In burial layer 3 there are two young adults, four young-middle adults, three middle adults, and three old adults. Chi-square tests revealed there is no statistical significance in which assemblage an individual was buried in and their age or sex.

Table 60 Burial location demography at St Andrews Library

Burial Layer				Sex: Male	Sex: Female	Total
Layer 1	Age	ADL	Count	1	0	1
			% within Age	100.0%	.0%	100.0%
		YMA	Count	2	1	3
			% within Age	66.7%	33.3%	100.0%
		MA	Count	3	0	3
			% within Age	100.0%	.0%	100.0%
	Total		Count	6	1	7
			% within Age	85.7%	14.3%	100.0%
Layer 2	Age	ADL	Count	3	0	3
			% within Age	100.0%	.0%	100.0%
		YA	Count	0	2	2
			% within Age	.0%	100.0%	100.0%
		YMA	Count	0	2	2
			% within Age	.0%	100.0%	100.0%
		MA	Count	5	1	6
			% within Age	83.3%	16.7%	100.0%
		OA	Count	1	0	1
			% within Age	100.0%	.0%	100.0%
	Total		Count	9	5	14
			% within Age	64.3%	35.7%	100.0%
Layer 3	Age	YA	Count	1	1	2
			% within Age	50.0%	50.0%	100.0%
		YMA	Count	1	3	4
			% within Age	25.0%	75.0%	100.0%
		MA	Count	2	1	3
			% within Age	66.7%	33.3%	100.0%
		OA	Count	3	0	3
			% within Age	100.0%	.0%	100.0%
	Total		Count	7	5	12
			% within Age	58.3%	41.7%	100.0%

4.3.12.2 Burial Location and Pathology

When chi-square tests were run between the three burial layers and each category of disease it was determined there are no statistically significance differences.

4.4 Whitefriars

4.4.1 Age at death

Of the 58 articulated skeletons in the Whitefriars assemblage, the age breakdown is as follows: there are six infants, 12 young juveniles, four old juveniles, one adolescent, 12 young adults, 12 young-middle adults, five middle adults, and three old adults (Table 61; Figure 78). Three skeletons cannot be aged more specifically, and are placed into the broad adult category. Of the population, infants are 10.3%, young juveniles are 20.7%, old juveniles are 6.9%, adolescents 1.7%, young adults 20.7%, young-middle adults 20.7%, middle adults 8.6%, old adults 5.2%, and 5.2% are in the broad category for adults. Comparing adults to non-adults; 82% of the assemblage are adults (aged 18 years and over) and 18% of the assemblage are non-adults (aged 17 years and younger).

Table 61 Whitefriars age at death

Category	Age Range	n	Percentage
Neonate	0-2 mo	0	0
Infant	2 mo-2yr	6	10.3
Young Juvenile	2-6	12	20.7
Old Juvenile	7-12	4	6.9
Adolescent	13-17	1	1.7
Young Adult	18-24	12	20.7
Young-Middle Adult	25-34	12	20.7
Middle Adult	35-44	5	8.6
Old Adult	45+	3	5.2
Adult	18+	3	5.2

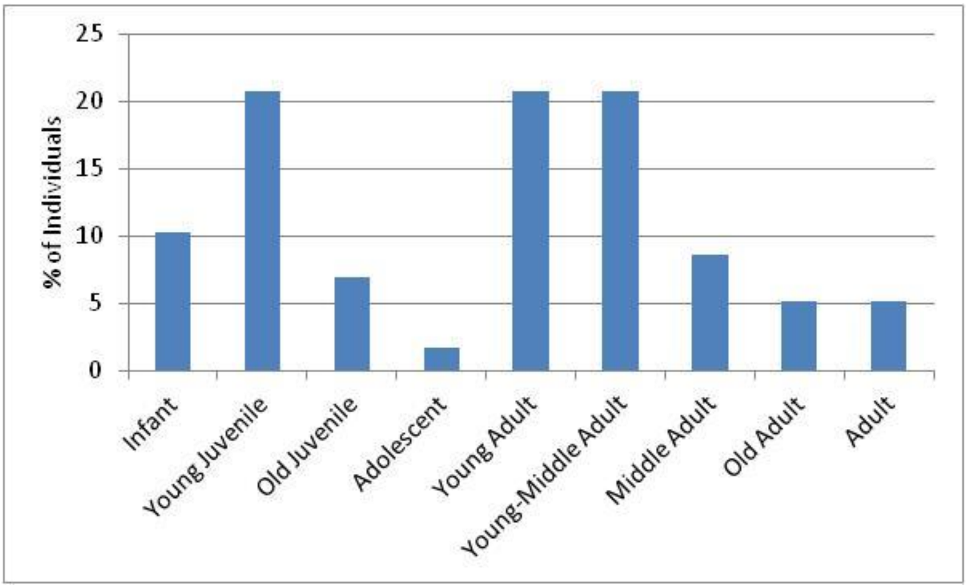


Figure 79 Whitefriars age at death profile

4.4.2 Sex

In the Whitefriars assemblage, 34 of 58 adult skeletons could be sexed. There are 22 males, 11 females, and one probable female. Sex for one skeleton could not be determined and 23 skeletons are unsexed non-adults. Males make up 38% of the population, females and probable females 39%, undetermined adults 2% and unsexed non-adults 21%. Among the 34 sexed skeletons, males make up 65% of the population and females make up 35%. Therefore the male to female ratio is 0.54:1 (Table 62; Figure 79).

Table 62 Whitefriars sex profile

Sex	n	Percentage
Male/Probable Male	22	37.9
Female/Probable Female	12	20.7
Undetermined	1	1.7
Non-Adults	23	39.7
Total	58	100

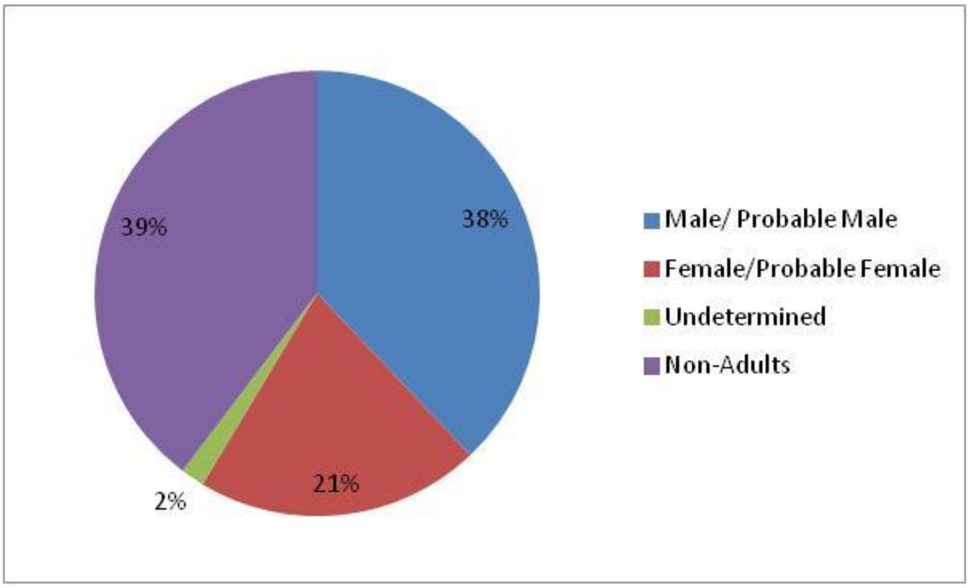


Figure 80 Whitefriars sex profile

4.4.3 Stature Estimation

Of the sexed individuals at Whitefriars, stature could be estimated for 19 skeletons, 13 males or probable males and six females or probable females. For males, stature ranged from 156.18 cm to 176.17 cm with a mean of 167.85 cm and a standard deviation of 5.23 cm. For females, stature ranged from 150.33 cm to 160.93 cm with a mean of 154.60 cm and a standard deviation of 5.01 cm. There were no male or female outliers for stature.

4.4.4 Pathological Conditions

In the Whitefriars assemblage 33 individuals (56.9%) have at least one type of pathological condition. Twenty-five individuals (43.1%) have no pathology that could be discerned from the skeleton (Figure 80). Six individuals (10.3%) have pathology that could be attributed to infectious disease. One individual (1.7%) has pathology that could be attributed to a congenital disorder. Two individuals (3.4%) have traumatic lesions. One individual (1.7%) has metabolic disease. Eighteen individuals (31%) have joint disease. Twenty-five individuals (43.1%) have pathology that could be attributed to dental disease.

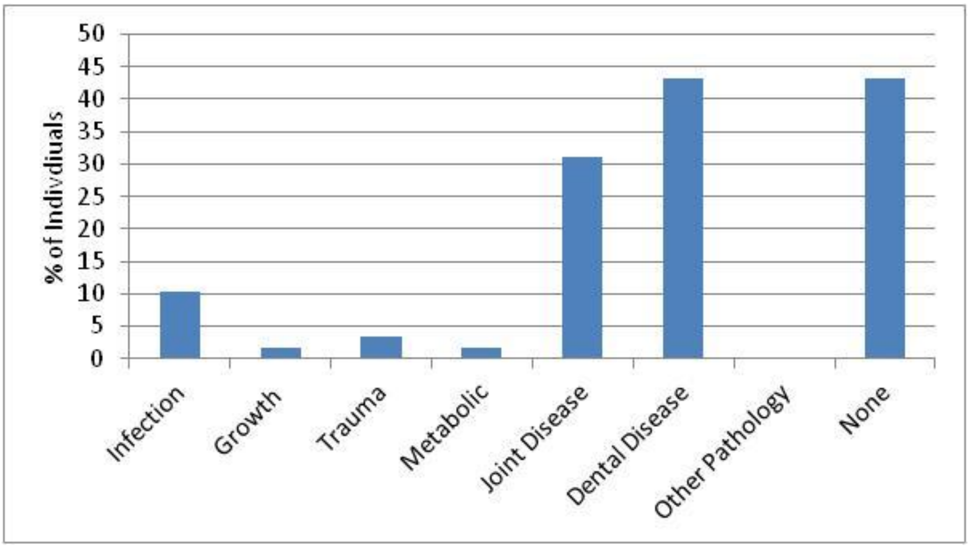


Figure 81 Whitefriars pathology profile

4.4.5 Infection

All six individuals that had infection in the Whitefriars assemblage had a non-specific infection.

4.4.5.1 Non-Specific Infections

4.4.5.1.1 Periostitis and Osteomyelitis

There are six individuals in Whitefriars with periostitic lesions (Table 63). None of the lesions are associated with fractures on the same bone. Four out of six skeletons with periostitic lesions have them on their femur. There are no cases of osteomyelitis in the Whitefriars assemblage.

Table 63 Cases of periostitis in Whitefriars

Skeleton	Bones affected by Periostitis	Fractured Bones
SK 182	Femur, Tibia	
SK 256	Femur, Tibia, Fibula	
SK 347	Maxilla	
SK 412	Femur	
SK 521	Ulna	
SK 626	Femur	

4.4.6 Congenital Disorders

In Whitefriars there is one skeleton with pathology that could be placed into the category of congenital or growth disorder. There were only five skeletons with at least one vertebra or sacrum present and none of these have spinal congenital anomalies.

4.4.6.1 Extra-Spinal Congenital Anomalies

The one skeleton with a congenital anomaly is SK 657, a middle adult male. The sagittal suture of this skeleton has an abnormal fusion, possibly indicating it fused early. The skull is also bathrocephalic, which may or may not be related to the sagittal suture fusion. The lateral maxillary incisors are also abnormal which could also relate to the congenital anomalies of the skull.

4.4.7 Trauma

In the Whitefriars assemblage, of the two individuals that suffered from trauma, both are healed fractures (Table 64). SK 447, a young-middle adult male, has a possible healed skull fracture on the left parietal. SK 485, a middle adult male, has a left clavicle with a malunited fracture at the sternal end. The high crude prevalence rates are misleading for cranial and clavicle fractures since the numbers of bone elements present are low.

Table 64 Whitefriars fractures

N = total number of individuals with bone present, n = number of individuals with fracture, CPR= percentage of individuals with fractures

Bone	**N**	**n**	**CPR**
Cranium	6	1	16.7
Mandible	9	0	0
Clavicle	4	1	25.0
Scapula	6	0	0
Rib	8	0	0
Vertebra	9	0	0
Innominate	33	0	0
Humerus	6	0	0
Radius	6	0	0
Ulna	7	0	0
Metacarpal	3	0	0
Hand Phalanx	5	0	0
Patella	4	0	0
Femur	10	0	0
Tibia	8	0	0
Fibula	9	0	0
Metatarsal	3	0	0
Foot Phalanx	3	0	0

4.4.8 Metabolic Disease

There is one individual (1.7%) in the Whitefriars assemblage with symptoms of a metabolic disease.

4.4.8.1 Cribra Orbitalia and Porotic Hyperostosis

Out of eight skeletons with at least a partial skull present, one has porotic hyperostosis. Out of the seven skeletons with orbits present, none have cribra orbitalia. Skeleton 182, an adolescent male, has slight porotic hyperostosis on the right and left parietals.

4.4.9 Joint Disease

There are 18 individuals (31%) with joint disease in the Whitefriars assemblage.

4.4.9.1 Extra-Spinal Arthropathies

There are 11 individuals (19%) with extra-spinal arthropathies. Many joint surfaces were not present or well preserved, even if part of the diaphysis survived. Therefore, the numbers of elements that could be counted here is extremely low. Table 65 lists the counts and percentages of arthropic changes by joint. The highest percentage of arthropic changes is in the elbow joint, at 39% of the population with at least one elbow joint surface present (Figure 81). The joints with the lowest percentage of arthropathies are the sterno-clavicular joint, the hand joint, and the ankle joint, each with 0% of the population with at least one of the joint surfaces present affected. The percentages are somewhat misleading due to the low counts of each element present and the preservation of the joint surfaces.

Table 65 Whitefriars extra-spinal arthropathies

Joint(s)	N	N	CPR
Shoulder	18	1	5.5
Sterno-clavicular	8	0	0
Acromio-clavicular	9	3	33.3
Elbow	18	7	38.8
Wrist	7	2	28.5
Hand	10	0	0
Hip	17	2	11.7
Knee	11	1	9.0
Ankle	4	0	0
Foot	9	1	11.1

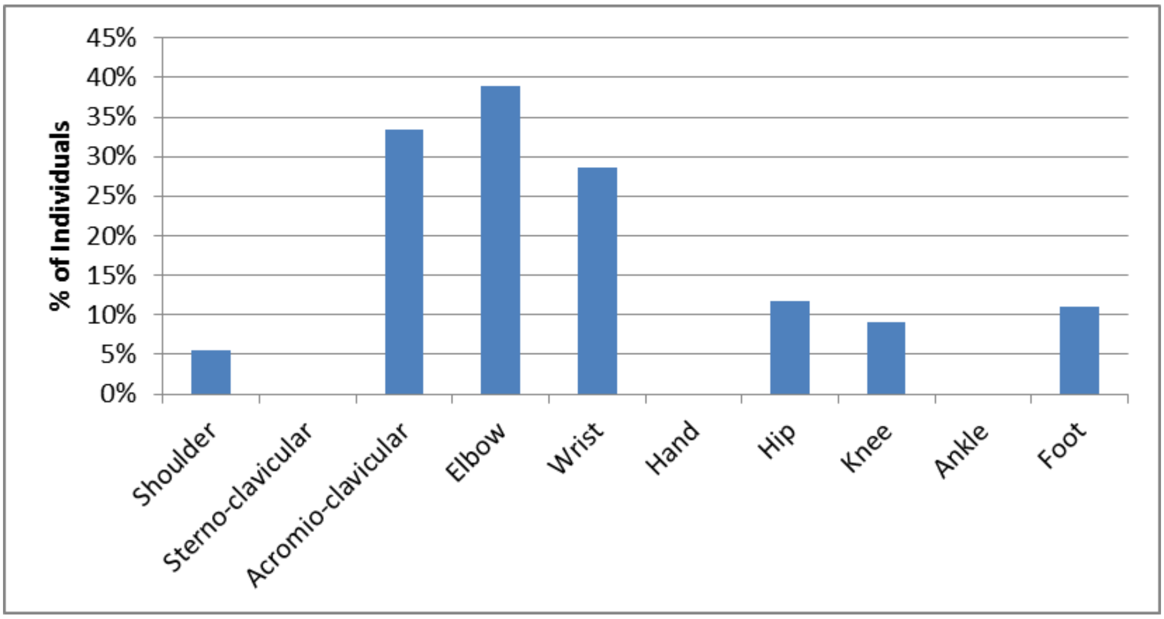


Figure 82 Extra-spinal arthropathies at Whitefriars

Shoulder arthropathies were only found in females, and females also had more acromio-clavicular arthropathies than males, however neither differences were statistically different (Figure 82). All the individuals with elbow, wrist, hip, knee, and foot arthropathies are male. No individuals have arthropathies in the sterno-clavicular, hand, or foot joints (Table 66).

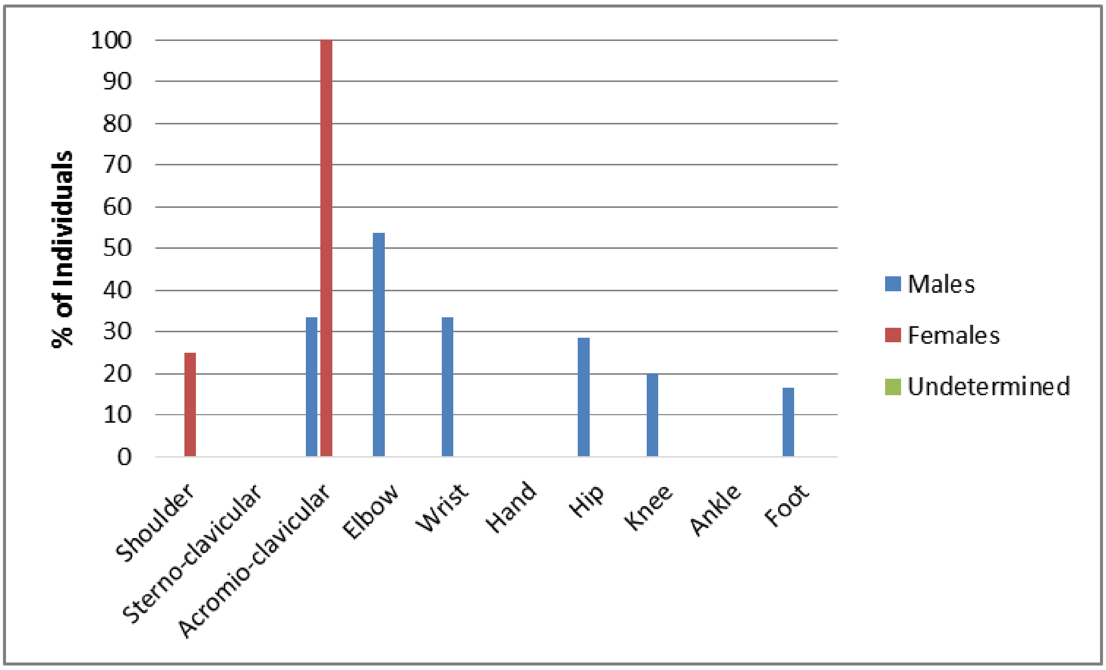


Figure 83 Whitefriars extra-spinal arthropathies by sex

Table 66 Whitefriars crude prevalence rates of extra-spinal arthropathies in adult skeletons

Joint (s)	Male			Female			Undetermined		
	N	n	CPR	N	n	CPR	N	n	CPR
Shoulder	13	0	0	4	1	25	0	0	0
Sterno-clavicular	5	0	0	0	0	0	0	0	0
Acromio-clavicular	6	2	33.3	1	1	100	0	0	0
Elbow	1	7	53.8	4	0	0	0	0	0
Wrist	6	2	33.3	1	0	0	0	0	0
Hand	6	0	0	4	0	0	0	0	0
Hip	7	2	28.6	6	0	0	0	0	0
Knee	5	1	20	3	0	0	0	0	0
Ankle	2	0	0	2	0	0	0	0	0
Foot	6	1	16.7	3	0	0	0	0	0

4.4.9.2 Spinal Joint Disease

One individual out of five with at least one cervical vertebra present, has cervical spinal joint disease (Figure 83). Out of seven individuals with at least one thoracic vertebra present, four have thoracic spinal joint disease. Likewise, out of seven individuals with at least one lumbar vertebra present, four have lumbar spinal joint disease. Again, the percentages are somewhat misleading due to the low counts of each element present and the poor preservation of the vertebrae.

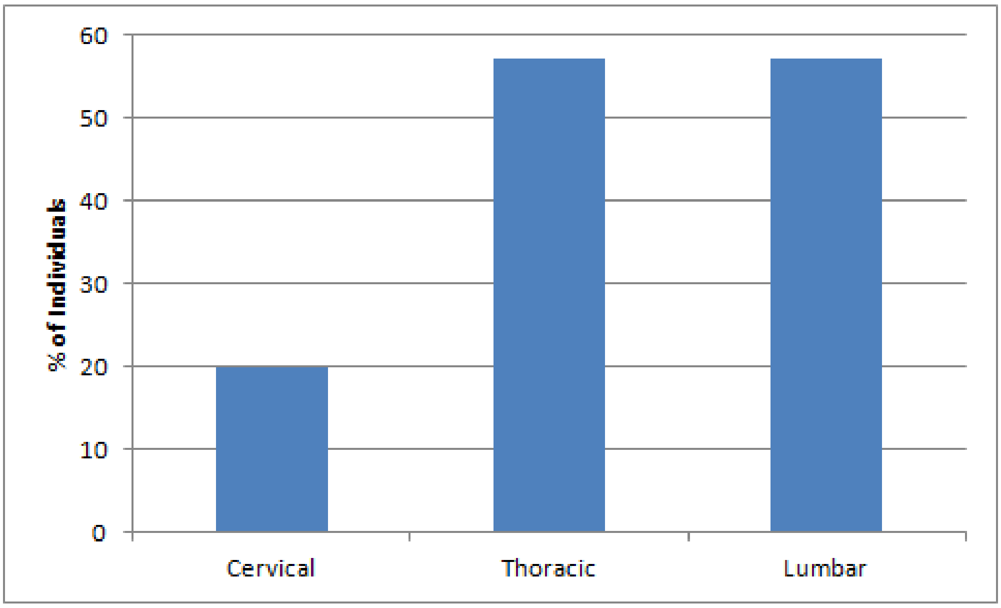


Figure 84 Whitefriars spinal joint disease

4.4.9.3 Erosive Arthropathies

One skeleton, SK 657 has a possible diagnosis of an erosive arthropathy. This skeleton is a middle adult male likely between the ages of 35-45. Along with spinal joint disease there is partial fusion of the sacro-iliac joint. A more precise diagnosis cannot be made due to the poor condition of the bone.

4.4.10 Dental Disease

The highest percentage of disease in the Whitefriars assemblage falls into the category of dental disease. Out of the total population at Whitefriars 25 individuals (43.1%) have dental disease. Over half (18 out of the 32) of the individuals with at least one tooth present showed dental caries (Table 67). There are 12.5%, or four individuals, with a dental abscess. Thirteen individuals (40.6%) suffered antemortem tooth loss. There is 34.4%, or 11 individuals, with enamel hypoplasia. Out of 574 teeth present, 115 (20.0%) have caries, six (1.0%) have abscesses, and 115 (20.0%) have enamel hypoplasia. Table 68 lists the counts and percentages of dental disease in Whitefriars Library by tooth.

Table 67 Dental disease in Whitefriars

Disease	**N**	**n**	**CPR**
Caries	32	18	56.3
Abscesses	32	4	12.5
Antemortem Tooth Loss	32	13	40.6
Enamel Hypoplasia	32	11	34.4

Table 68 Dental disease in Whitefriars by tooth

Disease	**N**	**n**	**TPR**
Caries	574	115	20.0
Abscesses	574	6	1.0
Enamel Hypoplasia	574	115	20.0

4.4.11 Other Disease

There are no individuals in the Whitefriars assemblage that have disease that could not be placed into one of the above categories.

4.4.12 Burial Location

As of now there is no information for burial location at Whitefriars.

4.5 Condition Comparison between all Four Study Sites

The Isle of May skeletons are the best preserved of the four study sites (Table 68; Figure 84). Forty percent of the skeletons (23 skeletons) at the Isle of May were in good condition, 50% (29 skeletons) were in fair condition, and 10.5% (6 skeletons) were in poor condition. The Ballumbie assemblage has the next highest percentage of skeletons in good condition at 29% (57 skeletons). Fifteen percent of the skeletons (30 skeletons) in Ballumbie are in fair condition, however 56% (110 skeletons) are in poor condition; the second highest percentage of poor preserved skeletons. The St Andrews Library collection has 7% of the skeletons in good condition (5 skeletons), 67% in fair condition (48 skeletons), and 26% in poor condition (19 skeletons). The majority of the skeletons in St Andrews Library were in fair condition. Whitefriars has by far the worst preserved skeletons with none in good condition, 16 (28%) in fair condition, and 42 (72%) in poor condition. Overall, there are 85 skeletons, or 21.9% of the total skeletons, in good condition, 123, or 32% in fair condition, and 177, or 46% in poor condition. When a chi-square test is run, it shows the differences between condition in these four sites is statistically significant (χ^2=117.289, p=.000, df=6).

Throughout the rest of the chapter, comparisons are made between the four study populations and the pathological conditions found. Due to the poor preservation of bone in the Whitefriars assemblage and in order to ensure the accuracy of the statistical results, chi-square tests for each type of disease were also run without Whitefriars to see if the outcome changed. With the removal of Whitefriars, none of the outcomes for any of the chi-square tests in this chapter changed. Therefore, the statistical results mentioned in this chapter are accurate even with the poor preservation of the Whitefriars assemblage.

Table 68 Condition of all four sites

			Condition			
			good	**fair**	**poor**	**Total**
Population	Ballumbie	Count	57	30	110	197
		% within Population	28.9%	15.2%	55.8%	100.0%
	Isle of May	Count	23	29	6	58
		% within Population	39.7%	50.0%	10.3%	100.0%
	St Andrews	Count	5	48	19	72
		% within Population	6.9%	66.7%	26.4%	100.0%
	Whitefriars	Count	0	16	42	58
		% within Population	.0%	27.6%	72.4%	100.0%
Total		Count	123	123	177	385
		% within Population	31.9%	31.9%	46.0%	100.0%

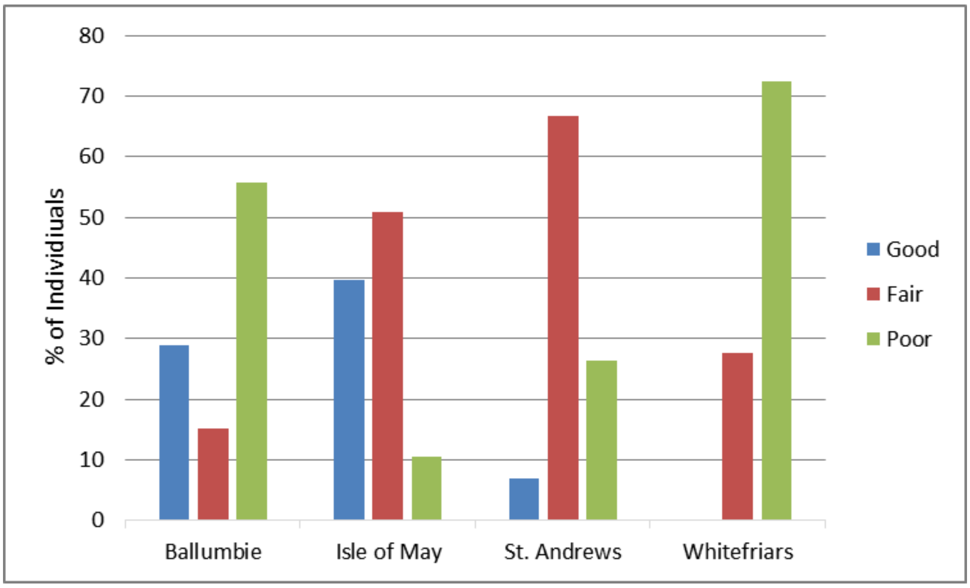


Figure 85 Condition of study populations

4.6 Demography Comparisons Between all Four Sites

4.6.1 Age at Death Comparisons

Table 69 illustrates the differences between age at death at Ballumbie, Isle of May, St Andrews Library and Whitefriars. The differences between age category and population is statistically significant (χ^2=80.018, p= .000, df= 27). Ballumbie has individuals from infant through old adulthood with young juvenile, old juvenile, and adolescent categories showing similar percentages. Young adult and middle adult have similar percentages as well, and they make up the majority of the population with a combined percentage of 42%. Old adults comprise 13.2% of the population, which is the 2nd highest percentage for old adults after the Isle of May at 19%. The individuals from Ballumbie tended to die in young or middle adulthood between 25 and 45 years of age.

The Isle of May assemblage has no neonates, infants, or children; the youngest articulated skeletons are young juveniles between 7-9 years old (SK 970, SK 972). The percentages from young juvenile through adolescent gradually increase with 6.1%, 7.5%, and 8.6% respectively. There is a large increase in percentage in young adult at 19%, and then another large increase in middle adult at 27.6%, however the percentage of old adults decreases to 19%. The majority of individuals at the Isle of May died in middle adulthood between 35 and 45 years of age.

The St Andrews Library assemblage has individuals from neonate through old age. In fact, the St Andrews Library collection is the only assemblage that has any neonates, however, there is only one present in this assemblage. Infants comprise a small percentage of the population at 4.2%, children increase at 9.7% and then the percentage decreases for young juveniles (2.8%). There is an increase in deaths between old juvenile through middle adult, with an exception at adolescent which has a percentage of only 5.6%. There is a decrease from middle adult to old adult from 19.4% to 9.7%. The majority of individuals at St Andrews Library (31.9%) died in young and middle adulthood between 25 and 45 years of age. However, this percentage could be misleading since there are 26.4% of individuals in the broad category of adult.

At Whitefriars there are a high percentage of infants, 10.3%, which is higher than the other three populations. This trend continues through childhood with a high percentage of 20.7%, higher than the other three sites combined. There is a decrease in young and old juvenile with percentages of 6.9% and 1.7% respectively. There is another large increase at adolescence at 20.7% which continues into young adulthood at the same percentage. There is a decrease in middle and old adult with 8.6% and 5.2% respectively. It would seem that the majority of individuals at Whitefriars die before they are 25 at 60.3%. The high percentage of subadults may indicate the purpose of the cemetery or the area of the cemetery that was excavated. Figures 86-90 illustrate the demography for the four sites.

Table 69 Age comparisons at study populations

			Population				Total
			Ballumbie	Isle of May	St Andrews	Whitefriars	
Age	NN	Count	0	0	1	0	1
		% within Age	.0%	.0%	100.0%	.0%	100.0%
		% within Population	.0%	.0%	1.4%	.0%	.3%
	IN	Count	4	0	3	6	13
		% within Age	30.8%	.0%	23.1%	46.2%	100.0%
		% within Population	2.0%	.0%	4.2%	10.3%	3.4%
	YJ	Count	5	0	7	12	24
		% within Age	20.8%	.0%	29.2%	50.0%	100.0%
		% within Population	2.5%	.0%	9.7%	20.7%	6.2%
	OJ	Count	12	2	2	4	20
		% within Age	60.0%	10.0%	10.0%	20.0%	100.0%
		% within Population	6.1%	3.4%	2.8%	6.9%	5.2%
	ADL	Count	15	3	6	1	25
		% within Age	60.0%	12.0%	24.0%	4.0%	100.0%
		% within Population	7.6%	5.2%	8.3%	1.7%	6.5%
	YA	Count	17	8	4	12	41
		% within Age	41.5%	19.5%	9.8%	29.3%	100.0%
		% within Population	8.6%	13.8%	5.6%	20.7%	10.6%
	YMA	Count	39	11	9	12	71
		% within Age	54.9%	15.5%	12.7%	16.9%	100.0%
		% within Population	19.8%	19.0%	12.5%	20.7%	18.4%
	MA	Count	44	16	14	5	79
		% within Age	55.7%	20.3%	17.7%	6.3%	100.0%
		% within Population	22.3%	27.6%	19.4%	8.6%	20.5%
	OA	Count	26	11	7	3	47
		% within Age	55.3%	23.4%	14.9%	6.4%	100.0%
		% within Population	13.2%	19.0%	9.7%	5.2%	12.2%
	AD	Count	35	7	19	3	64
		% within Age	54.7%	10.9%	29.7%	4.7%	100.0%
		% within Population	17.8%	12.1%	26.4%	5.2%	16.6%
Total		Count	197	58	72	58	385
		% within Age	51.2%	15.1%	18.7%	15.1%	100.0%
		% within Population	100.0%	100.0%	100.0%	100.0%	100.0%

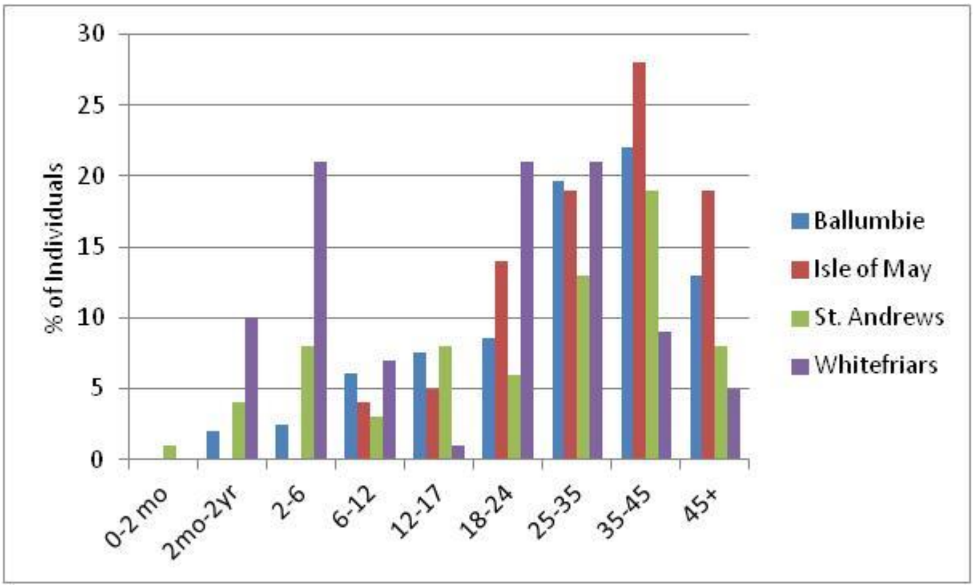


Figure 86 Demography for all study populations

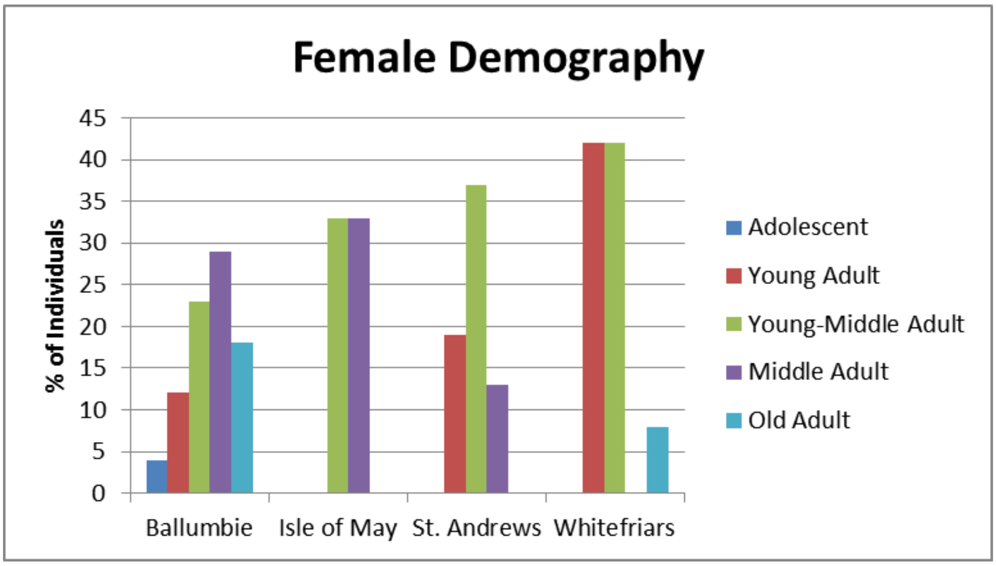


Figure 87 Female demography for all study populations

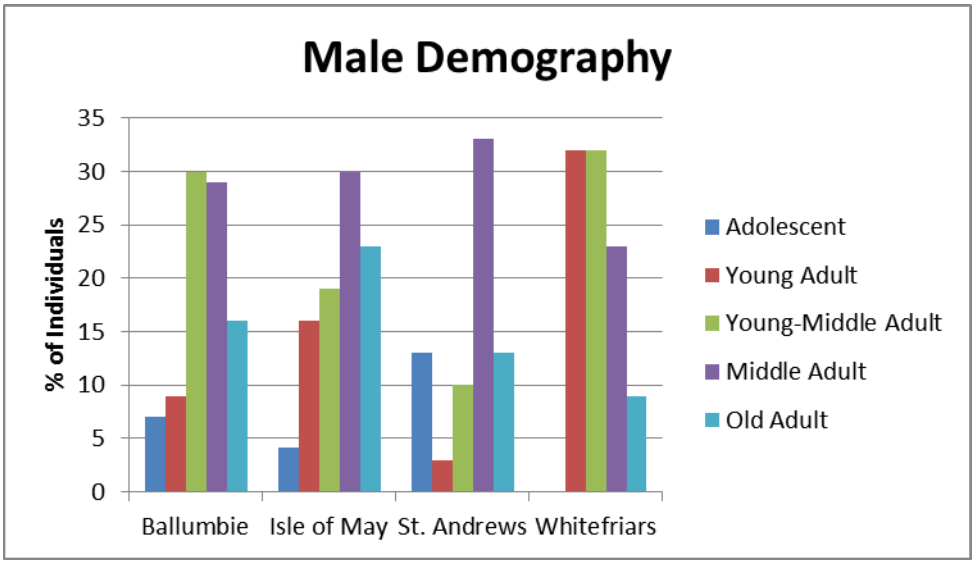


Figure 88 Male demography for all study populations

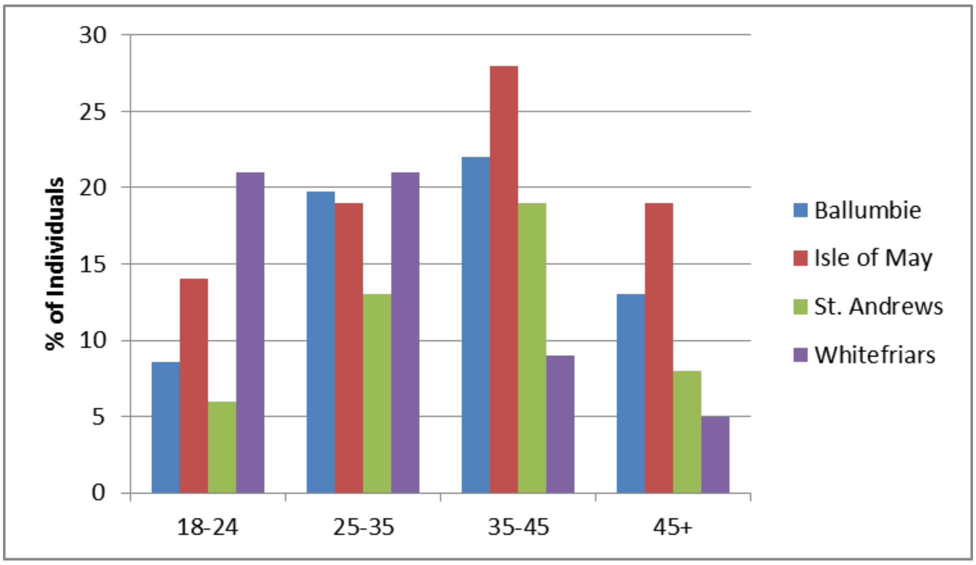


Figure 89 Adult demography for all study populations

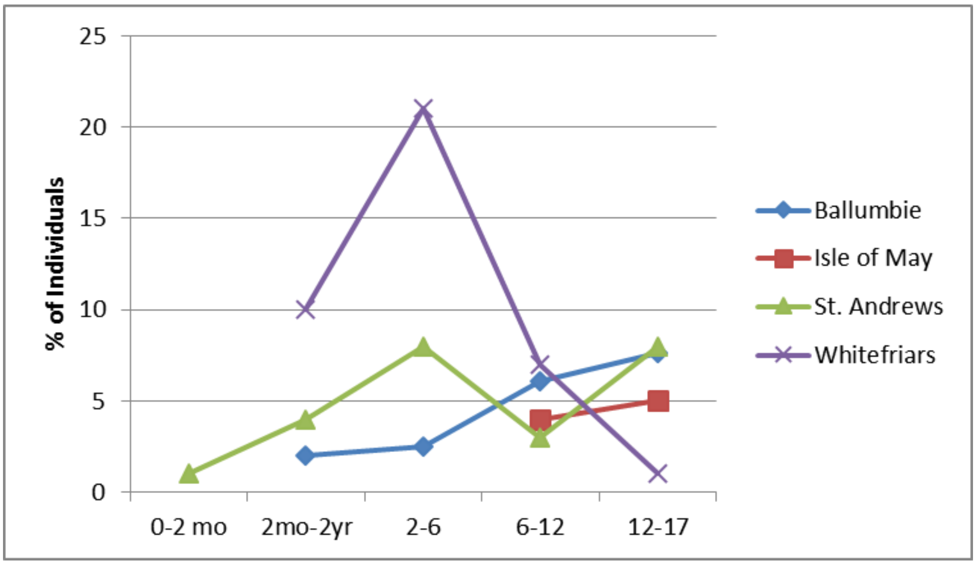


Figure 90 Non adult demography for all study populations

4.6.2 Sex Comparisons

The differences in the counts and percentages of males and females are shown in Table 70 and Figure 91. There is a significant relationship between sex and population (χ^2= 77.866, p=.000, df=9). Ballumbie has 70 males and 77 females. This difference is not statistically significant. In the Isle of May assemblage there are 49 males and two females. This drastic difference in sex ratio is statistically significant and will be examined further in the discussion chapter (χ^2=43.314, p=.000, df=1). In the St Andrews Library assemblage there are 30 males and 16 females. The difference between males and females is statistically significant (χ^2=4.261, p=.039, df=1). In Whitefriars there are 22 males and 12 females. The difference between males and females is not significant.

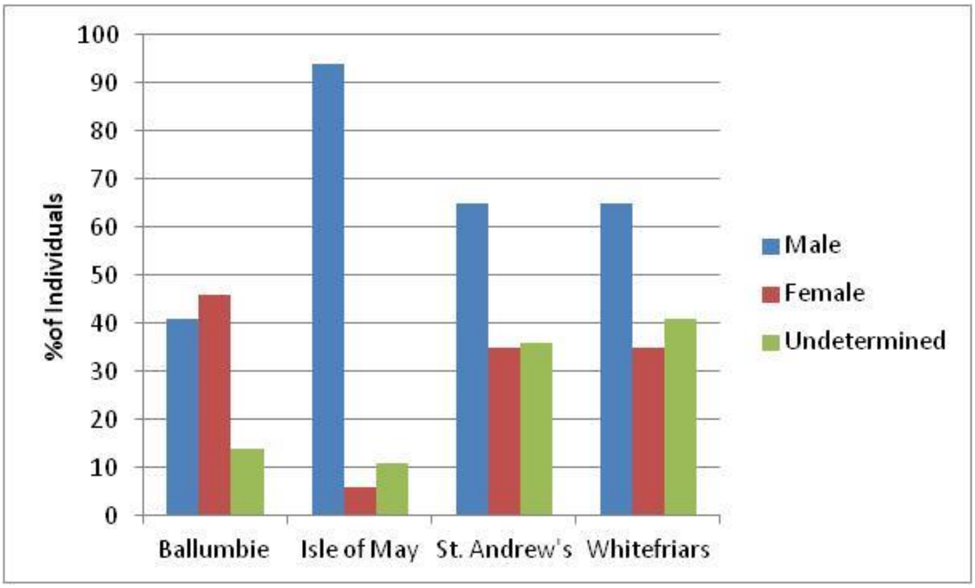


Figure 91 Sex comparisons for study populations

Table 70 Sex comparisons for study populations

			Population				
			Ballumbie	**Isle of May**	**St Andrews**	**Whitefriars**	**Total**
Sex	Male	Count	70	49	30	22	171
		% within Sex	40.9%	28.7%	17.5%	12.9%	100.0%
		% within Population	35.5%	84.5%	41.7%	37.9%	44.4%
	Female	Count	77	2	16	12	107
		% within Sex	72.0%	1.9%	15.0%	11.2%	100.0%
		% within Population	39.1%	3.4%	22.2%	20.7%	27.8%
	Undetermined	Count	22	4	12	1	39
		% within Sex	56.4%	10.3%	30.8%	2.6%	100.0%
		% within Population	11.2%	6.9%	16.7%	1.7%	10.1%
	Non-Adults	Count	28	3	14	23	68
		% within Sex	41.2%	4.4%	20.6%	33.8%	100.0%
		% within Population	14.2%	5.2%	19.4%	39.7%	17.7%
Total		Count	197	58	72	58	385
		% within Sex	51.2%	15.1%	18.7%	15.1%	100.0%
		% within Population	100.0%	100.0%	100.0%	100.0%	100.0%

4.6.3 Stature Comparisons

The males at the Isle of May have the highest mean stature at 171 cm, Ballumbie follows at 169 cm, then Whitefriars at 168 cm, and lastly St Andrews Library at 165 cm (Table 71). A one-way ANOVA test of the difference between stature for males in all four populations found the difference is statistically significant (F=13131.495, p=.000, df=3).

Table 71 Male stature at study populations

Population	**Mean**	**N**	**Std. Deviation**
Ballumbie	169	50	4.96
Isle of May	171	45	5.84
St Andrews	165	24	6.89
Whitefriars	168	13	5.23
Total	168	132	5.73

The mean stature for females was highest at the Isle of May. However, there was only one female whose stature could be estimated; therefore the mean can be misleading. The females at Ballumbie and St Andrews Library were nearly the same height at 157 cm. Lastly, the females at Whitefriars had a mean stature of 155 cm (Table 72). A one-way ANOVA test also showed the difference between female stature for all four populations is statistically significant (F=17452.513, p=.000, df=3). Figures 92 and 93 illustrate the stature distribution for males and females of all four sites.

Table 72 Female stature at study populations

Population	Mean	N	Std. Deviation
Ballumbie	157	59	4.91
Isle of May	163	2	9.20
St Andrews	157	14	8.03
Whitefriars	155	6	5.01
Total	158	81	6.79

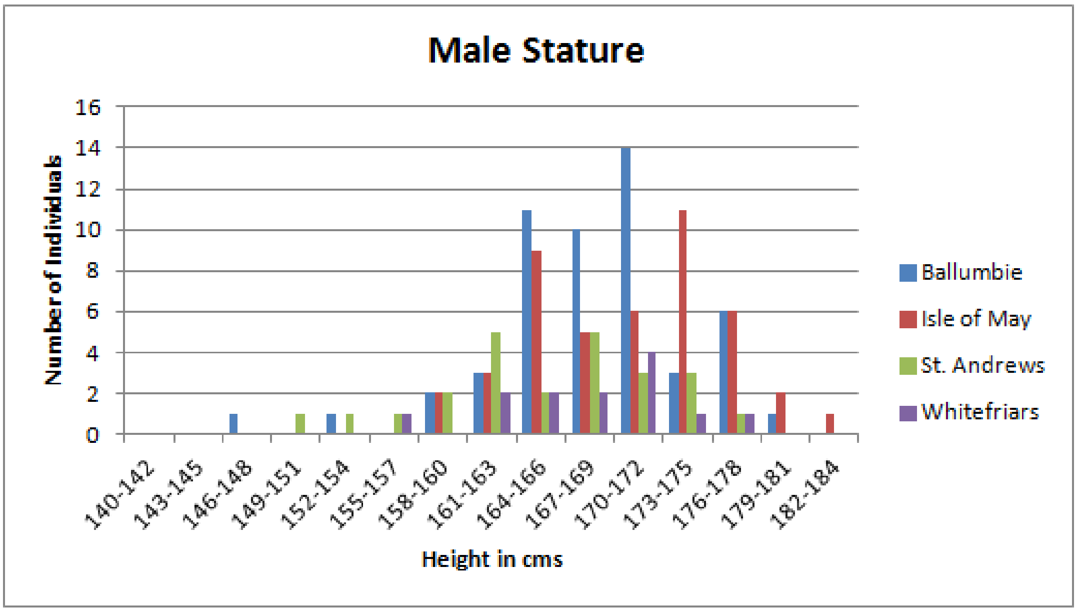


Figure 92 Male stature distribution for all study populations

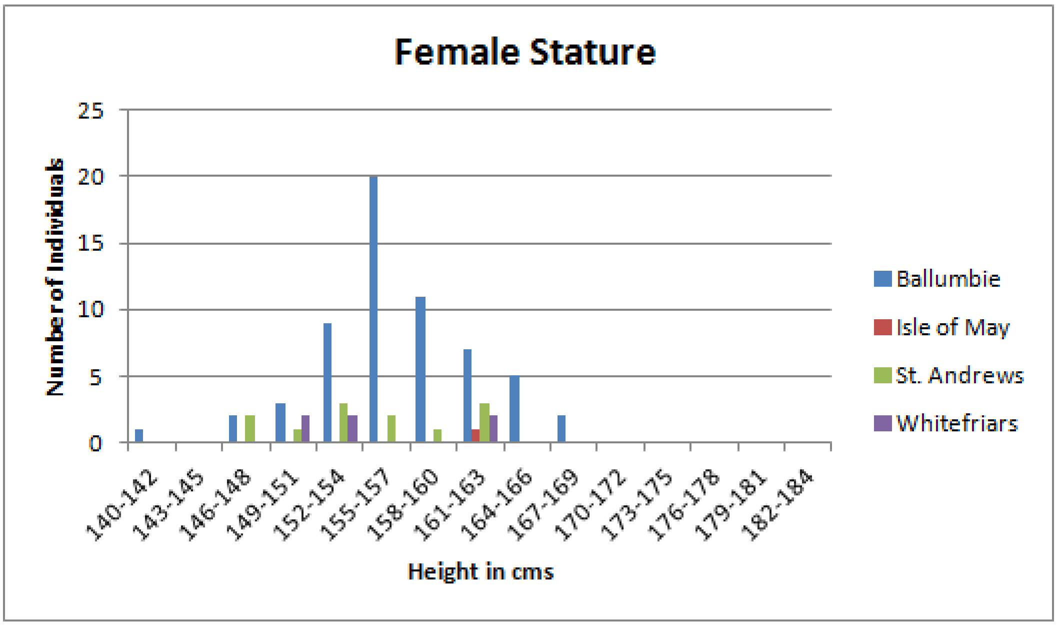


Figure 93 Female stature distribution for all study populations

4.6.4 Pathology Comparisons

For pathology prevalence, individuals who are counted have at least one type of pathological condition. The Isle of May has the highest prevalence for pathology among the four populations at 97% of the total population (Table 73; Figure 94). The St Andrews Library site also has a high prevalence of pathology with 90% of the total population. Ballumbie has the next highest prevalence for pathology at 62.9% of the total population. Lastly, Whitefriars has the least ratio of pathology with 56.9% of the total assemblage. The difference between pathology prevalence for the four populations is statistically significant (χ^2=44.042, p=.000, df=3).

St Andrews Library has the highest percentage of infectious disease, 61%, compared to the other populations (Table 74; Figure 95). Ballumbie and Isle of May have the highest percentage of congenital disorders compared to the other populations; both at 12%. The Isle of May has the highest percentage of trauma compared to the other populations, at 38%. The Isle of May also has the highest amount of joint disease, at 81% of the population. The Isle of May also has the highest amount of dental disease, at 47% of the population. The Isle of May has the highest amount of other pathology, at 31% of the population. Lastly Whitefriars has the highest amount of individuals with no pathology.

Table 73 Pathology prevalence at study populations

			Population				Total
			Ballumbie	Isle of May	St Andrews	Whitefriars	
	no pathology	Count	73	2	7	25	107
		% within Population	37.1%	3.4%	9.7%	43.1%	27.8%
	pathology	Count	124	56	65	33	278
		% within Population	62.9%	96.6%	90.3%	56.9%	72.2%
Total		Count	197	58	72	58	385
		% within Population	100.0%	100.0%	100.0%	100.0%	100.0%

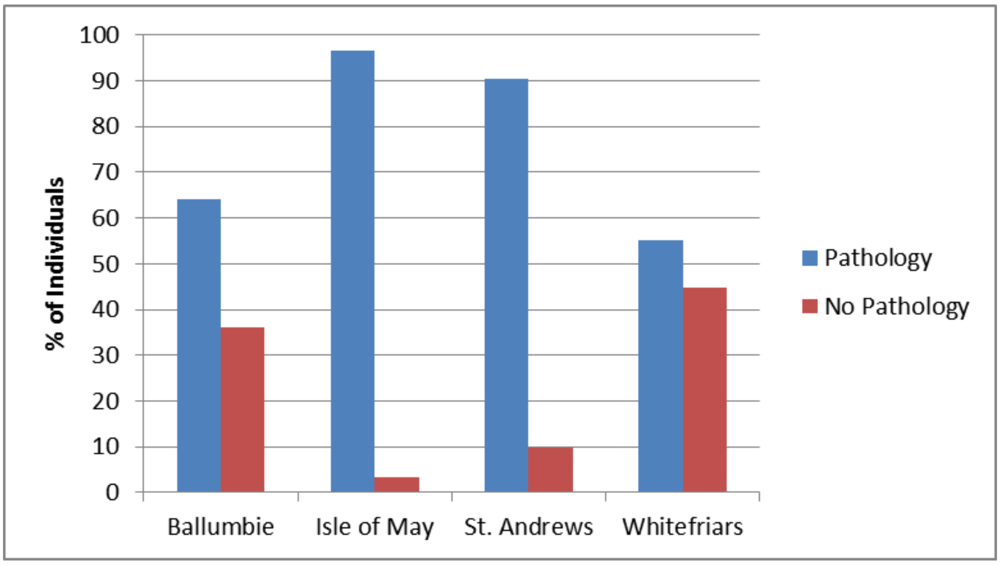


Figure 94 Pathology prevalence at study populations

Table 74 Pathology percentage comparisons

Disease	Ballumbie	Isle of May	St Andrews	Whitefriars
Infection	5.6	48.3	61.1	10.3
Growth	10.7	12.1	8.3	1.7
Trauma	13.2	39.7	16.7	3.4
Metabolic	16.8	39.7	27.8	1.7
Joint Disease	40.6	81	65.3	31
Dental Disease	42.6	44.8	37.5	43.1
Other Pathology	6.6	29.3	9.7	0
None	37	3.4	9.7	43.1

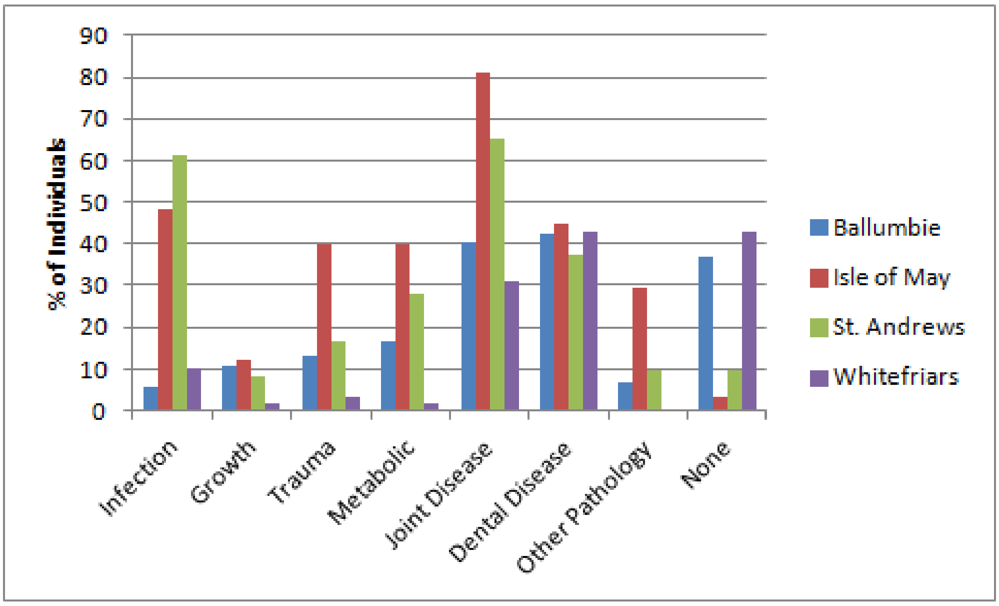


Figure 95 Study population pathology

Another way to compare the amount of pathology between these four populations is by comparing how many types of pathology each skeleton had during their life. For this purpose, the general categories of pathological conditions were used: infection, congenital, trauma, metabolic, joint, dental, and other. For example, if an individual had joint disease and dental disease, their count is 2. For Ballumbie, three-quarters of the population had less than two types of disease during their life (Table 75). Ballumbie has a mean of 1.41 types of pathology per individual (Table 76). For the Isle of May, the majority of the population had between two and five diseases during their life. Nearly a quarter of individuals at the Isle of May had five or more diseases during their life. The mean number of types of pathology individuals at the Isle of May have is 3.29. Three-quarters of the individuals at St Andrews Library had three or fewer diseases during their life. St Andrews Library has a mean of 2.42 types of pathology per individual. At Whitefriars, all individuals had three or fewer diseases; over 90% had two or fewer disease during their life. Whitefriars has a mean of 0.91 types of pathology per individual. The differences between the number of pathologies is statistically significant (χ^2=54.724, p=.000, df=3).

Table 75 Number of pathologies compared

			Population				
			Ballumbie	**Isle of May**	**St Andrews**	**Whitefriars**	**Total**
No. of Path	0	Count	73	2	7	25	107
		% within Population	37.1%	3.4%	9.7%	43.1%	27.8%
	1	Count	45	5	18	18	86
		% within Population	22.8%	8.6%	25.0%	31.0%	22.3%
	2	Count	40	16	16	10	82
		% within Population	20.3%	27.6%	22.2%	17.2%	21.3%
	3	Count	17	8	13	5	43
		% within Population	8.6%	13.8%	18.1%	8.6%	11.2%
	4	Count	12	13	8	0	33
		% within Population	6.1%	22.4%	11.1%	.0%	8.6%
	5	Count	8	8	7	0	23
		% within Population	4.1%	13.8%	9.7%	.0%	6.0%
	6	Count	1	4	3	0	8
		% within Population	.5%	6.9%	4.2%	.0%	2.1%
	7	Count	1	2	0	0	3
		% within Population	.5%	3.4%	.0%	.0%	.8%
Total		Count	197	58	72	58	385
		% within Population	100.0%	100.0%	100.0%	100.0%	100.0%

Table 76 Mean number of pathologies

Population	Mean	N	Standard deviation
Ballumbie	1.41	197	1.5
Isle of May	3.29	58	1.7
St Andrews Library	2.42	72	1.6
Whitefriars	0.91	58	1.0

The number of pathological conditions per individual was compared to the age of the individual to see if there was a correlation. There was no positive correlation between number of pathologies and age, which is surprising. This indicates that individuals of any age were just as likely to have or not have multiple pathological conditions. The condition of the skeletal remains was also compared to the number of pathological conditions found per skeleton. There was a weak positive correlation between condition and number of pathologies, which was statistically significant (r=.368, n=385, p=.000). As the condition of the skeletal remains improved, more pathological conditions could be visible and diagnosed.

4.6.4.1 Infection

Nearly two-thirds of the St Andrews population and nearly half of the Isle of May population have infectious disease (Table 77). Conversely, only 5.6% of the Ballumbie population and 10.3% of the Whitefriars population have infectious disease. The differences between the number of infection cases found within these populations are statistically significant (χ^2=118.534, p=.000, df=3). There is no significant relationship between infection and age or sex across the populations.

Table 77 Infection comparison

			Infection		Total
			no	yes	
Population	Ballumbie	Count	186	11	197
		% within Population	94.4%	5.6%	100.0%
	Isle of May	Count	30	28	58
		% within Population	51.7%	48.3%	100.0%
	St Andrews	Count	28	44	72
		% within Population	38.9%	61.1%	100.0%
	Whitefriars	Count	52	6	58
		% within Population	89.7%	10.3%	100.0%
Total		Count	296	89	385
		% within Population	76.9%	23.1%	100.0%

4.6.4.1.1 Non-Specific Infections

For Ballumbie and Whitefriars, nearly all the infectious disease found was non-specific (Table 78; Figure 96). For the Isle of May, 36% have non-specific infections. At St Andrews Library, 90% of the infectious disease was non-specific and at the Isle of May, three-quarters of the infectious disease was non-specific. The differences between how much non-specific disease was present in these populations are statistically significant (χ^2= 40.896, p=.000, df=3).

Table 78 Non-specific infection comparison

			Non-Specific Infection		
			no	**yes**	**Total**
Population	Ballumbie	Count	187	10	197
		% within Population	94.9%	5.1%	100.0%
	Isle of May	Count	37	21	58
		% within Population	63.8%	36.2%	100.0%
	St Andrews	Count	32	40	72
		% within Population	44.4%	55.6%	100.0%
	Whitefriars	Count	52	6	58
		% within Population	89.7%	10.3%	100.0%
Total		Count	308	77	385
		% within Population	80.0%	20.0%	100.0%

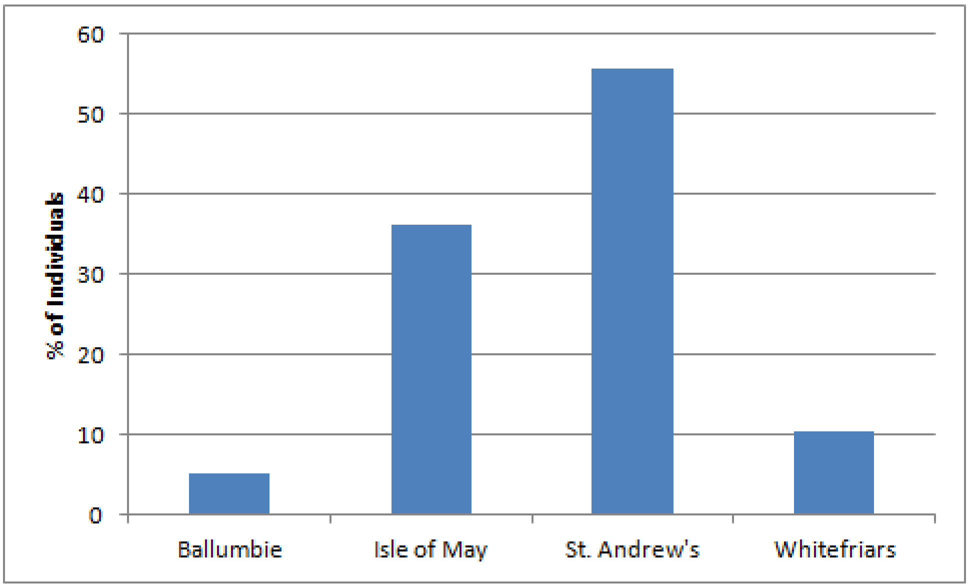


Figure 96 Non-specific infections

4.6.4.2 Congenital Disorders

Twenty-one individuals at Ballumbie (10.7%), seven individuals (12.1%) at the Isle of May, six individuals (8.3%) at St Andrews Library, and one individual (1.7%) at Whitefriars have congenital disorders (Table 79). The difference between the amounts of congenital disorder found at these populations is not statistically significant. The occurrence of congenital disorders was neither related to sex, nor age for Ballumbie, St Andrews Library or Whitefriars. However, there is a significant relationship between congenital disorders and age for Isle of May (χ^2=15.658, p=.016, df=6).

Table 79 Comparison of congenital disorders

			Congenital		
			no	yes	Total
Population	Ballumbie	Count	176	21	197
		% within Population	89.3%	10.7%	100.0%
	Isle of May	Count	51	7	58
		% within Population	87.9%	12.1%	100.0%
	St Andrews	Count	66	6	72
		% within Population	91.7%	8.3%	100.0%
	Whitefriars	Count	57	1	58
		% within Population	98.3%	1.7%	100.0%
Total		Count	350	35	385
		% within Population	90.9%	9.1%	100.0%

4.6.4.2.1 Spina Bifida and Spina Bifida Occulta

The occurrence of spina bifida and spina bifida occulta was found in 9.1% of the population at Ballumbie and 6.8% of the Population at the Isle of May (Table 80). There were no individuals with spina bifida or spina bifida occulta at St Andrews Library or at Whitefriars. The significance of the relationship between spina bifida or spina bifida occulta and population could not be tested due to the small number of cases. Relationships between age or sex and spina bifida and spina bifida occulta were likewise impossible to test across all populations.

Table 80 Spina bifida and spina bifida occulta

			Spina Bifida and Spina Bifida Occulta		
			no	yes	Total
Population	Ballumbie	Count	50	5	55
		% within Population	90.9%	9.1%	100.0%
	Isle of May	Count	41	3	44
		% within Population	93.2%	6.8%	100.0%
	St Andrews	Count	44	0	44
		% within Population	100.0%	.0%	100.0%
	Whitefriars	Count	5	0	5
		% within Population	100.0%	.0%	100.0%
Total		Count	140	8	148
		% within Population	94.6%	5.4%	100.0%

4.6.4.3 Trauma

In Ballumbie, 26 individuals (13.2%), in the Isle of May 22 individuals (37.9%), in St Andrews Library 12 individuals (16.7%), and in Whitefriars two individuals (3.4%) have trauma (Table 81). A chi-square test reveals the differences in trauma between these populations are statistically significant (χ^2=28.577, p=.000, df=3).

Table 81 Trauma comparisons

			Trauma		
			no	yes	Total
Population	Ballumbie	Count	171	26	197
		% within Population	86.8%	13.2%	100.0%
	Isle of May	Count	36	22	58
		% within Population	62.1%	37.9%	100.0%
	St Andrews	Count	60	12	72
		% within Population	83.3%	16.7%	100.0%
	Whitefriars	Count	56	2	58
		% within Population	96.6%	3.4%	100.0%
Total		Count	323	62	385
		% within Population	83.9%	16.1%	100.0%

4.6.4.3.1 Post-cranial Fractures

Out of the 26 individuals that have trauma in Ballumbie, 19 of those have fractures, or 73% of the population (Table 82). In the Isle of May, out of 22 individuals with trauma, 10, almost half, have fractures. In St Andrews Library, out of the 12 individuals with trauma, eight have fractures. In Whitefriars two individuals have trauma, and both of them have fractures.

Table 82 Fracture comparisons

Population	N	n	CPR
Ballumbie	26	19	73.1
Isle of May	22	10	45.5
St Andrews Library	12	8	66.6
Whitefriars	2	2	100

Of all the bones, clavicles have the highest percentage of fractures: 25% of individuals with a clavicle present at Whitefriars, 7.5% of individuals with a clavicle present at St Andrews Library, and 2.4% of the individuals with a clavicle present at Ballumbie (Table 83; Figure 97). The percentage of clavicle fractures at Whitefriars is somewhat biased since there were only four clavicles present in the assemblage, one of which was fractured. The next highest percentage of fractures for all populations is vertebra fractures (Figure 98). The Isle of May has the highest percentage of vertebra fractures at 10.6% of the population with vertebrae present. Ballumbie has the next highest with 6.8%, and St Andrews follows with 3.7%. Whitefriars has no vertebra fractures. Rib fractures are the next highest percentage of fractures. The Isle of May has the highest with 7.3%, Ballumbie is next with 5.1% and St Andrews follows with 3.7%. Whitefriars has no rib fractures. Ballumbie has the highest relative frequency of fibula fractures at 6.3%, and St Andrews has 3.3%. Assemblages from neither the Isle of May nor Whitefriars contained fractures of fibulae. The Isle of May is the only population that has scapula fractures, at 4.9% of the population with a scapula present. The Isle of May and St Andrews both have metacarpal fractures at 4.3% and 2.6% respectively. Ballumbie and St Andrews are the only populations that have metatarsal fractures at 3.5% and 3.3% respectively.

Ballumbie is the only population with tibia fractures, in which 3.1% of the population with tibiae present have fractures. Ballumbie and Isle of May are the only populations that have ulna fractures at 3% and 2.2% respectively. Ballumbie and Isle of May are the only populations that have radius fractures at 0.9% and 2.3% respectively. St Andrews is the only population with hand phalanx fractures at 2.5% of the population with at least one hand phalanx present. Ballumbie is the only population with foot phalanx fractures present at 1.8% of the population with at least one foot phalanx present. Ballumbie is the only population with humerus and femur fractures, at 0.8% and 0.6% respectively, of the populations with that element present. None of the populations had patella fractures. For all four populations, the difference in the amount of fractures for each element is not significant.

Table 83 Comparisons of crude prevalence rate of fractures by element

Bone	Ballumbie	Isle of May	St Andrews	Whitefriars
Cranium	1.9	2.7	0	16.7
Clavicle	2.4	0	7.5	25.0
Scapula	0	4.9	0	0
Rib	5.1	7.3	3.7	0
Vertebra	6.8	10.6	3.7	0
Innominate	0	2.2	0	0
Humerus	0.8	0	0	0
Radius	0.9	2.3	0	0
Ulna	3	2.2	0	0
Metacarpal	0	4.3	2.6	0
Hand Phalanx	0	0	2.5	0
Patella	0	0	0	0
Femur	0.6	0	0	0
Tibia	3.1	0	0	0
Fibula	6.3	2.6	0	0

Metatarsal	3.5	0	3.5	0
Foot Phalanx	1.8	0	0	0

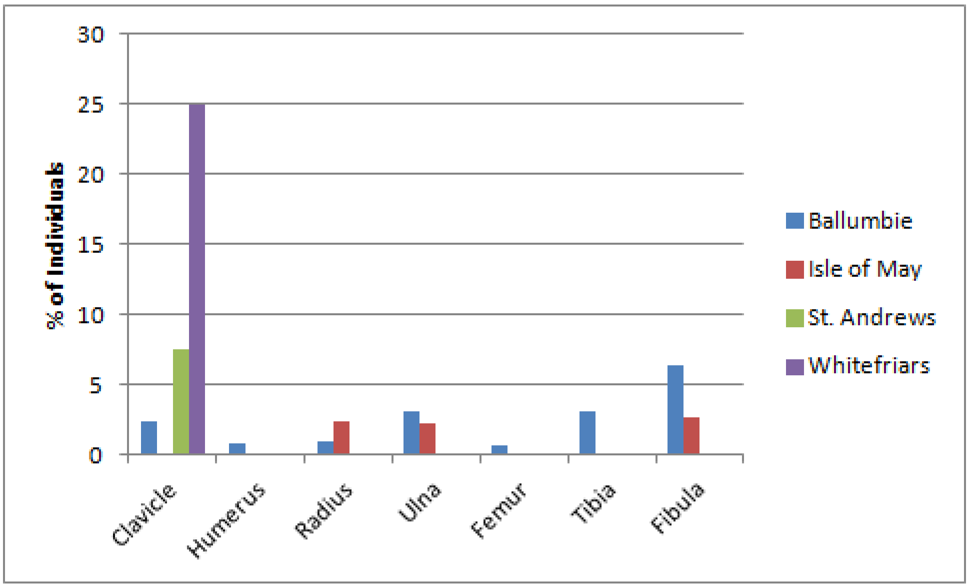


Figure 97 Long-bone fracture comparisons

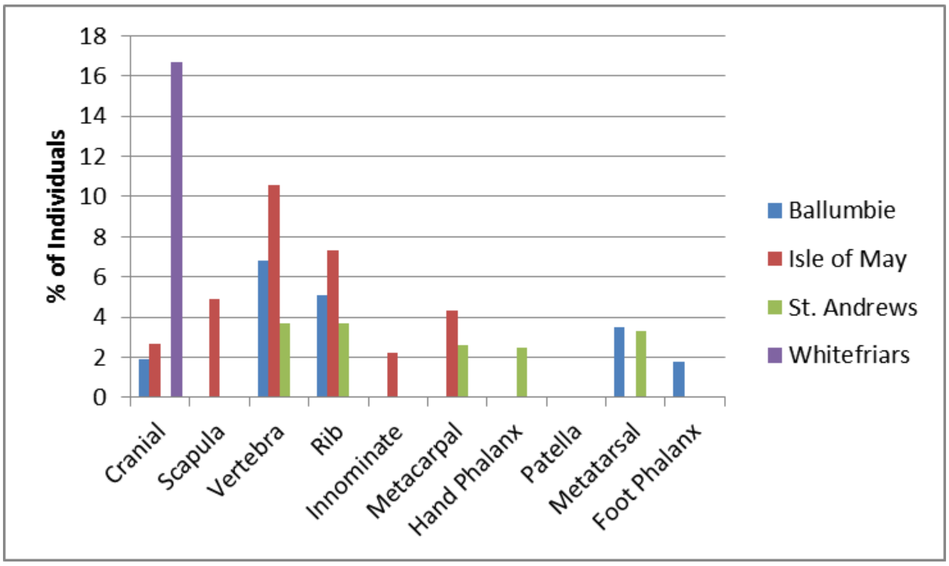


Figure 98 Non-long bone fracture comparisons

In the Ballumbie assemblage, males have significantly more rib fractures than females (χ^2=4.724, p=.030, df=1). Males and females do not have significantly different amounts of fractures for any other element for Ballumbie or the other study populations. The majority of fractures in all four study populations are from male individuals; in fact only 14 of the total fractures are in female individuals, which is

22% of all 63 fractures. However, when examining the fracture pattern by individuals, nine males (45% of fractures) and 11 (55% of fractures) females have fractures in Ballumbie. For the Isle of May and Whitefriars, 100% of the fractures are in male individuals. In St Andrews Library 86% of the fractures are in male individuals and 14% are in female individuals. None of the fracture pattern results are statistically significant.

4.6.4.3.2 Cranial Trauma

Whitefriars has the most cranial trauma at 16.7% of the population (Figure 91). However, there are only six skulls at Whitefriars, so this high percentage can be misleading. The next highest is the Isle of May with 2.7% of the population with cranial trauma. Ballumbie has a mere 0.9% of the population with cranial trauma, and St Andrews Library has none.

4.6.4.3.3 Spondylolysis and Spondylolisthesis

Of the 66 individuals at Ballumbie with at least one vertebra present, six (9.0%) have either spondylolysis or spondylolisthesis (Table 84). Of the 45 individuals at the Isle of May with at least one vertebra present, one individual (2.2%) has either spondylolysis or spondylolisthesis. Of the 44 individuals at St Andrews Library with at least one vertebra present, none have spondylolysis or spondylolisthesis. Of the five individuals at Whitefriars with at least one vertebra present, none have either spondylolysis or spondylolisthesis. The percentage differences between populations for spondylolysis and spondylolisthesis cannot be tested statistically due to the small number of cases. There is also no demonstrable significant relationship between the populations and spondylolysis or spondylolisthesis by age or sex.

Table 84 Spondylolysis and spondylolisthesis

			Spondylolysis and Spondylolisthesis		
			no	yes	Total
Population	Ballumbie	Count	49	6	66
		% within Population	89.1%	9.0%	100.0%
	Isle of May	Count	44	1	45
		% within Population	97.8%	2.2%	100.0%
	St Andrews	Count	44	0	44
		% within Population	100.0%	.0%	100.0%
	Whitefriars	Count	5	0	5
		% within Population	100.0%	.0%	100.0%
Total		Count	142	7	149
		% within Population	95.3%	4.7%	100.0%

4.6.4.3.4 Osteochondritis Dissecans

Out of the 197 individuals at Ballumbie, three (1.5%) have osteochondritis dissecans (Table 85). Out of the 58 individuals at Isle of May, nine (15.5%) have osteochondritis dissecans, the highest percentage of the four populations. Out of the 72 individuals at St Andrews Library, four (5.5%) have osteochondritis dissecans. Out of the 58 individuals at Whitefriars, none have osteochondritis dissecans. The differences between population and the amount of osteochondritis dissecans is statistically significant (χ^2=25.094, p=.000, df=3).

Table 85 Comparisons in osteochondritis dissecans

Population	N	n	CPR
Ballumbie	197	3	1.5
Isle of may	58	9	15.5
St Andrews	72	4	5.5
Whitefriars	58	0	0

4.6.4.4 Metabolic Disease

The Isle of May population has the highest proportion of metabolic disease at 39.7% of fifty-eight cases studied (Table 86). The St Andrews Library population has the next highest proportion of metabolic disease with 27.8% of the population.

Approximately 17% of the Ballumbie population has metabolic disease. Whitefriars has the least amount of metabolic disease, with only 1.7%. The difference in the amount of metabolic disease between these four populations is statistically significant (χ^2=30.134, p=.000, df=3).

Table 86 Comparisons of metabolic disease

			Metabolic		
			no	yes	Total
Population	Ballumbie	Count	164	33	197
		% within Population	83.2%	16.8%	100.0%
	Isle of May	Count	35	23	58
		% within Population	60.3%	39.7%	100.0%
	St Andrews	Count	52	20	72
		% within Population	72.2%	27.8%	100.0%
	Whitefriars	Count	57	1	58
		% within Population	98.3%	1.7%	100.0%
Total		Count	308	77	385
		% within Population	80.0%	20.0%	100.0%

More than three-quarters of individuals at Ballumbie with metabolic disease are female. At St Andrews Library the trend is opposite; two-thirds of the individuals with metabolic disease were male. However, these trends are not statistically significant, in fact there is no significance between the sexes and the amount of metabolic disease across any of the populations. At Ballumbie, nearly three-quarters of the cases of metabolic disease are in individuals over twenty-five. The trend is similar at the Isle of May and St Andrews Library with just over two-thirds of the cases of metabolic disease was in individuals over twenty-five. However, these trends are not statistically significant due to the small number of cases.

4.6.4.4.1 Cribra Orbitalia

In the Ballumbie assemblage 23% of the 74 individuals with at least one orbit present has cribra orbitalia (Table 87). For the Isle of May, 28.6% of 35 individuals with at least one orbit present has cribra orbitalia. Of the 29 individuals at St Andrews Library, 17.2% has cribra orbitalia and Whitefriars has none. There is no significant relationship between cribra orbitalia and population.

Table 87 Comparisons in cribra orbitalia

			Cribra Orbitalia		Total
			no	yes	
Population	Ballumbie	Count	59	15	74
		% within Population	79.7%	20.3%	100.0%
	Isle of May	Count	25	10	35
		% within Population	71.4%	28.6%	100.0%
	St Andrews	Count	24	5	29
		% within Population	82.8%	17.2%	100.0%
	Whitefriars	Count	7	0	7
		% within Population	100.0%	.0%	100.0%
Total		Count	115	30	145
		% within Population	79.3%	20.7%	100.0%

At Ballumbie, two-thirds of the individuals with cribra orbitalia were female. However, at St Andrews Library and Whitefriars, more males had cribra orbitalia. These trends were not statistically significant. Interestingly, at St Andrews Library all of the individuals with cribra orbitalia were over 18 years of age. This pattern, however, is not statistically significant, nor is there a significant relationship between age and cribra orbitalia in any of the other populations.

4.6.4.4.2 Porotic Hyperostosis

In the Ballumbie assemblage 10.9% of the individuals with at least a partial skull present has porotic hyperostosis (Table 88). In the Isle of May assemblage 36.8% of the individuals with at least a partial skull present has porotic hyperostosis. In the St Andrews Library assemblage 48.5% of the individuals with at least a partial skull present has porotic hyperostosis. In the Whitefriars assemblage 12.5% of the individuals with at least a partial skull present has porotic hyperostosis. There is a significant relationship between population and porotic hyperostosis (χ^2=22.515, p=.000, df=3).

Table 88 Comparisons in porotic hyperostosis

			Porotic Hyperostosis		
			no	yes	Total
Population	Ballumbie	Count	90	11	101
		% within Population	89.1%	10.9%	100.0%
	Isle of May	Count	24	14	38
		% within Population	63.2%	36.8%	100.0%
	St Andrews	Count	18	15	33
		% within Population	54.5%	45.5%	100.0%
	Whitefriars	Count	7	1	8
		% within Population	87.5%	12.5%	100.0%
Total		Count	139	41	180
		% within Population	77.2%	22.8%	100.0%

Two-thirds of the individuals with porotic hyperostosis at Ballumbie were male. This same pattern is seen at St Andrews Library, however these patterns are not statistically significant, nor is there any significant relationship between porotic hyperostosis and sex across Isle of May or Whitefriars. There is no significant relationship between age and porotic hyperostosis for Ballumbie, Isle of May, or St Andrews Library. However, there is a significant relationship between porotic hyperostosis and age for Whitefriars (χ^2=8.000, p=0.046, df=3). For the individuals with porotic hyperostosis in the Whitefriars assemblage, 100% are adolescents (Table 89). The counts in each age category are small, which could affect the chi-square test results.

Table 89 Porotic hyperostosis in Whitefriars by age

			Porotic Hyperostosis		Total
			no	yes	
Age	CH	Count	2	0	2
		% within Porotic Hyperostosis	28.6%	.0%	25.0%
	OJ	Count	1	0	1
		% within Porotic Hyperostosis	14.3%	.0%	12.5%
	ADL	Count	0	1	1
		% within Porotic Hyperostosis	.0%	100.0%	12.5%
	YA	Count	4	0	4
		% within Porotic Hyperostosis	57.1%	.0%	50.0%
Total		Count	7	1	8
		% within Porotic Hyperostosis	100.0%	100.0%	100.0%

In the Ballumbie assemblage, no individuals had both cribra orbitalia and porotic hyperostosis (Table 90; Figure 99). In the Isle of May assemblage, 14.3% of the individuals with at least one orbit and a partial skull had both cribra orbitalia and porotic hyperostosis. In the St Andrews Library assemblage, 10.3% of the individuals with at least one orbit and a partial skull had both cribra orbitalia and porotic hyperostosis. In the Whitefriars assemblage, no individuals had both cribra orbitalia and porotic hyperostosis. There is no significant relationship between population and having both cribra orbitalia and porotic hyperostosis. There is also no significant relationship between age or sex and having both cribra orbitalia and porotic hyperostosis across the populations.

Table 90 Comparisons of cribra orbitalia and porotic hyperostosis

			Cribra and Porotic Hyperostosis		
			no	**yes**	**Total**
Population	Ballumbie	Count	32	0	32
		% within Population	100.0%	.0%	100.0%
	Isle of May	Count	30	5	35
		% within Population	85.7%	14.3%	100.0%
	St Andrews	Count	27	2	29
		% within Population	93.1%	6.9%	100.0%
	Whitefriars	Count	8	0	8
		% within Population	100.0%	.0%	100.0%
Total		Count	97	7	104
		% within Population	93.3%	6.7%	100.0%

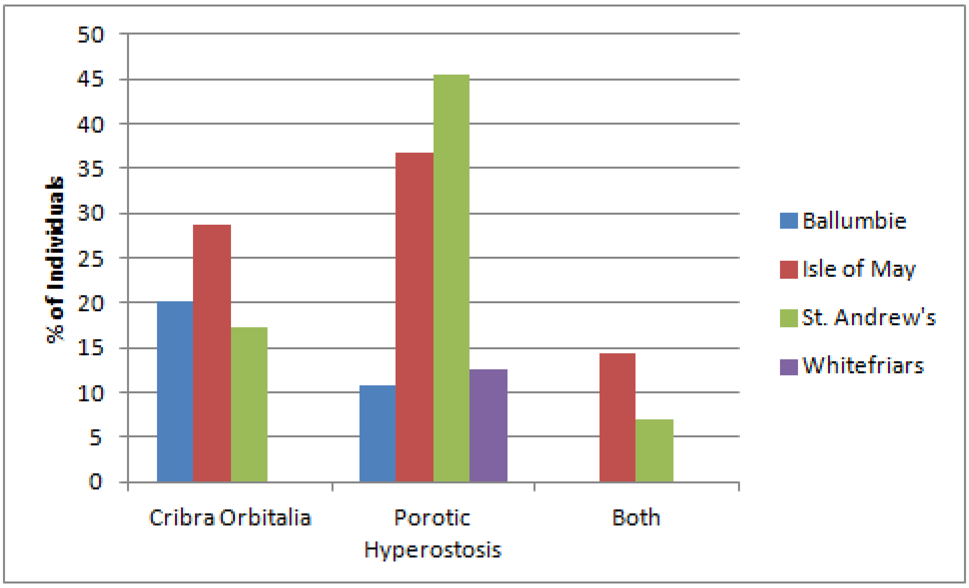


Figure 99 Comparisons with cribra orbitalia and porotic hyperostosis

4.6.4.4.3 Rickets

In the Ballumbie assemblage 2% of the individuals have a probable case of rickets (Table 91). For the Isle of May, none of the individuals have rickets. In St

Andrews Library, 4.2% of the individuals have a probable case of rickets. Whitefriars has no cases of possible rickets. There is no significant relationship between rickets and population.

Table 91 Comparison of rickets

			Rickets		Total
			no	yes	
Population	Ballumbie	Count	193	4	197
		% within Population	98.0%	2.0%	100.0%
	Isle of May	Count	58	0	58
		% within Population	100.0%	.0%	100.0%
	St Andrews	Count	69	3	72
		% within Population	95.8%	4.2%	100.0%
	Whitefriars	Count	58	0	58
		% within Population	100.0%	.0%	100.0%
Total		Count	378	7	385
		% within Population	98.2%	1.8%	100.0%

4.6.4.4.4 Osteopenia and Osteoporosis

In the Ballumbie assemblage 3.6% of the individuals have osteopenia or osteoporosis (Table 92). For the Isle of May, 7% of the individuals have osteopenia or osteoporosis. For St Andrews Library, 1.4% of the individuals have osteopenia or osteoporosis. There are no cases of osteopenia or osteoporosis in Whitefriars. There is no significant relationship between osteopenia or osteoporosis and population.

Table 92 Comparisons with osteopenia or osteoporosis

			Osteopenia or Osteoporosis		
			no	yes	Total
Population	Ballumbie	Count	190	7	197
		% within Population	96.4%	3.6%	100.0%
	Isle of May	Count	54	4	58
		% within Population	93.1%	6.9%	100.0%
	St Andrews	Count	71	1	72
		% within Population	98.6%	1.4%	100.0%
	Whitefriars	Count	58	0	58
		% within Population	100.0%	.0%	100.0%
Total		Count	373	12	385
		% within Population	96.9%	3.1%	100.0%

There is no significant relationship between age and osteopenia and osteoporosis across the populations. There is no significant relationship between sex and osteopenia and osteoporosis for Isle of May, St Andrews or Whitefriars. Conversely, there is a significant relationship between sex and osteopenia for Ballumbie (χ=6.682, p=.010, df=1). One hundred percent of the cases of osteopenia or osteoporosis were female (Table 93).

Table 93 Osteopenia or osteoporosis in Ballumbie by sex

			Osteopenia or Osteoporosis		Total
			no	yes	
Sex	Male	Count	70	0	70
		% within Osteopenia	50.0%	.0%	47.6%
	Female	Count	70	7	77
		% within Osteopenia	50.0%	100.0%	52.4%
Total		Count	140	7	147
		% within Osteopenia	100.0%	100.0%	100.0%

4.6.4.5 Joint Disease

In the Ballumbie assemblage, 40.6% of the population has joint disease (Table 94). In the Isle of May, 81% of the population has joint disease. In St Andrews Library, 65% of the population has joint disease. In Whitefriars, 31% of the population has joint disease. There is a significant relationship between joint disease and population (χ^2=44.359, p=.000, df=3).

Table 94 Comparisons with joint disease

			Joint Disease		
			no	yes	Total
Population	Ballumbie	Count	117	80	197
		% within Population	59.4%	40.6%	100.0%
	Isle of May	Count	11	47	58
		% within Population	19.0%	81.0%	100.0%
	St Andrews	Count	25	47	72
		% within Population	34.7%	65.3%	100.0%
	Whitefriars	Count	40	18	58
		% within Population	69.0%	31.0%	100.0%
Total		Count	193	192	385
		% within Population	50.1%	49.9%	100.0%

Among the eighty individuals in Ballumbie with joint disease, 51.9% are male, and 48.1% are female (Table 95). Among the forty-seven individuals in the Isle of May with joint disease, 95.5% are male, and 4.5% are female, not surprising since almost all individuals are male at the Isle of May. Among the forty-seven individuals in St Andrews Library with joint disease, 63.2% are male, and 36.8% are female. Among the individuals in eighteen Whitefriars with joint disease, 88.2% are male, and 11.8% are female. The differences between males and female who have joint disease are not statistically significant for Ballumbie, the Isle of May or St Andrews Library. However, the differences are statistically significant for Whitefriars. Chi-square results for Whitefriars are χ^2=9.795, p=.002, df=1.

Table 95 Comparisons of joint disease by sex

Population				Sex: Male	Sex: Female	Total
Ballumbie	Joint Disease	No	Count	30	40	70
			% within Joint Disease	42.9%	57.1%	100.0%
		yes	Count	40	37	77
			% within Joint Disease	51.9%	48.1%	100.0%
	Total		Count	70	77	147
			% within Joint Disease	47.6%	52.4%	100.0%
Isle of May	Joint Disease	no	Count	7	0	7
			% within Joint Disease	100.0%	.0%	100.0%
		yes	Count	42	2	44
			% within Joint Disease	95.5%	4.5%	100.0%
	Total		Count	49	2	51
			% within Joint Disease	96.1%	3.9%	100.0%
St Andrews	Joint Disease	no	Count	6	2	8
			% within Joint Disease	75.0%	25.0%	100.0%
		yes	Count	24	14	38
			% within Joint Disease	63.2%	36.8%	100.0%
	Total		Count	30	16	46
			% within Joint Disease	65.2%	34.8%	100.0%
Whitefriars	Joint Disease	no	Count	6	10	16
			% within Joint Disease	37.5%	62.5%	100.0%
		yes	Count	16	2	18
			% within Joint Disease	88.9%	11.1%	100.0%
	Total		Count	22	12	34
			% within Joint Disease	64.7%	35.3%	100.0%

Among the eighty individuals in Ballumbie with joint disease, over three-quarters are over twenty-five years (Table 96). While the percentages are not as high as at Ballumbie, three-quarters of the forty-seven individuals with joint disease at the Isle of May are also over twenty-five years. Two-thirds of the forty-seven individuals at St Andrews Library with joint disease are over twenty-five years; the other third of individuals with joint disease are in the broad category for adult, therefore are eighteen years or older. Three-quarter of the eighteen individuals with joint disease at Whitefriars are over twenty-five years. The differences in the percentages of individuals with joint disease in the various age categories are statistically significant for all four populations. For Ballumbie the chi-square results are χ^2=74.546, p=.000, df=8. For the Isle of May the chi-square results are χ^2=21.361, p=.002, df=6. For St Andrews Library the chi-square results are χ^2=46.430, p=.000, df=9. For Whitefriars the chi-square results are χ^2=25.294, p=.001, df=8.

Table 96 Comparisons of joint disease by age

Table 96 Comparisons of joint disease by age

Table 96 Comparisons of joint disease by age

Population				Joint Disease no	Joint Disease yes	Total
Ballumbie	Age	IN	Count	4	0	4
			% within Joint Disease	3.5%	.0%	2.0%
		YJ	Count	5	0	5
			% within Joint Disease	4.4%	.0%	2.5%
		OJ	Count	12	0	12
			% within Joint Disease	10.5%	.0%	6.1%
		ADL	Count	14	1	15
			% within Joint Disease	12.3%	1.2%	7.6%
		YA	Count	15	2	17
			% within Joint Disease	13.2%	2.4%	8.6%
		YMA	Count	22	17	39
			% within Joint Disease	19.3%	20.5%	19.8%
		MA	Count	9	33	44
			% within Joint Disease	7.0%	43.4%	22.3%
		OA	Count	7	19	26
			% within Joint Disease	5.3%	24.1%	13.2%
		AD	Count	28	7	35
			% within Joint Disease	24.6%	8.4%	17.8%
	Total		Count	117	80	197
			% within Joint Disease	100.0%	100.0%	100.0%

Table 96 Comparisons of joint disease by age

Isle of May	Age	OJ	Count	2	0	2
			% within Joint Disease	18.2%	.0%	3.4%
		ADL	Count	1	2	3
			% within Joint Disease	9.1%	4.3%	5.2%
		YA	Count	2	6	8
			% within Joint Disease	18.2%	12.8%	13.8%
		YMA	Count	0	11	11
			% within Joint Disease	.0%	23.4%	19.0%
		MA	Count	2	14	16
			% within Joint Disease	18.2%	29.8%	27.6%
		OA	Count	0	11	11
			% within Joint Disease	.0%	23.4%	19.0%
		AD	Count	4	3	7
			% within Joint Disease	36.4%	6.4%	12.1%
	Total		Count	11	47	58
			% within Joint Disease	100.0%	100.0%	100.0%
St Andrews	Age	NN	Count	1	0	1
			% within Joint Disease	4.0%	.0%	1.4%
		IN	Count	3	0	3
			% within Joint Disease	12.0%	.0%	4.2%
		YJ	Count	7	0	7
			% within Joint Disease	28.0%	.0%	9.7%

Table 96 Comparisons of joint disease by age

		OJ	Count	2	0	2
			% within Joint Disease	8.0%	.0%	2.8%
		ADL	Count	5	1	6
			% within Joint Disease	20.0%	2.1%	8.3%
		YA	Count	0	4	4
			% within Joint Disease	.0%	8.5%	5.6%
		YMA	Count	0	9	9
			% within Joint Disease	.0%	19.1%	12.5%
		MA	Count	0	14	14
			% within Joint Disease	.0%	29.8%	19.4%
		OA	Count	1	6	7
			% within Joint Disease	4.0%	12.8%	9.7%
		AD	Count	6	13	19
			% within Joint Disease	24.0%	27.7%	26.4%
	Total		Count	25	47	72
			% within Joint Disease	100.0%	100.0%	100.0%
Whitefriars	Age	IN	Count	6	0	6
			% within Joint Disease	14.6%	.0%	10.3%
		YJ	Count	12	0	12
			% within Joint Disease	29.3%	.0%	20.7%
		OJ	Count	4	0	4
			% within Joint Disease	9.8%	.0%	6.9%

Table 96 Comparisons of joint disease by age

	ADL	Count	1	0	1
		% within Joint Disease	2.4%	.0%	1.7%
	YA	Count	8	4	12
		% within Joint Disease	20.0%	22.2%	20.7%
	YMA	Count	6	6	12
		% within Joint Disease	14.6%	35.3%	20.7%
	MA	Count	0	5	5
		% within Joint Disease	.0%	29.4%	8.6%
	OA	Count	1	2	3
		% within Joint Disease	2.4%	11.8%	5.2%
	AD	Count	2	1	3
		% within Joint Disease	4.9%	5.9%	5.2%
Total		Count	40	18	58
		% within Joint Disease	100.0%	100.0%	100.0%

4.6.4.5.1 Extra-spinal Arthropathies

In the Ballumbie population, 31% of the 197 individuals have extra-spinal arthropathies (Table 97). In the Isle of May population, 65.5% have extra-spinal arthropathies. In St Andrews Library assemblage, 62.5% show extra-spinal arthropathies. In Whitefriars, 19.0% have extra-spinal arthropathies. These differences in extra-spinal arthropathies are statistically significant (χ^2=48.203, p=.000, df=3).

Table 97 Comparisons with extra-spinal arthropathies

			Extraspinal Arthropathy		
			no	yes	Total
Population	Ballumbie	Count	136	61	197
		% within Population	69.0%	31.0%	100.0%
	Isle of May	Count	20	38	58
		% within Population	34.5%	65.5%	100.0%
	St Andrews	Count	27	45	72
		% within Population	37.5%	62.5%	100.0%
	Whitefriars	Count	47	11	58
		% within Population	81.0%	19.0%	100.0%
Total		Count	230	155	385
		% within Population	59.7%	40.3%	100.0%

The Isle of May has the highest percentage of arthropathies on the shoulder (52%), elbow (42%), wrist (36%), hip (33%), knee (44%), ankle (20%), and foot (37%) joints (Figure 100). St Andrews Library has the highest percentage of arthropathies at the sterno-clavicular (41%), and the acromio-clavicular (51%) joints. Ballumbie has the highest percentage of arthropathy at the hand joints (28%).

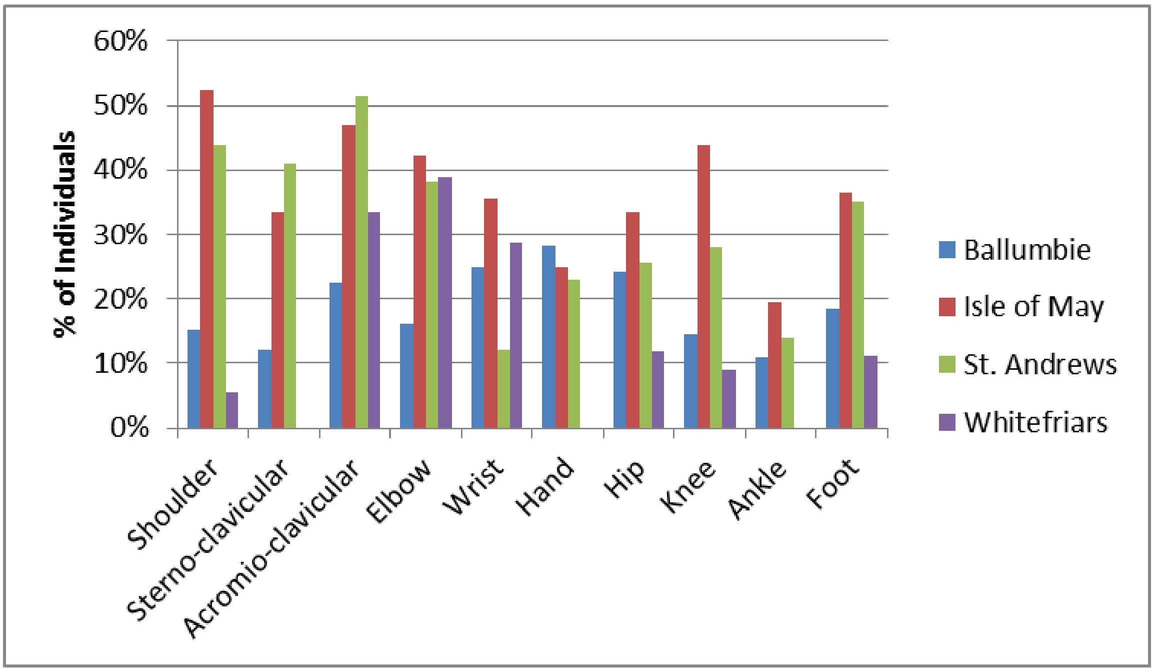


Figure 100 Comparisons of extra-spinal arthropathies by joint

Among the 61 individuals in Ballumbie with extra-spinal arthropathies three-quarters are over twenty-five years old (Table 98). Over three-quarters of the 38 individuals at the Isle of May who display extra-spinal arthropathies are over twenty-five years old. Among the 45 St Andrews Library individuals with extra-spinal arthropathies, two-thirds are over twenty-five and the other third are individuals that are in the broad adult category, therefore are 18 years or older. Over three-quarters of the 11 individuals at Whitefriars who have extra-spinal arthropathies are over twenty-five years old. The differences in the percentages of individuals with extra-spinal arthropathies in the various age categories are statistically significant for all four populations. For Ballumbie the chi-square results are χ^2=65.175, p=.000, df=8. For the Isle of May the chi-square results are χ^2=16.033, p=.014, df=6. For St Andrews Library the chi-square results are χ^2=40.279, p=.000, df=9. For Whitefriars the chi-square results are χ^2=31.973, p=.000, df=8.

Table 98 Comparisons of extra-spinal arthropathies by age

Table 98 Comparisons of extra-spinal arthropathies by age

Table 98 Comparisons of extra-spinal arthropathies by age

Population				Extraspinal Arthropathy no	Extraspinal Arthropathy yes	Total
Ballumbie	Age	IN	Count	4	0	4
			% within EA	3.0%	.0%	2.0%
		YJ	Count	5	0	5
			% within EA	3.7%	.0%	2.5%
		OJ	Count	12	0	12
			% within EA	8.9%	.0%	6.1%
		ADL	Count	14	1	15
			% within EA	10.4%	1.6%	7.6%
		YA	Count	14	3	17
			% within EA	10.4%	4.8%	8.6%
		YMA	Count	35	4	39
			% within EA	25.9%	6.5%	19.8%
		MA	Count	16	28	44
			% within EA	11.9%	45.2%	22.3%
		OA	Count	8	18	26
			% within EA	5.9%	29.0%	13.2%
		AD	Count	27	8	35
			% within EA	20.0%	12.9%	17.8%
	Total		Count	135	62	197
			% within EA	100.0%	100.0%	100.0%
Isle of May	Age	OJ	Count	2	0	2
			% within EA	10.0%	.0%	3.4%

Table 98 Comparisons of extra-spinal arthropathies by age

		ADL	Count	3	0	3
			% within EA	15.0%	.0%	5.2%
		YA	Count	3	5	8
			% within EA	15.0%	13.2%	13.8%
		YMA	Count	4	7	11
			% within EA	20.0%	18.4%	19.0%
		MA	Count	3	13	16
			% within EA	15.0%	34.2%	27.6%
		OA	Count	1	10	11
			% within EA	5.0%	26.3%	19.0%
		AD	Count	4	3	7
			% within EA	20.0%	7.9%	12.1%
	Total		Count	20	38	58
			% within EA	100.0%	100.0%	100.0%
St Andrews	Age	NN	Count	1	0	1
			% within EA	3.7%	.0%	1.4%
		IN	Count	3	0	3
			% within EA	11.1%	.0%	4.2%
		YJ	Count	7	0	7
			% within EA	25.9%	.0%	9.7%
		OJ	Count	2	0	2
			% within EA	7.4%	.0%	2.8%
		ADL	Count	5	1	6
			% within EA	18.5%	2.2%	8.3%
		YA	Count	1	3	4

Table 98 Comparisons of extra-spinal arthropathies by age

			% within EA	3.7%	6.7%	5.6%
		YMA	Count	1	8	9
			% within EA	3.7%	17.8%	12.5%
		MA	Count	0	14	14
			% within EA	.0%	31.1%	19.4%
		OA	Count	1	6	7
			% within EA	3.7%	13.3%	9.7%
		AD	Count	6	13	19
			% within EA	22.2%	28.9%	26.4%
	Total		Count	27	45	72
			% within EA	100.0%	100.0%	100.0%
Whitefriars	Age	IN	Count	6	0	6
			% within EA	12.8%	.0%	10.3%
		YJ	Count	12	0	12
			% within EA	25.5%	.0%	20.7%
		OJ	Count	4	0	4
			% within EA	8.5%	.0%	6.9%
		ADL	Count	1	0	1
			% within EA	2.1%	.0%	1.7%
		YA	Count	10	2	12
			% within EA	21.3%	18.2%	20.7%
		YMA	Count	10	2	12
			% within EA	21.3%	18.2%	20.7%
		MA	Count	0	5	5
			% within EA	.0%	45.5%	8.6%

Table 98 Comparisons of extra-spinal arthropathies by age

	OA	Count	1	2	3
		% within EA	2.1%	18.2%	5.2%
	AD	Count	3	0	3
		% within EA	6.4%	.0%	5.2%
Total		Count	47	11	58
		% within EA	100.0%	100.0%	100.0%

There is no significant relationship between sex and extra-spinal arthropathies for Ballumbie, Isle of May, or St Andrews. There is a significant relationship between sex and extra-spinal arthropathies for Whitefriars (χ=4.889, p= .027, df=1). When the specific joints are considered for Ballumbie, males and females have no statistically significant differences. However, for all joints except for the foot joints males have more arthropic changes than females. The most considerable difference in arthropathies between males and females are in the wrist; males have twice the amount of arthropathies in the wrist joints than females. When specific joints are considered for the Isle of May, males and females have no statistically significant differences. Although males have much more arthropic changes in every joint than females, since there are few females in the population none of the results are significant. When the specific joints are considered for St Andrews Library, males and females have no statistically significant differences. Males have much more arthropic changes in the joints than females, especially in the wrist, hand, shoulder, and sterno-clavicular joints where males have over twice the rate for arthropathies as much as females. Males and females have the same prevalence of arthropic changes in the hip and females have more arthropic changes in the knees than males. The results for the ankle joint are misleading since there are so many individuals of undetermined sex with arthropathies of the ankle. If the undetermined skeletons are male, than males would have much more arthropathies of the ankle. However, if the undetermined skeletons are female, than females would have much more arthropathies of the ankle than males. It is more likely that some of the undetermined individuals are male and some are female, though it is impossible to say whether males or females have more arthropathies of the ankle. When the specific joints are considered for Whitefriars, males and females have no statistically significant differences. Females are the only ones affected by shoulder arthropathies and males are the only ones affected by elbow, wrist, hip, knee, or foot arthropathies. Males have twice the prevalence rate for arthropathies of the acromio-clavicular joint than females. The above results are misleading, since many joint surfaces were not preserved. It is likely that if the joint surfaces were better preserved the results would be different, though it is impossible to say by how much.

4.6.4.5.2 Spinal Joint Disease

For Ballumbie, 46% of the sixty-three individuals with at least one cervical vertebra present have cervical joint disease (Table 99). For the Isle of May, 40.5% of the cases have cervical joint disease. For St Andrews Library, 32.4% have cervical joint disease. For Whitefriars, 20% has cervical joint disease. There is no significant relationship between cervical joint disease and population. Figure 101 illustrates the amount of cervical, thoracic, and lumbar joint disease in all four populations.

Table 99 Comparisons with cervical joint disease

			Cervical Joint Disease		Total
			no	yes	
Population	Ballumbie	Count	34	29	63
		% within Population	54.0%	46.0%	100.0%
	Isle of May	Count	25	17	42
		% within Population	59.5%	40.5%	100.0%
	St Andrews	Count	23	11	34
		% within Population	67.6%	32.4%	100.0%
	Whitefriars	Count	4	1	5
		% within Population	80.0%	20.0%	100.0%
Total		Count	86	58	144
		% within Population	59.7%	40.3%	100.0%

There is no significant relationship between sex and cervical spinal joint disease across the populations. There is also no significant relationship between age and cervical joint disease for St Andrews or Whitefriars. There is a significant relationship between age and cervical joint disease in Ballumbie and the Isle of May (Table 100). For individuals in Ballumbie with cervical joint disease, none are young adults, 13.8% are young-middle adults, 48.3% are middle adults, and 37.9% are old adults. Chi-square results are χ^2=26.107, p=.000, df=3.

Table 100 Cervical spinal joint disease for Ballumbie by age

			Cervical Joint Disease		
			no	yes	Total
Age	YA	Count	8	0	8
		% within Cervical JD	23.5%	.0%	11.6%
	YMA	Count	18	5	23
		% within Cervical JD	52.9%	14.3%	33.3%
	MA	Count	5	13	18
		% within Cervical JD	14.7%	37.1%	26.1%
	OA	Count	3	17	20
		% within Cervical JD	8.8%	48.6%	29.0%
Total		Count	34	35	69
		% within Cervical JD	100.0%	100.0%	100.0%

There is also a significant relationship between age and cervical joint disease in the Isle of May. For individuals in the Isle of May with cervical joint disease, 5.9% are adolescents, none are young adults, 5.9% are young-middle adults, 41.2% are middle adults, 41.2% are old adults, and 5.9% are adults (Table 101). Chi-square results are χ^2=16.954, p=.009, df=6.

Table 101 Cervical spinal joint disease for Isle of May by age

			Cervical Joint Disease		Total
			no	yes	
Age	OJ	Count	2	0	2
		% within Cervical JD	8.0%	.0%	4.8%
	ADL	Count	1	1	2
		% within Cervical JD	4.0%	5.9%	4.8%
	YA	Count	7	0	7
		% within Cervical JD	28.0%	.0%	16.7%
	YMA	Count	8	1	9
		% within Cervical JD	32.0%	5.9%	21.4%
	MA	Count	4	7	11
		% within Cervical JD	16.0%	41.2%	26.2%
	OA	Count	3	7	10
		% within Cervical JD	12.0%	41.2%	23.8%
	AD	Count	0	1	1
		% within Cervical JD	.0%	5.9%	2.4%
Total		Count	25	17	42
		% within Cervical JD	100.0%	100.0%	100.0%

For Ballumbie, 68.3% of the sixty individuals with at least one thoracic vertebra present has thoracic joint disease (Table 102). For the Isle of May, 77.3% of the forty-four cases have thoracic joint disease. For St Andrews Library, 48.8% of the forty-three cases have thoracic joint disease. For Whitefriars, 57.1% of the seven cases have thoracic joint disease. There is a significant relationship between thoracic joint disease and population (χ^2=8.326, p=.040, df=3).

Table 102 Comparisons with thoracic joint disease

			Thoracic Joint Disease		
			no	**yes**	**Total**
Population	Ballumbie	Count	19	41	60
		% within Population	31.7%	68.3%	100.0%
	Isle of May	Count	10	34	44
		% within Population	22.7%	77.3%	100.0%
	St Andrews	Count	22	21	43
		% within Population	51.2%	48.8%	100.0%
	Whitefriars	Count	3	4	7
		% within Population	42.9%	57.1%	100.0%
Total		Count	54	100	154
		% within Population	35.1%	64.9%	100.0%

There is no significant relationship between sex and thoracic joint disease across the populations. There is no significant relationship between age and thoracic joint disease for Isle of May, St Andrews Library, or Whitefriars. However, there is a significant relationship between age and thoracic joint disease in Ballumbie. Among the individuals with thoracic joint disease in Ballumbie, none are young adult, 22% are young-middle adult, 53.7% are middle adult, and 24.4% are old adult (Table 103). The chi-square results are χ^2= 23.030, p=.000, df=3.

Table 103 Thoracic joint disease in Ballumbie by age

			Thoracic Joint Disease		
			no	**yes**	**Total**
Age	YA	Count	6	0	6
		% within Thoracic JD	31.6%	.0%	9.5%
	YMA	Count	8	10	18
		% within Thoracic JD	42.1%	22.7%	28.6%
	MA	Count	2	17	19
		% within Thoracic JD	10.5%	38.6%	30.2%
	OA	Count	3	17	20
		% within Thoracic JD	15.8%	38.6%	31.7%
Total		Count	19	44	63
		% within Thoracic JD	100.0%	100.0%	100.0%

In Ballumbie, 49.3% of the sixty-nine individuals with at least one lumbar vertebra present have lumbar joint disease (Table 104). In the Isle of May, 78.6% of the forty-two individuals with lumbar vertebrae have lumbar joint disease. In St Andrews Library, 100% of the nineteen individuals with lumbar vertebrae have lumbar joint disease. In Whitefriars, 57.1% of the seven individuals have lumbar joint disease. There is a significant relationship between lumbar joint disease and population (χ=21.493, p=.000, df=3).

Table 104 Comparisons with lumbar joint disease

			Lumbar Joint Disease		Total
			no	yes	
Population	Ballumbie	Count	35	34	69
		% within Population	50.7%	49.3%	100.0%
	Isle of May	Count	9	33	42
		% within Population	21.4%	78.6%	100.0%
	St Andrews	Count	0	19	19
		% within Population	.0%	100.0%	100.0%
	Whitefriars	Count	3	4	7
		% within Population	42.9%	57.1%	100.0%
Total		Count	47	90	137
		% within Population	34.3%	65.7%	100.0%

There is no significant relationship between sex and lumbar joint disease across the populations. There is no significant relationship between age and thoracic joint disease for St Andrews Library, or Whitefriars. However, there is a significant relationship between age and lumbar joint disease in Ballumbie and the Isle of May. Among the individuals with lumbar joint disease in Ballumbie, none are adolescents, 26.5% are young adult, 38.2% are middle adult, and 35.3% are old adult (Table 105). The chi-square results are χ^2= 16.167, p=.001, df=3.

Among the 33 individuals with lumbar joint disease at the Isle of May, none are old juveniles, 6.1% are adolescents, 9.4% are young adults, 24.2% are young-middle adults, 33.3% are middle adults, and 27.3% are old adults (Table 106). The chi-square results are χ^2=20.140, p=.001, df=5.

Table 105 Lumbar joint disease in Ballumbie by age

			Lumbar Joint Disease		
			no	yes	Total
Age	YA	Count	6	0	6
		% within Lumbar JD	17.1%	.0%	8.7%
	YMA	Count	13	9	22
		% within Lumbar JD	37.1%	26.5%	31.9%
	MA	Count	15	13	28
		% within Lumbar JD	42.9%	38.2%	40.6%
	OA	Count	1	12	13
		% within Lumbar JD	2.9%	35.3%	18.8%
Total		Count	35	34	69
		% within Lumbar JD	100.0%	100.0%	100.0%

Table 106 Lumbar joint disease in Isle of May by age

			Lumbar Joint Disease		
			no	yes	Total
Age	OJ	Count	2	0	2
		% within Lumbar JD	22.2%	.0%	4.8%
	ADL	Count	0	2	2
		% within Lumbar JD	.0%	6.1%	4.8%
	YA	Count	5	3	8
		% within Lumbar JD	55.6%	9.1%	19.0%
	YMA	Count	1	8	9
		% within Lumbar JD	11.1%	24.2%	21.4%
	MA	Count	1	11	12
		% within Lumbar JD	11.1%	33.3%	28.6%
	OA	Count	0	9	9
		% within Lumbar JD	.0%	27.3%	21.4%
Total		Count	9	33	42
		% within Lumbar JD	100.0%	100.0%	100.0%

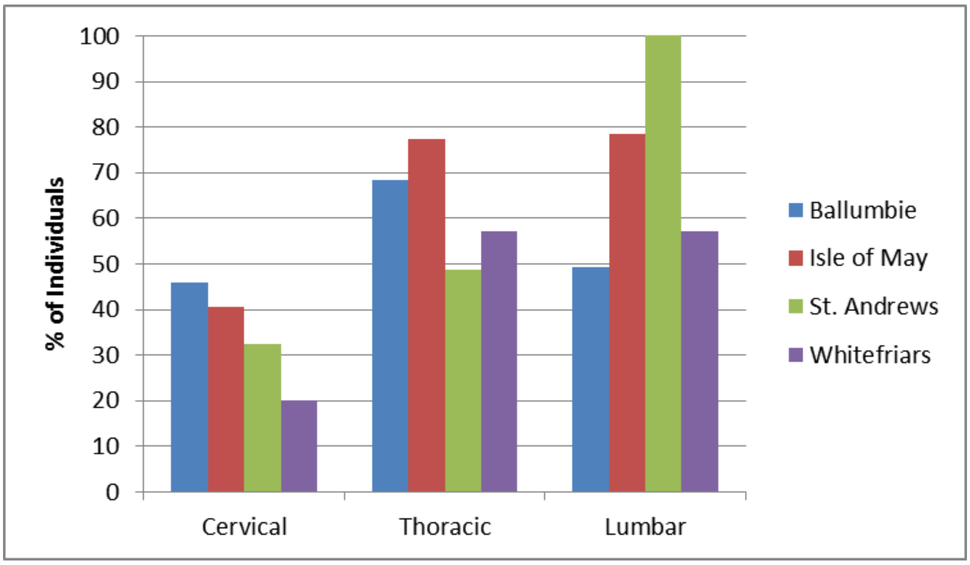


Figure 101 Comparisons with spinal joint disease

4.6.4.6 Dental Disease

In Ballumbie, 42.6% of the entire population has dental disease. In the Isle of May, 44.8% of the population has dental disease (Table 107). In St Andrews Library, 37.5% of the population has dental disease. In Whitefriars, 43.1% of the population has dental disease. Since the percentages are very similar, it is not surprising that there is no statistically significant difference between the populations and the frequency of dental disease. Figure 102 illustrates the frequencies of individuals with caries, abscesses, antemortem tooth loss, and enamel hypoplasia while Figure 103 displays the frequencies of caries, abscesses and enamel hypoplasia by number of teeth present.

Table 107 Comparisons with dental disease

			Dental Disease		
			no	**yes**	**Total**
Population	Ballumbie	Count	113	84	197
		% within Population	57.4%	42.6%	100.0%
	Isle of May	Count	32	26	58
		% within Population	55.2%	44.8%	100.0%
	St Andrews	Count	45	27	72
		% within Population	62.5%	37.5%	100.0%
	Whitefriars	Count	33	25	58
		% within Population	56.9%	43.1%	100.0%
Total		Count	223	162	385
		% within Population	57.9%	42.1%	100.0%

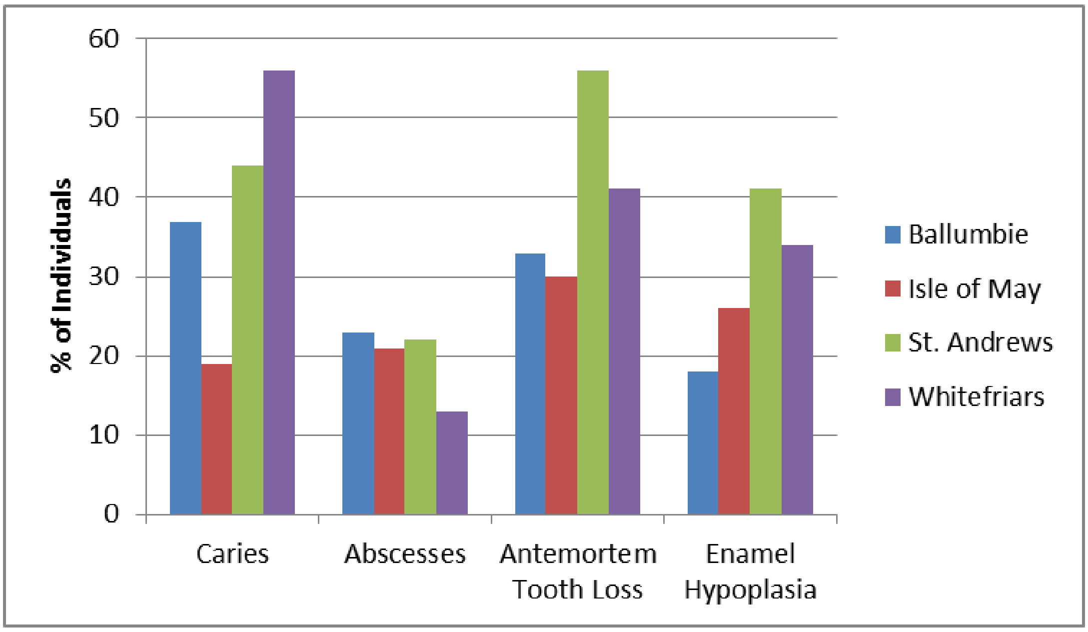


Figure 102 Dental disease by individual for all study populations

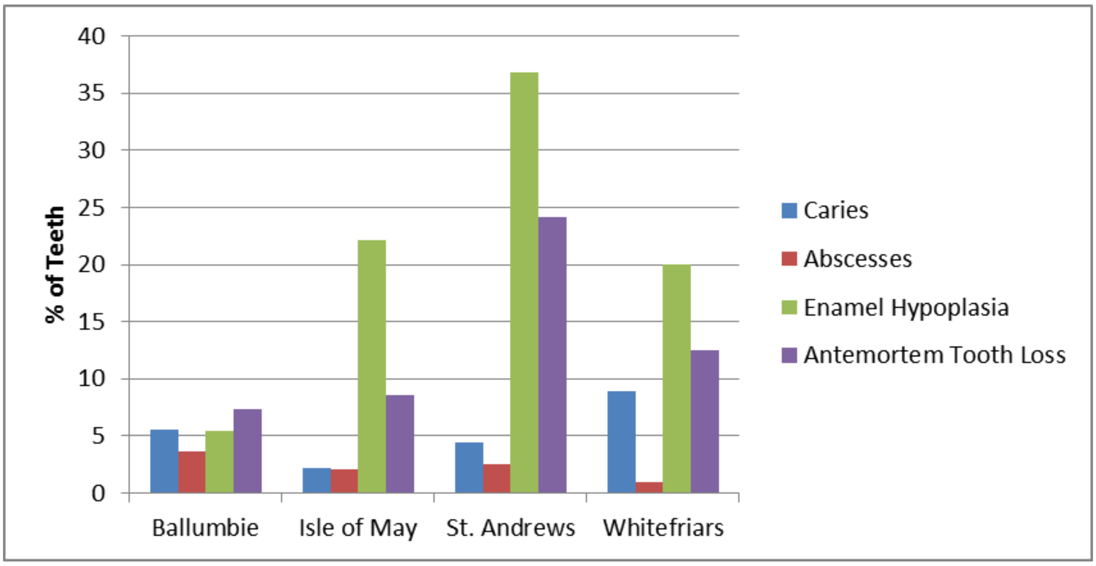


Figure 103 Dental disease by tooth for all study populations

There are interesting age patterns within the individuals with dental disease, however due to the small numbers, statistical significance could not be tested. Among the 84 individuals with dental disease at Ballumbie over three-quarter are over twenty-five years old (Table 108).

Table 108 Dental disease in Ballumbie by age

			Dental Disease		Total
			no	yes	
Age	IN	Count	4	0	4
		% within Dental Disease	3.5%	.0%	2.0%
	YJ	Count	5	0	5
		% within Dental Disease	4.4%	.0%	2.5%
	OJ	Count	9	3	12
		% within Dental Disease	8.0%	3.6%	6.1%
	ADL	Count	12	3	15
		% within Dental Disease	10.6%	3.6%	7.6%
	YA	Count	10	7	17
		% within Dental Disease	8.8%	8.3%	8.6%
	YMA	Count	14	25	39
		% within Dental Disease	12.4%	29.8%	19.8%
	MA	Count	16	28	44
		% within Dental Disease	14.2%	33.3%	22.3%
	OA	Count	9	17	26
		% within Dental Disease	8.0%	20.2%	13.2%
	AD	Count	34	1	35
		% within Dental Disease	30.1%	1.2%	17.8%
Total		Count	113	84	197
		% within Dental Disease	100.0%	100.0%	100.0%

A similar pattern can also be seen in the twenty-six individuals with dental disease at the Isle of May. Three-quarters of the individuals with dental disease are over 25 years old (Table 109).

Table 109 Dental disease in Isle of May by age

			Dental Disease		Total
			no	yes	
Age	OJ	Count	1	1	2
		% within Dental Disease	3.1%	3.8%	3.4%
	ADL	Count	1	2	3
		% within Dental Disease	3.1%	7.7%	5.2%
	YA	Count	4	4	8
		% within Dental Disease	12.5%	15.4%	13.8%
	YMA	Count	6	5	11
		% within Dental Disease	18.8%	19.2%	19.0%
	MA	Count	9	7	16
		% within Dental Disease	28.1%	26.9%	27.6%
	OA	Count	4	7	11
		% within Dental Disease	12.5%	26.9%	19.0%
	AD	Count	7	0	7
		% within Dental Disease	21.9%	.0%	12.1%
Total		Count	32	26	58
		% within Dental Disease	100.0%	100.0%	100.0%

Table 110 Dental disease in St Andrews Library by age

			Dental Disease		
			no	yes	Total
Age	NN	Count	1	0	1
		% within Dental Disease	2.2%	.0%	1.4%
	IN	Count	3	0	3
		% within Dental Disease	6.7%	.0%	4.2%
	YJ	Count	6	1	7
		% within Dental Disease	13.3%	3.7%	9.7%
	OJ	Count	2	0	2
		% within Dental Disease	4.4%	.0%	2.8%
	ADL	Count	3	3	6
		% within Dental Disease	6.7%	11.1%	8.3%
	YA	Count	1	3	4
		% within Dental Disease	2.2%	11.1%	5.6%
	YMA	Count	1	8	9
		% within Dental Disease	2.2%	29.6%	12.5%
	MA	Count	6	8	14
		% within Dental Disease	13.3%	29.6%	19.4%
	OA	Count	3	4	7
		% within Dental Disease	6.7%	14.8%	9.7%
	AD	Count	19	0	19
		% within Dental Disease	42.2%	.0%	26.4%
Total		Count	45	27	72
		% within Dental Disease	100.0%	100.0%	100.0%

Among the 27 individuals with dental disease at St Andrews Library, three-quarters are over 25 years old (Table 110).

Table 111 Dental disease in Whitefriars by age

			Dental Disease		
			no	yes	Total
Age	NN	Count	1	0	1
		% within Dental Disease	2.2%	.0%	1.4%
	IN	Count	3	0	3
		% within Dental Disease	6.7%	.0%	4.2%
	YJ	Count	6	1	7
		% within Dental Disease	13.3%	3.7%	9.7%
	OJ	Count	2	0	2
		% within Dental Disease	4.4%	.0%	2.8%
	ADL	Count	3	3	6
		% within Dental Disease	6.7%	11.1%	8.3%
	YA	Count	1	3	4
		% within Dental Disease	2.2%	11.1%	5.6%
	YMA	Count	1	8	9
		% within Dental Disease	2.2%	29.6%	12.5%
	MA	Count	6	8	14
		% within Dental Disease	13.3%	29.6%	19.4%
	OA	Count	3	4	7
		% within Dental Disease	6.7%	14.8%	9.7%
	AD	Count	19	0	19
		% within Dental Disease	42.2%	.0%	26.4%
Total		Count	45	27	72
		% within Dental Disease	100.0%	100.0%	100.0%

There was the same pattern at Whitefriars as there was at the other three study populations; three-quarters of the 27 individuals who have dental disease are over 25 years old (Table 111). The chi-square results are χ^2= 17.519, p=.025, df=8.

4.6.4.6.1 Caries

In Ballumbie, 36.8% of the 114 individuals who have at least one tooth present have dental caries (Table 112). In the Isle of May, 18.6% of the 43 individuals who have at least one tooth present have dental caries. In St Andrews, 43.8% of the 32 individuals who have at least one tooth present have dental caries. In Whitefriars, 56.3% of the 32 individuals who have at least one tooth present have dental caries. The difference between the amount of caries each population has is statistically significant (χ^2=11.941, p=.008, df=3). There is no significant relationship between age or sex and whether an individual has dental caries across the four populations.

Table 112 Comparisons with caries

			Caries		
			no	yes	Total
Population	Ballumbie	Count	72	42	114
		% within Population	63.2%	36.8%	100.0%
	Isle of May	Count	35	8	43
		% within Population	81.4%	18.6%	100.0%
	St Andrews	Count	18	14	32
		% within Population	56.3%	43.8%	100.0%
	Whitefriars	Count	14	18	32
		% within Population	43.8%	56.3%	100.0%
Total		Count	139	82	221
		% within Population	62.9%	37.1%	100.0%

Whitefriars had the highest frequency of carious lesions with 20% out of the 574 teeth observed (Table 113). Ballumbie had the next highest frequency at 5.6% of the 2,310 teeth observed had dental caries. At St Andrews Library, 4.4% of the 473 teeth observed had dental caries. Lastly, in the Isle of May assemblage 2.2% of the 778 teeth observed had dental caries.

Table 113 Caries true prevalence rate

Population	N	n	TPR
Ballumbie	2310	129	5.6
Isle of May	778	17	2.2
St Andrews Library	473	21	4.4
Whitefriars	574	115	20.0

4.6.4.6.2 Abscesses

In Ballumbie, 22.8% of the 114 individuals with at least one tooth present have a dental abscess (Table 114). In the Isle of May, 20.9% of the 43 individuals with at least one tooth present have a dental abscess. In St Andrews Library, 21.9% of the 32 individuals with at least one tooth present have a dental abscess. In Whitefriars, 12.5 of the 32 individuals with at least one tooth present have dental abscess. There is no statistical difference between the populations and how many individuals have dental abscesses.

Table 114 Comparisons with abscesses

			Abscesses		
			no	**yes**	**Total**
Population	Ballumbie	Count	88	26	114
		% within Population	77.2%	22.8%	100.0%
	Isle of May	Count	34	9	43
		% within Population	79.1%	20.9%	100.0%
	St Andrews	Count	25	7	32
		% within Population	78.1%	21.9%	100.0%
	Whitefriars	Count	28	4	32
		% within Population	87.5%	12.5%	100.0%
Total		Count	175	46	221
		% within Population	79.2%	20.8%	100.0%

There is no significant relationship between having an abscess and whether the individual is male or female across all four populations. A significant relationship between having an abscess and the age of the individual for the Isle of May, St Andrews Library, and Whitefriars is also lacking. However, there is a significant relationship between having an abscess and the age of the individual in Ballumbie. Dental abscesses are only found in individuals in the age categories of young adult or older. Among the individuals with a dental abscess in Ballumbie, none are younger than the 7.7% young adults (Table 115). Similarly, 7.7% are young-middle adults, while 50% are middle adults, and 34.6% are old adults. The chi-square results are χ^2=27.113, p=.001, df=8.

Table 115 Dental abscesses in Ballumbie by age

			Abscesses		Total
			No	yes	
Age	IN	Count	2	0	2
		% within Abscesses	2.3%	.0%	1.8%
	YJ	Count	4	0	4
		% within Abscesses	4.5%	.0%	3.5%
	OJ	Count	6	0	6
		% within Abscesses	6.8%	.0%	5.3%
	ADL	Count	5	0	5
		% within Abscesses	5.7%	.0%	4.4%
	YA	Count	10	2	12
		% within Abscesses	11.4%	7.7%	10.5%
	YMA	Count	31	2	33
		% within Abscesses	35.2%	7.7%	28.9%
	MA	Count	17	13	30
		% within Abscesses	19.3%	50.0%	26.3%
	OA	Count	10	9	19
		% within Abscesses	11.4%	34.6%	16.7%
	AD	Count	3	0	3
		% within Abscesses	3.4%	.0%	2.6%
Total		Count	88	26	114
		% within Abscesses	100.0%	100.0%	100.0%

Ballumbie has the highest frequency of abscesses with 3.6% of 2,310 teeth observed (Table 116). The St Andrews Library has the next highest frequency with 2.5% of 473 teeth observed. In the Isle of May assemblage 2.1% among the 778 teeth observed had an abscess. In Whitefriars, 1.0% of 574 teeth observed had an abscess.

Table 116 Abscesses true prevalence rate

Population	N	N	TPR
Ballumbie	2310	84	3.6
Isle of May	778	16	2.1
St Andrews Library	473	12	2.5
Whitefriars	574	6	1.0

4.6.4.6.3 Antemortem Tooth Loss

In Ballumbie, 33.3% of the 114 individuals with at least one tooth present showed antemortem tooth loss (Table 117). In the Isle of May, 30.2% of the 43 individuals with at least one tooth present have antemortem tooth loss. In the St Andrews Library assemblage, 55.3% of the 32 individuals with at least one tooth present have antemortem tooth loss. In Whitefriars, 40.6% of the 32 individuals with at least one tooth present have antemortem tooth loss. The difference between the frequencies of individuals that have antemortem tooth loss is not statistically significant.

Table 117 Comparisons with antemortem tooth loss

			AMTL		
			no	yes	Total
Population	Ballumbie	Count	76	38	114
		% within Population	66.7%	33.3%	100.0%
	Isle of May	Count	30	13	43
		% within Population	69.8%	30.2%	100.0%
	St Andrews	Count	14	18	32
		% within Population	43.8%	56.3%	100.0%
	Whitefriars	Count	19	13	32
		% within Population	59.4%	40.6%	100.0%
Total		Count	139	82	221
		% within Population	62.9%	37.1%	100.0%

There is no significant relationship between whether an individual has antemortem tooth loss and whether they are male or female. There is also no significant relationship between antemortem tooth loss and age for Isle of May or Whitefriars. However, there is a significant relationship between whether an individual has antemortem tooth loss and their age for Ballumbie and St Andrews Library. Among the individuals in Ballumbie with antemortem tooth loss, there are no infants, no children, no old juveniles, 5.3% adolescents, 15.8% young adults, 42.1% middle adults, 36.8% old adults, and no adults (Table 118). The chi-square results are χ^2=34.230, df=8, p=.000. Among the individuals in St Andrews Library with antemortem tooth loss, there are no infants, no children, no old juveniles, no adolescents, 33.3% young adults, 44.4% middle adults, and 22.2% old adults (Table 119). The chi-square results are χ^2=20.261, p=.002, df=6.

Table 118 Ballumbie antemortem tooth loss by age

			AMTL		
			no	yes	Total
Age	IN	Count	2	0	2
		% within AMTL	2.6%	.0%	1.8%
	CH	Count	4	0	4
		% within AMTL	5.3%	.0%	3.5%
	YJ	Count	6	0	6
		% within AMTL	7.9%	.0%	5.3%
	OJ	Count	5	0	5
		% within AMTL	6.6%	.0%	4.4%
	ADL	Count	10	2	12
		% within AMTL	13.2%	5.3%	10.5%
	YA	Count	27	6	33
		% within AMTL	35.5%	15.8%	28.9%
	MA	Count	14	16	30
		% within AMTL	18.4%	42.1%	26.3%
	OA	Count	5	14	19
		% within AMTL	6.6%	36.8%	16.7%
	AD	Count	3	0	3
		% within AMTL	3.9%	.0%	2.6%
Total		Count	76	38	114
		% within AMTL	100.0%	100.0%	100.0%

Table 119 St Andrews antemortem tooth loss by age

			AMTL		Total
			no	yes	
Age	IN	Count	2	0	2
		% within AMTL	14.3%	.0%	6.3%
	CH	Count	1	0	1
		% within AMTL	7.1%	.0%	3.1%
	OJ	Count	3	0	3
		% within AMTL	21.4%	.0%	9.4%
	ADL	Count	4	0	4
		% within AMTL	28.6%	.0%	12.5%
	YA	Count	3	6	9
		% within AMTL	21.4%	33.3%	28.1%
	MA	Count	1	8	9
		% within AMTL	7.1%	44.4%	28.1%
	OA	Count	0	4	4
		% within AMTL	.0%	22.2%	12.5%
Total		Count	14	18	32
		% within AMTL	100.0%	100.0%	100.0%

4.6.4.6.4 Enamel Hypoplasia

In Ballumbie, 17.7% of the 113 individuals with at least one tooth present have dental enamel hypoplasia (Table 120). In the Isle of May, 25.6% of the 43 individuals with at least one tooth present developed dental enamel hypoplasia. In St Andrews Library, 40.6% of the 32 individuals with at least one tooth present have dental enamel hypoplasia. In Whitefriars, 34.4% of the 32 individuals with at least one tooth present have dental enamel hypoplasia. The difference between the populations and the frequency of dental enamel hypoplasia is statistically significant (χ^2=8.887, p=.031, df=3). There is no significant relationship between whether an individual has dental enamel hypoplasia and either sex or age.

Table 120 Comparisons with enamel hypoplasia

			Enamel Hypoplasia		Total
			no	yes	
Population	Ballumbie	Count	93	20	113
		% within Population	82.3%	17.7%	100.0%
	Isle of May	Count	32	11	43
		% within Population	74.4%	25.6%	100.0%
	St Andrews	Count	19	13	32
		% within Population	59.4%	40.6%	100.0%
	Whitefriars	Count	21	11	32
		% within Population	65.6%	34.4%	100.0%
Total		Count	165	55	220
		% within Population	75.0%	25.0%	100.0%

St Andrews Library has the highest frequency of enamel hypoplasia with 36.8% of 473 teeth observed (Table 121). The Isle of May assemblage has the next highest frequency at 22.1% of 778 teeth observed. In the Whitefriars assemblage 20% of 574 teeth observed have enamel hypoplasia. Ballumbie has the lowest frequency of enamel hypoplasia with 5.5% of 2,310 teeth observed.

Table 121 Enamel hypoplasia true prevalence rate

Population	N	N	TPR
Ballumbie	2310	128	5.5
Isle of May	778	172	22.1
St Andrews Library	473	174	36.8
Whitefriars	574	115	20.0

4.6.4.7 Other Disease

In Ballumbie, 7.1% of the population has a disease that could not be placed into any of the above categories and therefore are placed into the broad category of other disease (Table 122). In the Isle of May, 31% of the population has other disease. In St Andrews Library, 9.7% of the population has other disease. There are no individuals with other disease in Whitefriars. The difference between the populations and the amount of other disease is statistically significant (χ^2=36.370, p=.000, df=3). There is no significant relationship between whether an individual had a disease in the category of other disease and either sex or age.

Table 122 Comparisons with other disease

			Other Disease		Total
			no	yes	
Population	Ballumbie	Count	184	13	197
		% within Population	93.4%	6.6%	100.0%
	Isle of May	Count	41	17	58
		% within Population	70.7%	29.3%	100.0%
	St Andrews	Count	65	7	72
		% within Population	90.3%	9.7%	100.0%
	Whitefriars	Count	58	0	58
		% within Population	100.0%	.0%	100.0%
Total		Count	348	37	385
		% within Population	90.4%	9.6%	100.0%

4.7 Isotope Results

For this thesis, $\delta^{13}C$, $\delta^{15}N$, $^{87}Sr/^{86}Sr$, and $\delta^{18}O$ (water) values were obtained for five individuals from the Isle of May: contexts 155, 814, 972, 859, and 997 (see section 3.1.9 for background to isotope analysis). Results from previous isotope analysis on the study populations by SUAT (unpublished) and Caldeira (2010) are also included here (Table 123). The $\delta^{13}C$ ratios from the twelve Ballumbie samples range from -21.0‰ and -18.9‰ with a mean of -19.97 ± 0.77‰. $\delta^{15}N$ values were only available for two of the twelve samples, their range is between 11.2‰ and 12.5‰ with a mean of 11.85 ± 0.92‰. The $\delta^{13}C$ ratios from the five Isle of May samples (completed for this PhD) range from -20.8‰ and -16.5‰ with a mean of -19.56 ± 1.76‰. The associated $\delta^{15}N$ values range between 6.7‰ and 13.6‰ with a mean of 11.46 ± 2.74‰. The $\delta^{13}C$ ratios from the four St Andrews samples range from -21.2‰ and -19.0‰ with a mean of -19.80 ± 0.96‰. The associated $\delta^{15}N$ values range between 9.8‰ and 12.0‰ with a mean of 11.3 ± 1.01‰. For all twenty-one samples from the study populations the $\delta^{13}C$ ratios samples range from -

21.2‰ and -16.5‰ with a mean of -19.84 ± 1.05‰. The associated $\delta^{15}N$ values for eleven samples from the study populations range between 6.7‰ and 13.6‰ with a mean of 11.47 ± 1.85‰. Table 124 provides the mean, standard deviation, average error, variance, minimum, maximum, and sample size for Ballumbie, Isle of May, and St Andrews for carbon and nitrogen isotopes. Figures 104 and 105 are stem and leaf plots for $\delta^{13}C$ and $\delta^{15}N$ for Ballumbie, the Isle of May, and St Andrews which illustrate SK 972 as an outlier for both. Figure 106 plots $\delta^{13}C$ against $\delta^{15}N$ for the five Isle of May samples collected for this thesis as well as Ballumbie and St Andrews from Caldeira (2010).

Table 123 Stable isotope values for Ballumbie, St Andrews, and the Isle of May

Sample	**Cal AD**	**$\delta^{13}C$**	**$\delta^{15}N$**	**$\delta^{18}O$ (Water)**	**$^{87}Sr/^{86}Sr$**	**Age**	**Sex**	**Completed by**
Ballumbie 092	1030-1230	-20.9				35-45	M	SUAT
Ballumbie 153	1420-1630	-20.4				18-24	F	SUAT
Ballumbie 207		-21.0	11.2			40-44	M	Caldeira
Ballumbie 279	1020-1180	-20.1				AD	?	SUAT
Ballumbie 467	1290-1420	-18.9				35-45	F	SUAT
Ballumbie 501	1450-1640	-20.1				35-45	F	SUAT
Ballumbie 512	1400-1610	-19.6				25-35	F	SUAT
Ballumbie 630		-19.0	12.5			45+	M	Caldeira
Ballumbie 682	1430-1640	-20.3				35-45	M	SUAT
Ballumbie 725	1410-1620	-19.2				45+	M	SUAT
Ballumbie 747	560-660	-20.9				AD	M	SUAT
Ballumbie 832	1410-1620	-19.2				45+	M	SUAT
St Andrews 28		-19.6	11.6			25-35	M	Caldeira
St Andrews 47		-21.2	9.8			35-45	M	Caldeira

Sample	**Cal AD**	**$\delta^{13}C$**	**$\delta^{15}N$**	**$\delta^{18}O$ (Water)**	**$^{87}Sr/^{86}Sr$**	**Age**	**Sex**	**Completed by**
St Andrews 69		-19.0	12.0			54-64	M	Caldeira
St Andrews 75		-19.4	11.8			45-55	M	Caldeira
Isle of May 155	1280-1430	-19.6	13.6	-7.8	0.7095	20-25	M	Willows
Isle of May 814	1328-1453	-20.8	12.1	-8.0	0.7096	14-16	M?	Willows
Isle of May 859	775-980	-20.5	12.9	-8.9	0.7133	45-59	M	Willows
Isle of May 972	655-773	-16.5	6.7	-8.0	0.7090	7-9	n/a	Willows
Isle of May 997	660-860	-20.4	12.0?	-8.8	0.7097	15-17	M?	Willows

Table 124 Mean, standard deviation, average error, and variance for Ballumbie, Isle of May, and St Andrews

		$\delta^{13}C$	$\delta^{15}N$
Ballumbie	Mean	-19.97	11.85
	Standard Deviation	0.77	0.92
	Mean Error	0.22	0.65
	Variance	0.59	0.84
	Minimum	-21.0	11.2
	Maximum	-18.9	12.5
	Sample Size	12	2
Isle of May	Mean	-19.56	11.46
	Standard Deviation	1.76	2.74
	Mean Error	0.79	1.23
	Variance	3.12	7.5
	Minimum	-20.8	6.7
	Maximum	-16.5	13.6
	Sample Size	5	5
St Andrews	Mean	-19.80	11.3
	Standard Deviation	0.96	1.01
	Mean Error	0.48	0.51
	Variance	0.93	1.03
	Minimum	-21.2	9.8
	Maximum	-19.0	12.0
	Sample Size	4	4
Total	Mean	-19.84	11.47
	Standard Deviation	1.05	1.85
	Mean Error	0.23	0.56
	Variance	1.12	3.43
	Minimum	-21.2	6.7
	Maximum	-16.5	13.6
	Sample Size	21	11

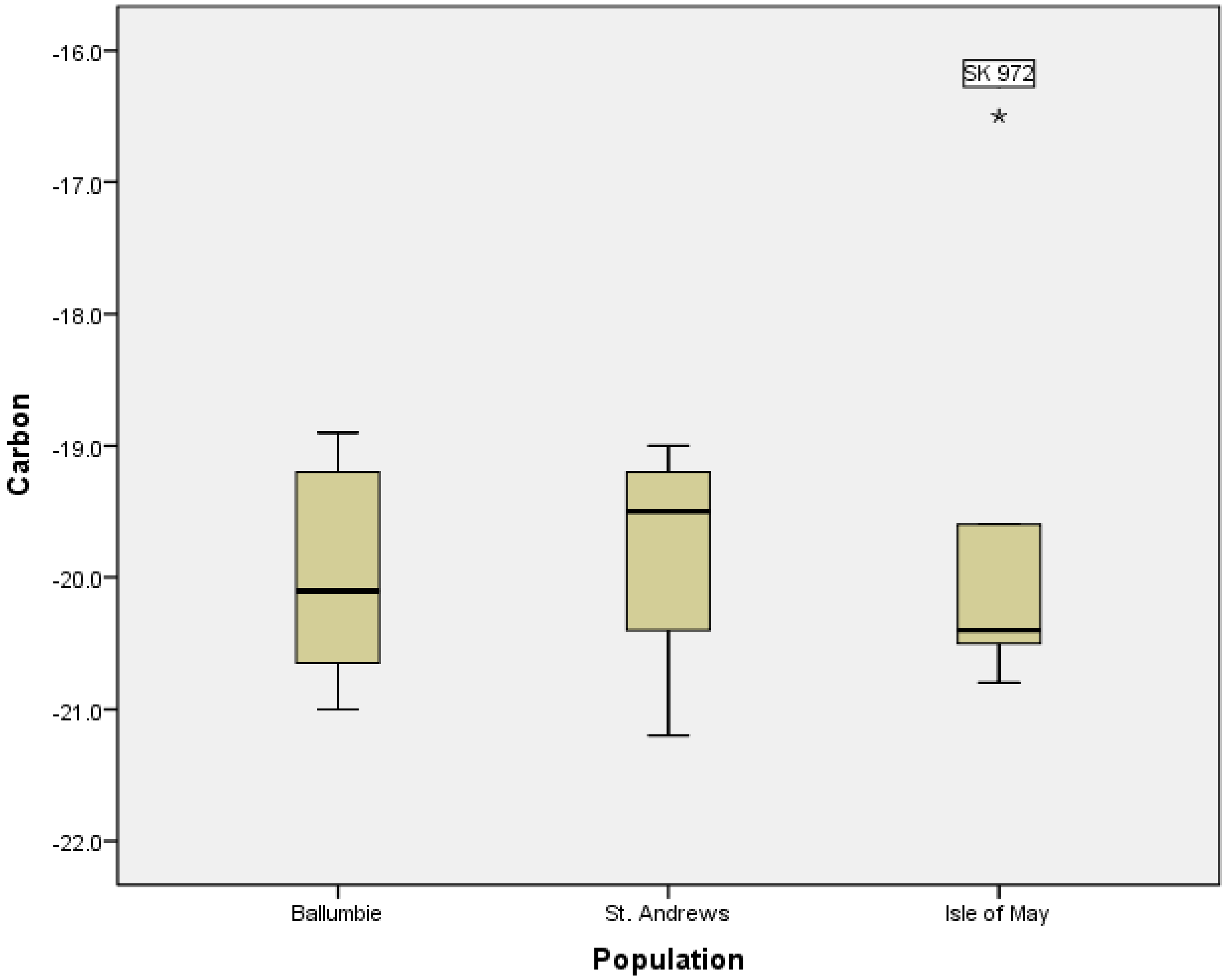


Figure 104 Stem and leaf plots for δ^{13}C for Ballumbie, St Andrews and the Isle of May with SK 972 as an outlier

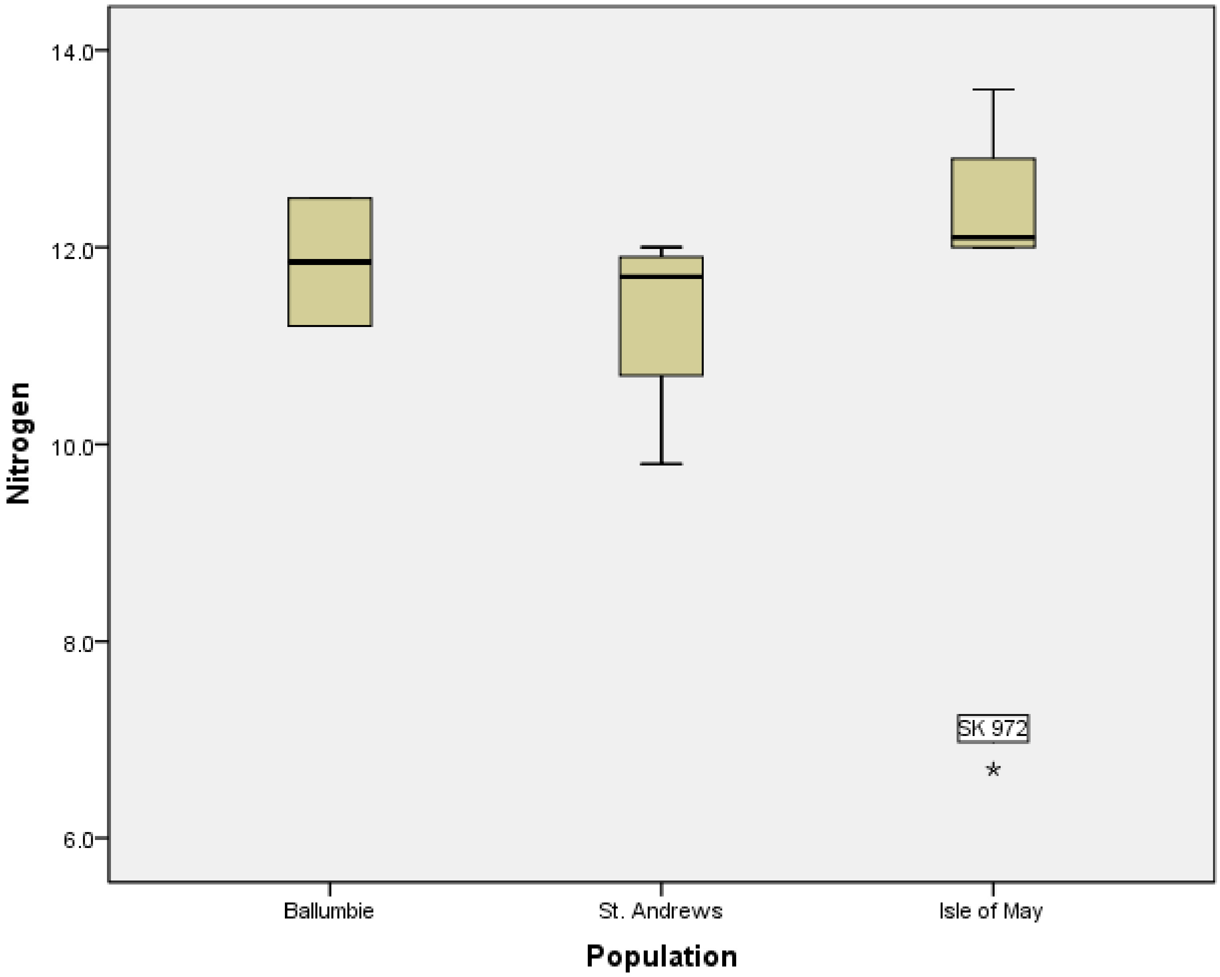


Figure 105 Stem and leaf plots for δ[15]N for Ballumbie, St Andrews and the Isle of May with SK 972 as an outlier

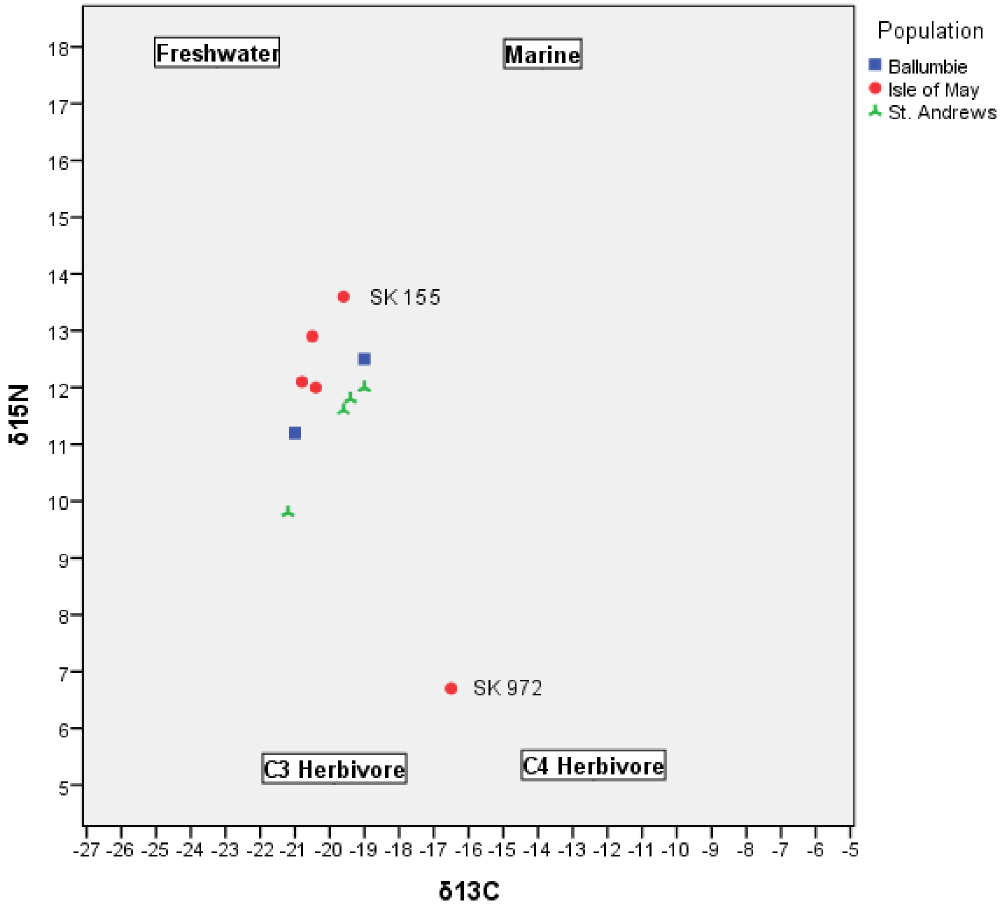


Figure 106 δ^{13}C plotted against δ^{15}N from bone collagen from individuals at Isle of May. Data from Ballumbie and St Andrews Library are from Caldeira (2010)

Linear mixing models on δ^{13}C values estimated the percentage of marine resources in each individual's diet (Figures 107 and 108) (Cook et al. 2001). Figure 101 excludes Isle of May SK 972 since the δ^{13}C value may be skewed due to the type of plants eaten and not based on marine protein intake, an issue that is discussed in section 5.2.3.1.

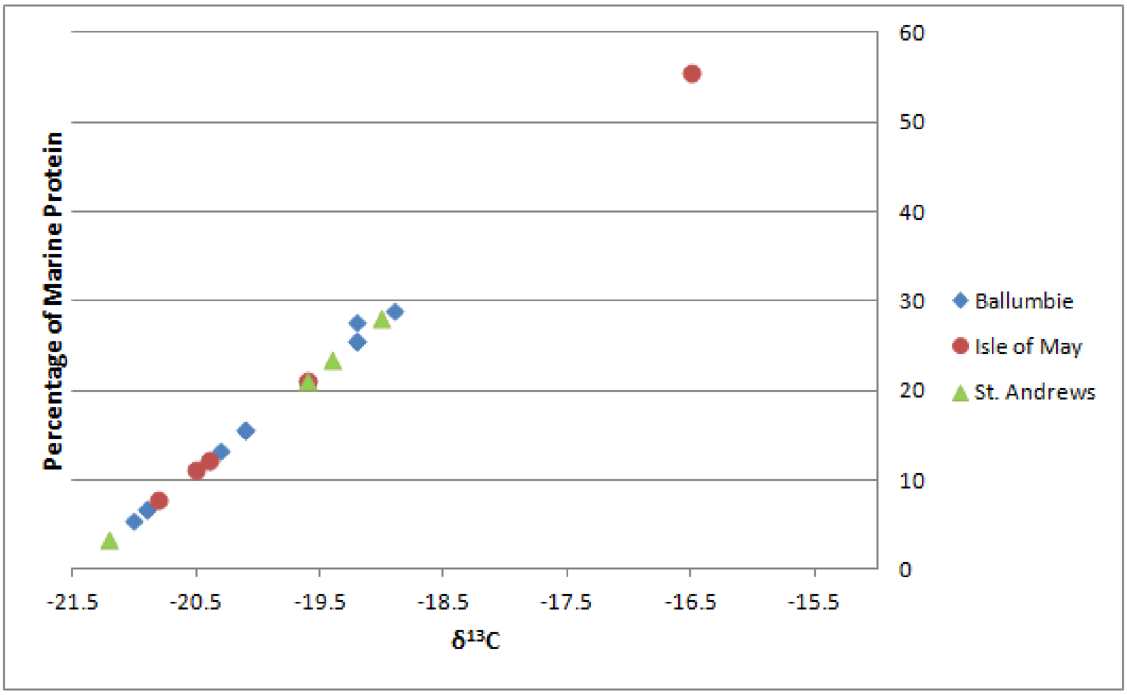


Figure 107 Percentage of marine protein for Ballumbie, St Andrews and the Isle of May

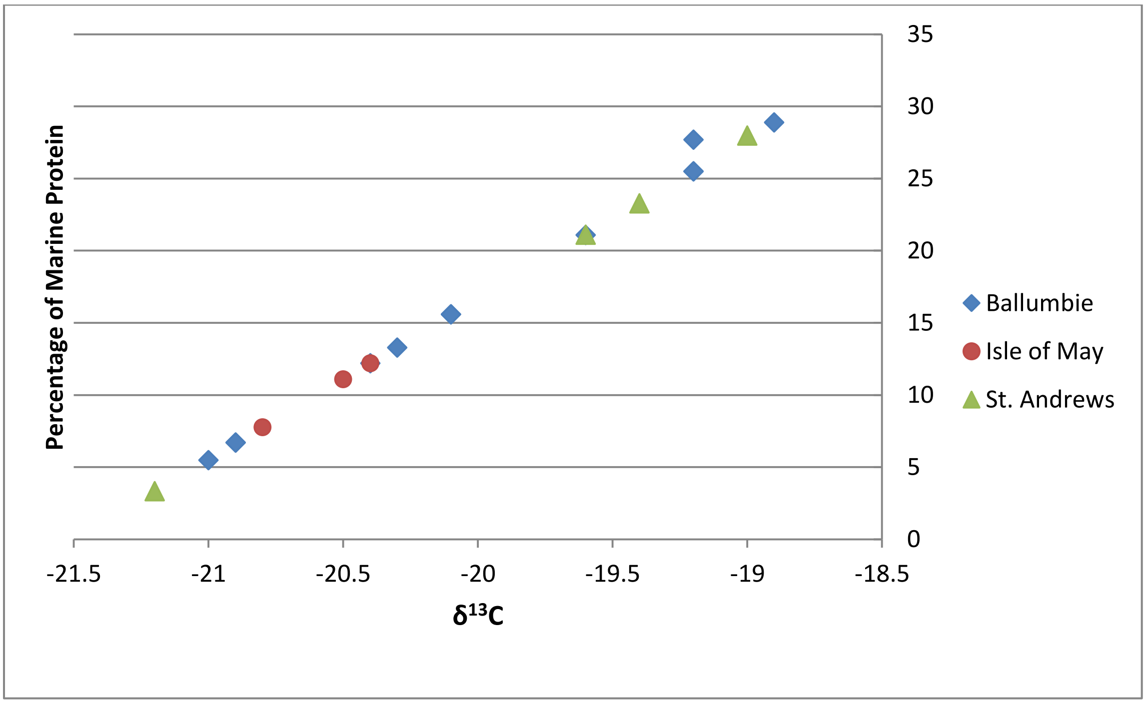


Figure 108 Percentage of marine protein without SK 972

Both males and females were represented in the Ballumbie samples provided by SUAT (unpublished), which allows for comparisons for $\delta^{13}C$ only. $\delta^{13}C$ ratios from the eight samples of males at Ballumbie range from -21.0‰ and -19.‰ with a mean of -20.08 ± 0.84‰. $\delta^{13}C$ ratios from the four samples of females at Ballumbie range from -20.4‰ and -18.9‰ with a mean of -19.75 ± 0.66‰. Table 125 presents the mean, standard deviation, minimum, and maximum values for $\delta^{13}C$ for males and females at Ballumbie.

Table 125 Comparisons of $\delta^{13}C$ ratios for Males and Females at Ballumbie

		$\delta^{13}C$
Ballumbie Males	Mean	-20.08
	Standard Deviation	0.84
	Minimum	-21.0
	Maximum	-19.0
	Sample Size	8
Ballumbie Females	Mean	-19.75
	Standard Deviation	0.66
	Minimum	-20.4
	Maximum	-18.9
	Sample Size	4

The data from strontium and oxygen analyses for the Isle of May are presented in Table 123 and Figure 109. $^{87}Sr/^{86}Sr$ ratios from the five Isle of May samples ranges from 0.7090 and 0.7133 with a mean of 0.7102 ± 0.509. The oxygen isotope data from the Isle of May ranges from $\delta^{18}O$ (water) = -8.9 to -7.8‰ with a mean of -8.3 ± 0.509‰. Table 126 provides the mean, standard deviation, mean error, variance, minimum, and maximum $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ (Water) values for the Isle of May.

Table 126 Mean, standard deviation, mean error, variance, minimum, and maximum $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ (Water) values for the five Isle of May samples

		$^{87}Sr/^{86}Sr$	$\delta^{18}O$ (Water)
Isle of May	Mean	0.7102	-8.3
	Standard Deviation	0.0001	0.509
	Mean Error	0.0007	0.228
	Variance	0.0000	0.260
	Minimum	0.7090	-8.9
	Maximum	0.7133	-7.8
	Sample Size	5	5

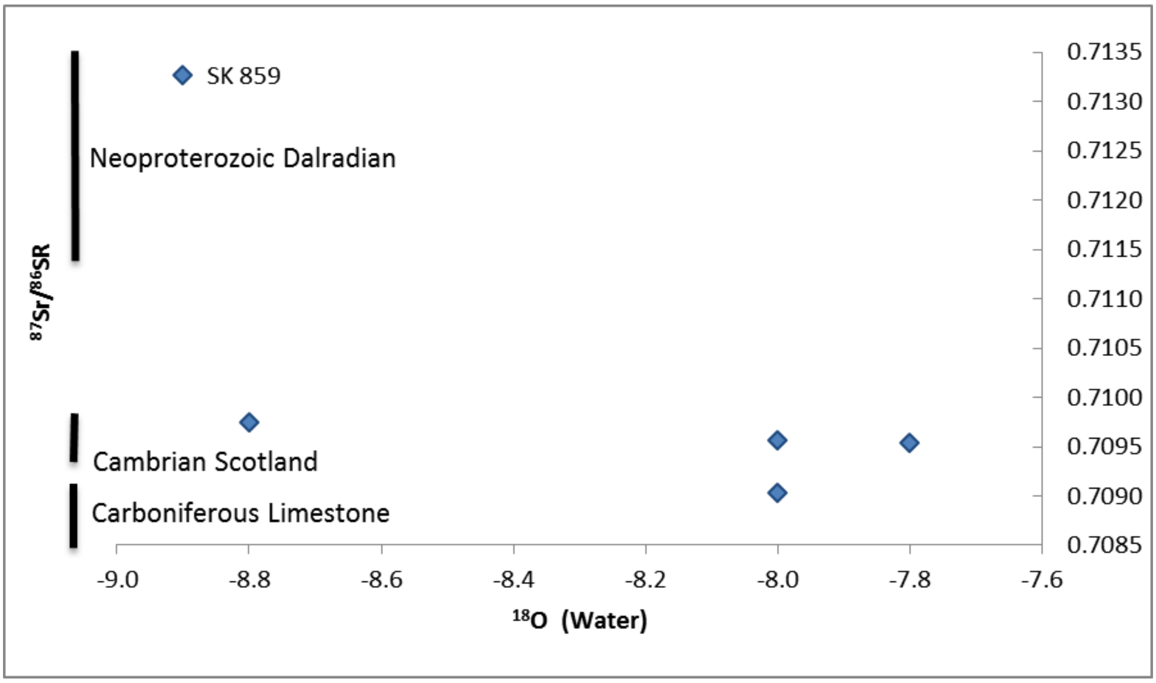


Figure 109 $^{87}Sr/^{86}Sr$ vs. $\delta^{18}O$ (Water) of the Isle of May samples

Figure highlights SK 859 as an outlier and includes typical ranges for local bedrock geology (Evans 2010)

4.7.1 Radiocarbon Dating

For this thesis, new radiocarbon dates were ascertained for four individuals from the Isle of May, contexts 814, 972, 859, and 997. In the prior work on the Isle of May material by James and Yeoman (2008), radiocarbon dates were provided for seventeen other individuals. Prior work at Ballumbie by Scottish Urban Archaeological Trust (unpublished) also provided radiocarbon dates for ten individuals. All known radiocarbon dates for the study populations were produced in

OxCal (Ramsey 2009) for representation here. Figure 110 illustrates all known radiocarbon dates for Isle of May and Figure 111 for Ballumbie.

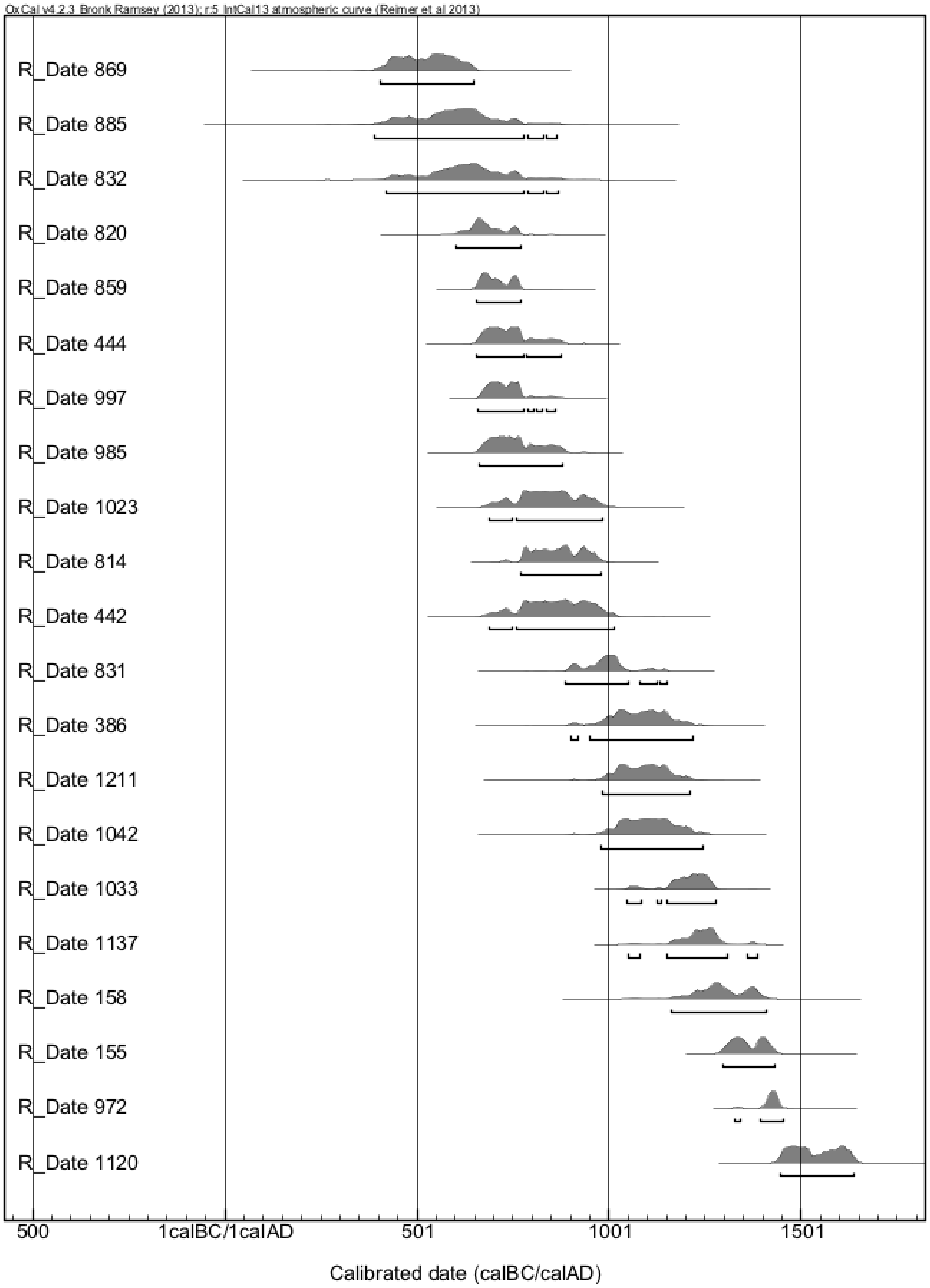


Figure 110 Radiocarbon for Isle of May burials.

SK 814, 859, 972, and 997 were completed for this thesis, all other Isle of May data is after James and Yeoman (2008).

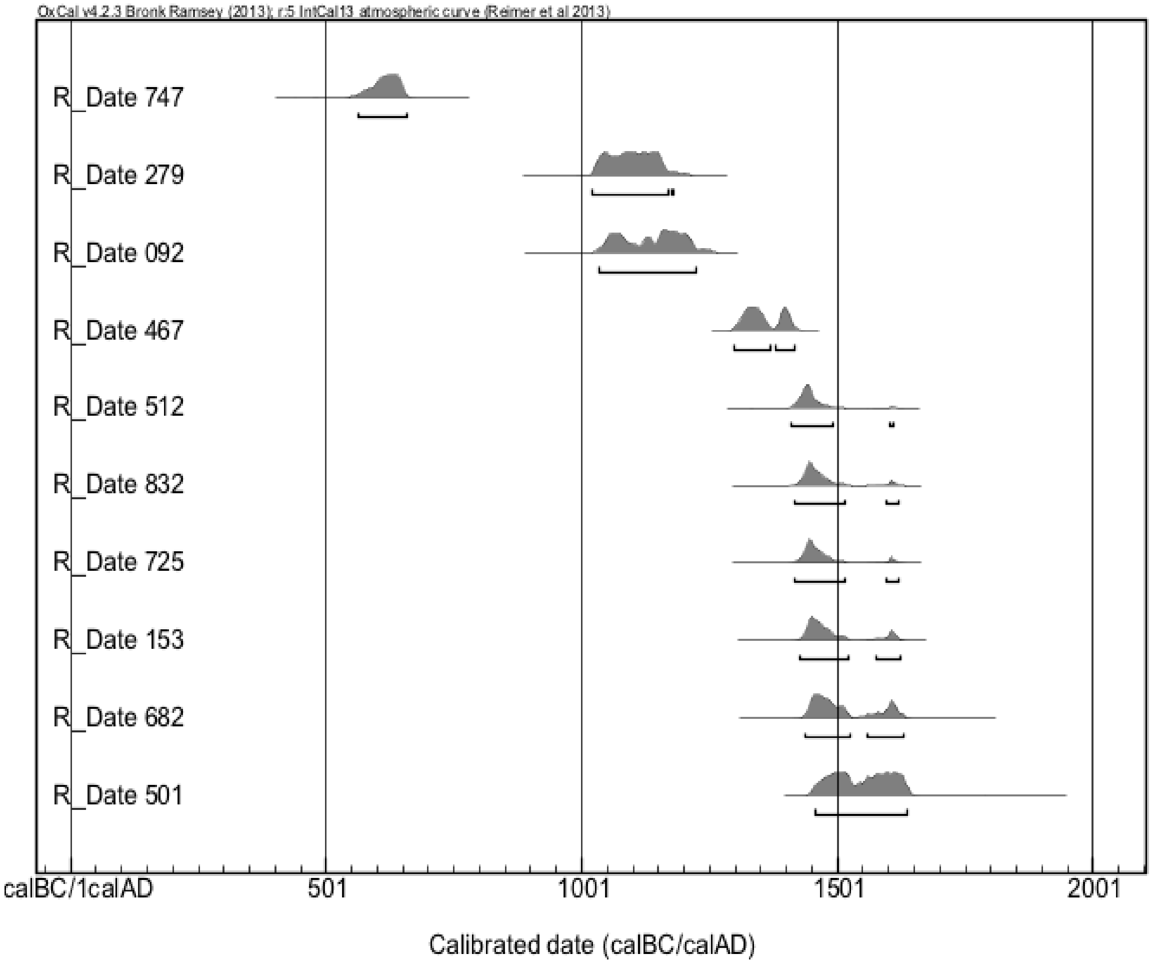


Figure 111 Radiocarbon for Ballumbie burials

(SUAT unpublished)

Health Status in Lowland Medieval Scotland: A Regional Analysis of Four Skeletal Populations

Volume 2 of 2

Discussion, Conclusion, Bibliography, and Appendices

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Doctor of Philosophy

The University of Edinburgh

2016

5. Discussion

The four study populations are all located within the area of lowland, east coast of Scotland. However, when evaluating health status it is imperative to discern further distinctions between the lifestyles of individuals living in each of these populations. The relative health status of lowland medieval Scotland can be understood, in part, by evaluating the differences between the four study populations through the lens of rural/urban, low/high status perspectives. Beyond the four assemblages of Ballumbie, Isle of May, St Andrews Library and Whitefriars, a further, mostly contemporary, twenty-three other Scottish sites are used for comparison purposes in this chapter (Table 8). For further information about the populations used for comparative purposes, see Appendix 12 and for a map of the compiled sites, see Appendix 10.

5.1 Rural vs. urban

One of the main differences between the study populations is their location within the landscape of eastern, lowland Scotland. The lifestyle differences between those that lived in rural or urban environments affected their health. The factors that appear to influence health the greatest are discussed here which include: access to health care, population density/pathogen load, diet, and subadult mortality.

5.1.1 Access to health care

The majority of individuals that lived in the compiled lowland medieval populations died between the ages of 35-45 years old (Figure 112). Overall females tended to die earlier than males for the study populations (Figure 113). However, there is a peak of deaths in the compiled rural populations between 18-24 years of age (Figure 112); this peak represents the reproductive years for females. Females living in rural areas may not have had many options if there was a complication during childbirth, perhaps leading to a higher mortality rate. Maternal stress also includes infection and malnutrition, both of which pregnant women are more susceptible to (Roberts and Manchester 2007, Sullivan 2005. In the modern developing world, 30-40 percent of deaths are caused by maternal mortality; in the Middle Ages this figure could have been upwards of 50 percent (Sayer and

Dickinson 2013). At the rural site of Ballumbie, more than three-quarters of those that suffered from metabolic disease were female, whereas at the urban St Andrews Library site males were the main sufferers of metabolic disease. While these results are not statistically significant it does suggest the possibility that rural females had poorer health than their counterparts in urban environments. Females in the urban areas could also have potentially suffered from infections and malnutrition related to pregnancy; however the differences between mortality rates in rural and urban areas suggests females in the urban areas were surviving past reproductive years. This higher survival rate could have been due to better access to health care throughout pregnancy, childbirth, and post-childbirth in urban areas.

Health care beyond folk healing was not available to most rural people, especially in Eastern and Lowland Scotland, but in urban areas there were physicians, apothecaries, barbers and surgeons (Hamilton 2003). As secular education advanced, physicians would diagnose a disease by natural techniques, such as taking a pulse and urine analysis. Causes of disease were based on the Hippocratic system of the four humors: black bile, yellow bile, phlegm, and blood and an imbalance in one of these would result in an affliction (Dingwall 2003, Finucane 1995, Hamilton 2003). If the diagnosis was an excess of one of the four humors, purgatives, laxatives, or blood-letting were common prescriptions. Other medicines prescribed would be made by the apothecary. By the end of the fifteenth century there were at least 100 hospitals established in Scotland, however they were still not hospitals in the modern sense; they were usually outside the walls of larger towns and generally were founded to care for specific diseases such as leprosy, plague, and syphilis (Ewan 1990, Hall 2006, Hamilton 2003, Roberts and Cox 2003)

Sayer and Dickinson (2013) also found maternal mortality to be significantly higher in rural areas in the modern developing world. Urban children 2 months to 6 years have a higher mortality rate than those in rural areas, but this shifts once the children survive these age groups and then live longer lives than their rural counterparts after seven (Figure 112). This shift in mortality between urban and rural children could also indicate a lower access to health care in rural settlements.

Though, the shift in rates could also indicate differential location for subadult burials within the excavated areas, thereby skewing the results (section 1.3.3).

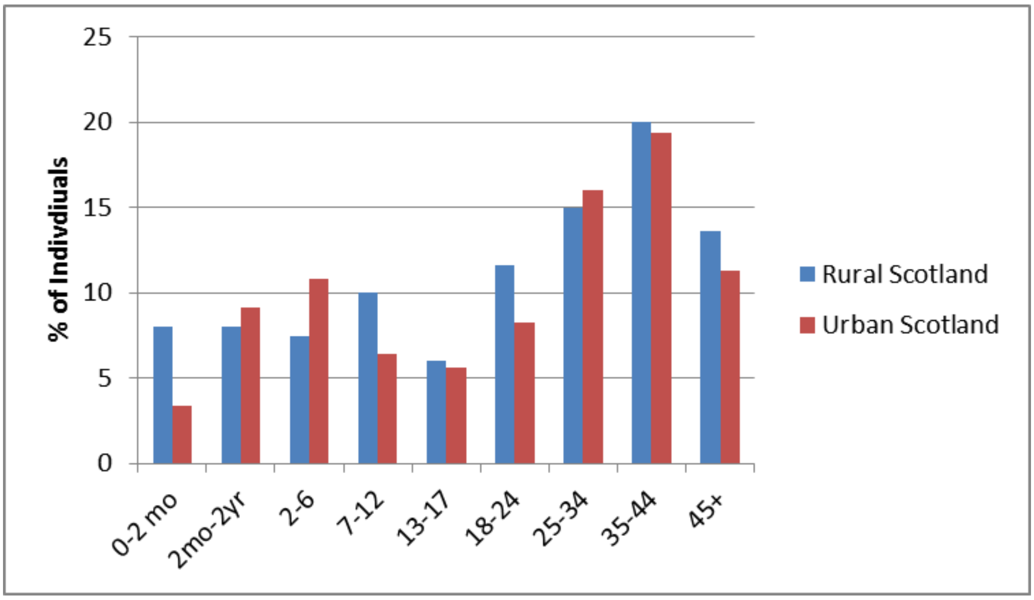

Figure 112 Age at death in rural and urban medieval Scotland from compiled sites, n=613

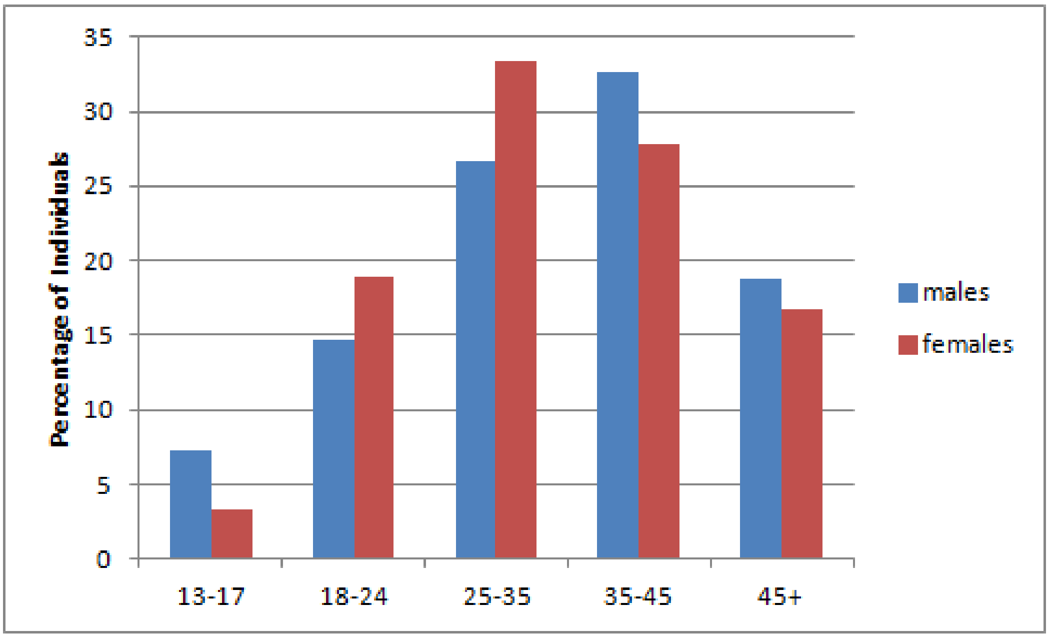

Figure 113 Demography within study populations, n= 240 sexed individuals

5.1.2 Diet

Over two-thirds of the rural sites have more than 14% of the population suffering from metabolic disease (Figure 114). Conversely, three-quarters of urban sites have fewer than 14% of the population affected. This indicates that those in rural areas were more susceptible to food shortages. Food availability was reliant on the harvest cycle (Dyer 2006, Fenton 2007), so during years of a poor harvest metabolic disease would have increased, especially for rural farming communities. Urban areas may have more options such as preserved or dried foods. Seasonal variation in climate contributes to availability of certain fruits and vegetables which can then affect an individual's health. If a diet is deficient in nutrients, an individual can suffer from metabolic disease. One anomaly was St Andrews Library, which had the second highest frequency of metabolic disease, which may be related to pathogen load (as will be discussed further in section 5.1.3).

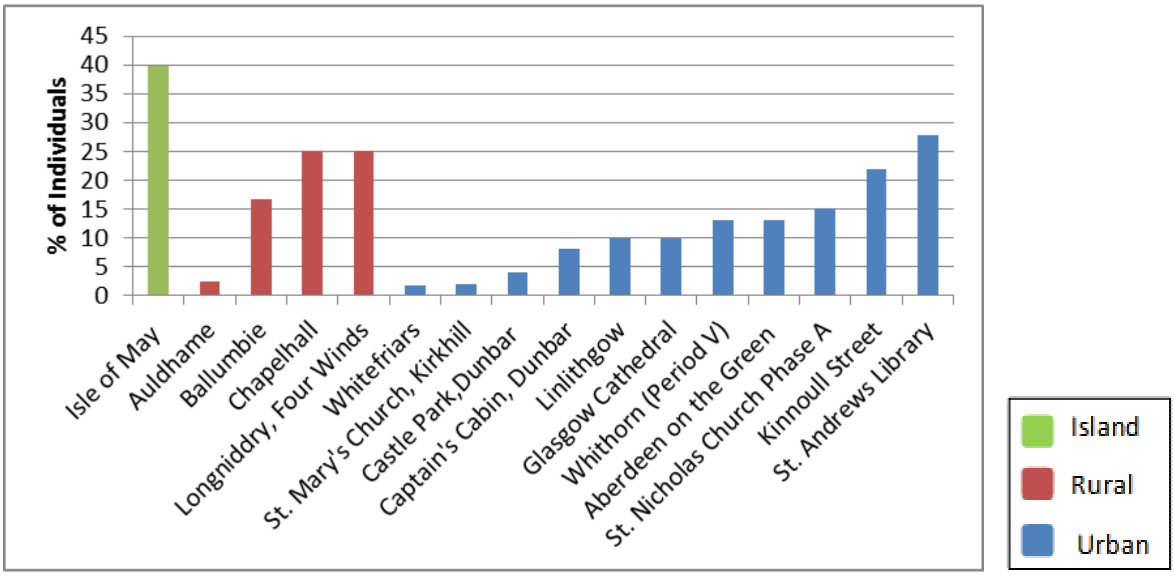

Figure 114 Prevalence of metabolic disease in lowland medieval Scotland

The climate of medieval Scotland played a major role in the history of the region, particularly by affecting the diet of those living then. Starting around 1000 BC the northern hemisphere began cooling (Brimblecombe 1982). There was a period of respite, with what is known as the Medieval Warm Epoch, which was between 1000-1200 AD (Brimblecombe 1982, Cowan and Henderson 2011, Harvie 2002, Yeoman 1995). During this warmer epoch boggy lands dried out and allowed for better cultivation. Peter Yeoman (1995) argues that years of good harvest led to a rise in population, which led to more farming settlements and more clearance of woodland. This increase in prosperity progressed further with the foundation of burghs and monasteries by David I in the twelfth century. However, the climate shifted in the fourteenth century to what is known as the Little Ice Age. The next five centuries were characterized by cold winters, wet summers, strong winds, heavy rains, and flooding (Brimblecombe 1982, Cowan and Henderson 2011, Yeoman 1995). This poor climate resulted in frequent crop failure and famines, including the Great Famine of 1315-1322 (Barrell 2000, Dyer 2003, Oram 2011, Yeoman 1995). It is estimated that 15% of the population died during the Great Famine (Bartlett 2013, Yeoman 1995). Due to wide radiocarbon ranges, individuals in the study populations cannot be tied securely to the dates of known famines, however general diet deficiencies are illustrated through metabolic disease.

Lacking certain nutrients in a diet causes various metabolic diseases, including cribra orbitalia, porotic hyperostosis, rickets, scurvy, osteopenia, and linear enamel hypoplasia (section 3.1.8.4). Iron deficiency, or anemia, leads to cribra orbitalia and porotic hyperostosis. There is a statistically significant difference in the prevalence of porotic hyperostosis between the four study populations (χ^2=22.515, p= .000, df= 3) (Table 88). Ballumbie (11.9%) and Whitefriars (12.5%) have similar rates of porotic hyperostosis, comparable to the average rate of 16.5% of individuals living in lowland medieval Scotland with porotic hyperostosis. Isle of May (36.8%) and St Andrews Library (48.5%) have markedly higher rates of porotic hyperostosis. Most reports of other Scottish and English medieval populations either did not disclose porotic hyperostosis findings or combined the results with the rates of cribra orbitalia; both of these scenarios could produce bias. Another potential bias can be the methods of scoring porotic hyperostosis.

In dietary iron deficiency there is extensive marrow hypertrophy that leads to a reduction in overall growth, prohibits vital functions such as DNA synthesis, impedes cognition and maintenance of a healthy immune system (Goodman 1994). Heavy pathogen loads can mimic iron-deficiency anemia as the body's adaptive response; however, this form is generally mild (Sullivan 2005, Walker et al. 2009). The high frequency of porotic hyperostosis at the Isle of May and St Andrews Library more probably indicates higher pathogen loads at these sites (Figure 115). At the Isle of May, this is likely due to sick individuals traveling to the Isle of May (section 5.4). The higher pathogen loads seen at St Andrews is likely a reflection of the close proximity of those living there, higher population density poor sanitation controls, and also pilgrimage or trade which would allow people and pathogens from other locations into the area, further discussed in section 5.1.3. St Helen-on-the-Walls has drastically higher rates of porotic hyperostosis than all other compared populations (Figure 115). St Helen-on-the-Walls is known as the poorest parish in York and described as squalid with ‘putrid’ streets, contaminated water, and poor air quality (Grauer 1993). The squalid environment explains the high rates of porotic hyperostosis, and sheds a light on the next highest prevalence rate at St Andrews Library. However, at St Andrews it does appear that multiple factors are influencing these high rates (section 5.1.3)

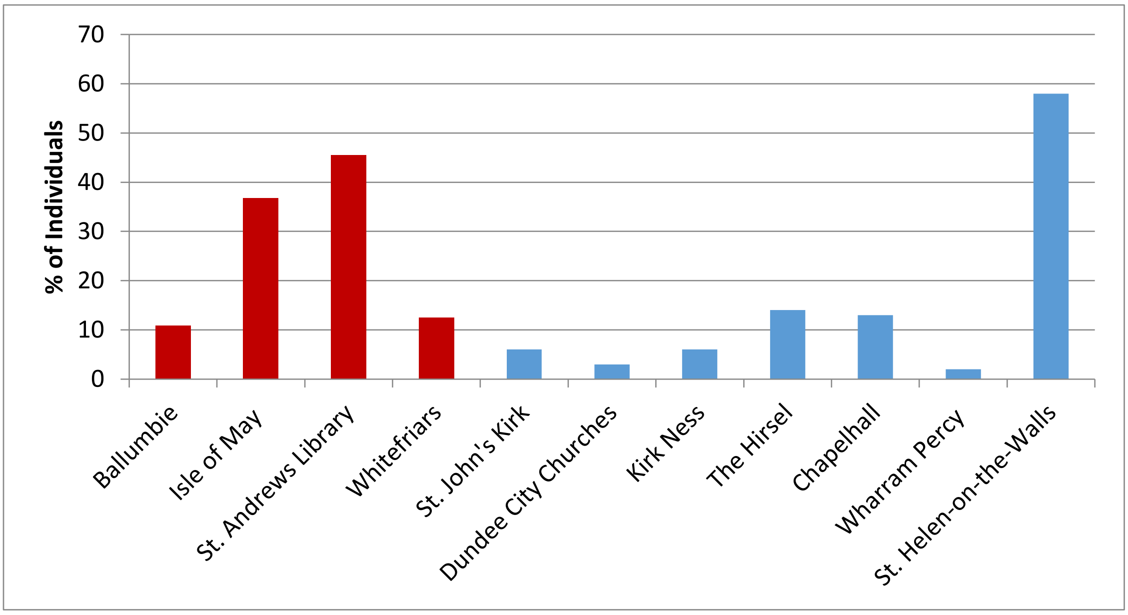

Figure 115 Prevalence rates for porotic hyperostosis in medieval Britain.
Study populations are in red.

As mentioned, a diet deficient in vitamins can lead to metabolic diseases such as rickets (vitamin D) and scurvy (vitamin C) (Brickley and Ives 2008). Rickets has several causes, one of which is a deficiency of vitamin D in the diet (Brickley and Ives 2008; Ortner and Mays 1998). The deficiency causes an interruption of the mineralization of osteoid which produces limbs lacking in mechanical strength and tending to deform easily when bearing any weight (Resnick and Niwayama 1995). Similarly, weight bearing on the under-mineralized spine causes scoliosis (Brickley and Ives 2008). Vitamin D deficiency in adults causes osteomalacia, which is characterized by bone softening leading to skeletal deformities and pseudo-fractures (Brickley and Ives 2008). Vegetarian diets, whether intentional or not, that do not contain oily fish, meat, or eggs may risk vitamin D deficiency. Insufficient vitamin D levels also hinder calcium absorption, which can lead to osteopenia. Within the study populations there were low prevalence rates of rickets (under 4%) suggesting Vitamin D deficiency did not play a large role in the health of lowland medieval Scotland. A middle-aged female from St Giles, Edinburgh was found with multiple conditions suggesting overall poor health, possibly beginning from malnutrition in childhood. This female suffered from

> "childhood anemia, followed by osteomalacia, leading to a deformed spine, pelvis and legs, the stress of which occasioned osteoarthritis of the knees. Also, in adulthood, she contracted leprosy (a lesion in her left orbit may indicate a loss of sight in that eye) and her teeth were badly affected with cavities and abscesses. At some point she sustained fractures to her sixth to ninth ribs on the left side, which were still in the process of healing when she finally died" (Henderson 2006:38.)

This sad example demonstrates how malnutrition in childhood could lead to susceptibility for a number of conditions later in life.

Even though historical research (Fenton 2007, Gies 2005) indicates the Scottish medieval diet lacked sufficient vitamin C, there is no indication based on skeletal evidence from the compared populations in this study. There were no cases of scurvy at any of the study populations, indicating no vitamin C deficiency. Scurvy is rare in other medieval Scottish populations, for example there is only one possible case at The Hirsel (Anderson 1994). Vitamin C (ascorbic acid) deficiency inhibits the formation of collagen, which manifests most noticeably in growing infant skeletons (Ortner 2003). Adult scurvy can affect those deprived of fresh fruits and vegetables. High temperatures destroy vitamin C, therefore individuals that only eat cooked fruits and vegetables can still suffer from scurvy. Most often affected are the metaphyses and in severe cases fractures occur in areas with inadequate trabecular bone (Ortner 2003). The body then responds to the frequent trauma with hemorrhages, which can be fatal. Adult forms tend to appear with bleeding gums and antemortem tooth loss. The blood vessels already weakened by the poorly formed collagen burst easily in both adult and infant cases (Brickley and Ives 2008).

Another potentially diet-related metabolic disease is osteopenia. Osteopenia is a generic term for bone loss. At the rural site of Ballumbie, only females suffered from osteopenia or osteoporosis, a statistically significant result (χ^2=6.682, p=.010, df=1). Osteopenia can be caused by infections such as tuberculosis, leprosy, treponemal disease, poliomyelitis, other non-specific infections, anemia, congenital conditions, haematopoietic conditions, neoplastic conditions, and joint disease (Brickley and Ives 2008, Stini 1990). Dietary insufficiency of calcium, protein, fatty acids, fruits and vegetables commonly causes osteopenia and likely affected many past communities (Brickley and Ives 2008). Other minerals such as magnesium, zinc, and iron can interfere with the bioavailability of calcium leading to osteopenia. Once the skeletal health has been comprised by osteopenia it can lead to osteoporosis, a disease characterized by fractures due to skeletal fragility (Brickley and Ives 2008, Stini 1990). A study in 2001 by Turner-Walker et al. found that 23% of women in medieval England and Norway experienced a decrease in bone mineral density, a rate comparable to modern post-menopausal women. The authors attribute these cases of bone loss to multiple births, short birth intervals, and prolonged lactation, coupled with inadequate nutrition. The significant result at Ballumbie where osteopenia only affected females suggests similar post-menopausal related causes of osteopenia.

Deficiencies in diet can also lead to linear enamel hypoplasia (LEH), a metabolic condition where normal enamel production is halted in favor of vital functions. Within the study populations there is significantly more LEH in the urban areas than in the rural ones (χ^2=8.887, p=.031, df=3) (Table 120). LEH can occur in individuals due to trauma or hereditary conditions, however individuals with multiple bands of LEH is typical in systematic metabolic disruptions (Goodman and Rose 1990). Metabolic disturbances can be caused by infections, hormonal changes and malnutrition (Goodman and Armelagos 1985a). The timing of a specific metabolic disturbance can be measured by the location of the enamel defect against known rates of crown development (Goodman and Armelagos 1985b, Goodman and Rose

1990, Reid and Dean 2000). With the same method, the number of metabolic disturbances an individual had throughout their childhood can also be distinguished. LEH is commonly used in paleopathology to assess nutritional status in past communities. In a clinical study by May et al. (1993) the authors supplemented the diet of 63 rural Guatemalan children with protein and found a decrease of LEH, proving the strong connection between diet and LEH. Larsen (1997) found that in contemporary populations "less than 10% of individuals from developed nations have one or more hypoplasias, whereas hypoplasias are commonplace in many underdeveloped settings or in disadvantaged subgroups or populations with poorer diets, more disease, or some combination of undernutrition and disease" (Larsen 1997:50).

Since it is the urban areas with more LEH in the study populations, it cannot solely be tied to lack of available fruits and vegetables in rural environments as was the case for other metabolic diseases. It is likely poorer individuals living in medieval Scotland in either environment would have suffered from malnutrition sometime during their lives, especially during the winter months and times of famine. LEH has also been correlated with weaning; a baby being breast-fed acquires vitamin D from the breast milk, however once the baby is cut-off from breast milk and does not receive adequate amounts of vitamin D from its diet, a metabolic disturbance arises (Hillson 1979). If that baby is born into a poorer family that regularly consumes a deficient diet, it will likely develop LEH around the age of weaning. It is important to keep in mind that higher status individuals could have also had deficiencies in certain vitamins due to cultural dietary practices.

The diet of an individual can also result in pathological changes in the skeleton through dental caries. However in this case it is due to the inclusion of too much or certain foods in the diet, rather than deficiencies in the diet. Through statistical analysis this research found urban sites did have more carious lesions per tooth than rural sites ($r= .509$, $p= .031$, $n= 18$) (Figure 116). The presence of caries generally indicates a diet of cariogenic foods such as quickly fermentable carbohydrates (Hardwick 1960). Refined sugar is the biggest cause of carious lesions; however sugar was not easily accessible in medieval Scotland since it was only first introduced to England in the twelfth century (Hardwick 1960). Dried fruit is also highly cariogenic as is refined flour since it tends to remain around the teeth. Sugar, dried fruit, and refined flour were difficult to acquire and usually only available in urban environments; however due to their difficulty to acquire these foods were also expensive and were mostly enjoyed by the elite. The relationship between dental caries and status will be discussed further in section 5.2.3.2.

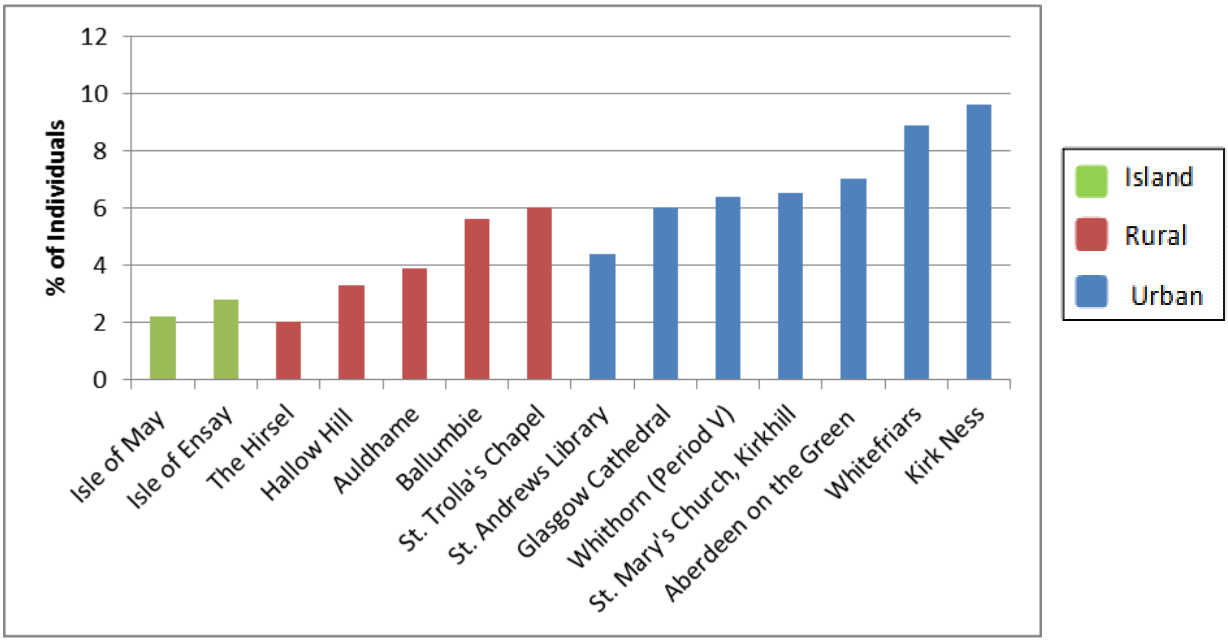

Figure 116 Prevalence of caries by tooth in lowland medieval Scotland

5.1.3 Population density and pathogen load

Among the study populations, urban St Andrews has significantly more infectious disease than rural Ballumbie (χ^2=118.534, p=.000, df=3). Comparing the compiled sites, those in urban environments have more infectious disease overall than the rural ones (Figure 117). The majority of rural sites have less than 12% of individuals with infectious disease in their populations. Conversely, over 18% of the populations at half of all the urban sites suffered from infectious disease.

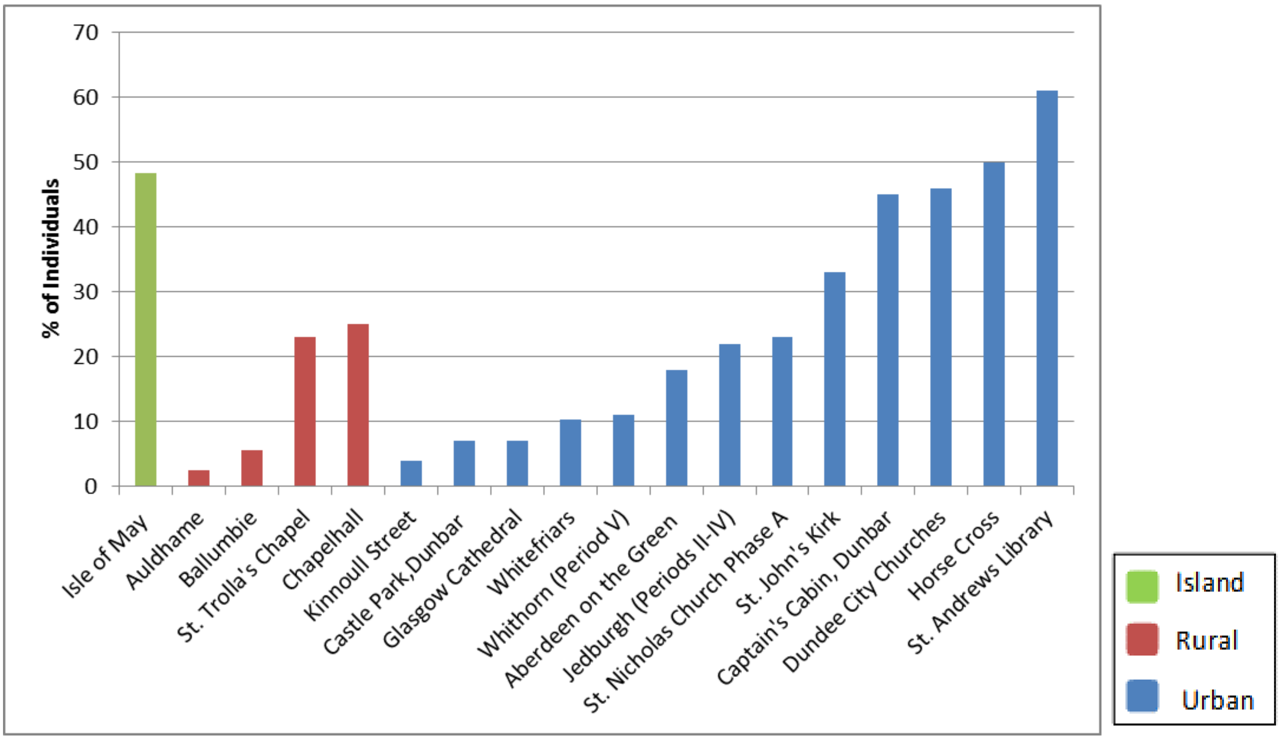

Figure 117 Prevalence of infection in lowland medieval Scotland

Ballumbie has a low rate of infectious disease. In fact, it is the second lowest percentage of all 25 populations compared here, the lowest being Auldhame (2%) (Figure 116). Perhaps Ballumbie has a low infectious disease frequency because it is rural, had a low population density, possibly had better hygiene, and therefore lower pathogen loads. Of the four study populations, Ballumbie also has significantly lower rates of non-specific infections (χ^2=40.896, p=.000, df=3) (Figure 96). Low population density and better hygiene likely explain this finding. Auldhame, which boasts the lowest rates of infection, was also a rural population (Melikian and Ives forthcoming). Chapelhall and St Trolla's Chapel, both rural sites that have high rates of infectious disease, are anomalous. The low sample sizes in these assemblages could be biasing the data. Glasgow Cathedral is an urban site that had low rates of infectious disease, which is likely related to its high status reputation rather than population density, which will be discussed further in section 5.2.

Urban St Andrews Library has the highest rate of infection (61%) within the study populations (Table 77), which is a significant difference. In fact, St Andrews Library has more infection than any other medieval Scottish population compiled here (Figure 117); the next highest is the Isle of May which has a prevalence of 49%

of infection in the population (section 5.4). Other urban populations with high rates of infection are Dundee City Churches (46%), Captain's Cabin (45%), St John's Kirk (33%), St Nicholas (23%), and Aberdeen (18%) (Cardy unpublished, Duffy unpublished, Roberts 2000, Roberts 2000b, Roberts 2001, Roberts 2005). These high rates of infectious disease are likely related to population density, poor hygienic standards, and poor living environments. Horse Cross in urban Perth had high rates of infectious disease as well as a case of hypertrophic pulmonary osteoarthropathy, which in this case is argued to be caused by chemical exposure from industrial activities (Roberts 2007) (section 5.1.3).

Population size in twelfth century Scotland was most likely around a few hundred thousand; population estimates for the largest burghs were Edinburgh, Aberdeen, Dundee, and Perth are around 2,000 people (Dennison and Simpson 2000, Dyer 2003). By the later Middle Ages the larger burghs, such as Edinburgh, had a population of around 12,500 and national population estimates were around 700,000 (Dennison and Simpson 2000, Dyer 2003). Of the national population, 90% lived in the rural countryside until the sixteenth century. While in Edinburgh, one of the largest burghs of the time, was described as having 400 houses in 1380, rural settlements saw populations between 12-60 houses (Dyer 2003, Ewan 1990, Harvie 2002, Lynch et al. 1988).

Migration from the countryside into the burghs continually raised the urban population size. There was more opportunity to make money and make a living in the burghs where manufacture and markets took place (Dyer 2003). Since most burghs had finite boundaries such as lochs, the sea, or cliffs, burghs often built upwards when they became more settled. The burghs became densely populated, with most people living in cramped quarters, subsequently leading to poor hygienic conditions (Yeoman 1995). In Perth, the narrow rigs forced wattle and daub houses to be built right next to cess pits, middens, and manure heaps (Dyer 2003).

Holt and Rosser (1990) explain that although the type of housing individuals lived in was based on what they could afford, even the wealthiest were not safeguarded from the poor sanitation in the cities.

> “Standards of housing and nutrition depended largely on familial income, but other features of urban life- filth running in open ditches in the streets, fly-blown meat and stinking fish, contaminated and adulterated ale, polluted well-water, unspeakable privies, epidemic disease, casual interpersonal violence, disastrous fires- were experienced indiscriminately by all social classes” (Holt and Rosser 1990:15) .

While conditions in the public areas in towns would have been suffered by all, it is argued in section 5.2 the upper classes would have been somewhat protected in their more comfortable and hygienic homes.

In urban environments industries like butchery fouled the streets, tanning fouled the waters, and all industries fouled the air (Dyer 2003). In England, air pollution is mentioned as early as the thirteenth century (Brimblecome 1982). Lewis et al. (1995) analyzed 663 medieval individuals from Wharram Percy, a rural population, and 1,042 individuals from St Helen-on-the-Walls, an urban population, for maxillary sinusitis. The authors found a higher prevalence for sinusitis in the St Helen-on-the-Walls population that they suggest was due to air pollution from the medieval city of York. Charlotte Roberts (2007) also examined skeletons for maxillary sinusitis and agreed with earlier proposals that the pathological lesions are related to poor air quality. The challenges with analyzing maxillary sinusitis are outlined by Boocock et al. (1995) where the authors claim the most efficient method requires the help of an endoscope, which is not always available to researchers. Unfortunately an endoscope was not available at the time of this research, therefore maxillary sinusitis was not analyzed. Industry in medieval Scotland was not as further developed as seen in medieval England, therefore air pollution from industry alone may not have affected as many. Air quality due to smoky houses, however could have affected those in medieval Scotland.

The streets in towns were typically muddy or filthy with household rubbish, animal waste, wastage from butchers and fishmongers, and even human waste. Shoes often had wooden platforms or had wooden stilt-like shoe accessories that permitted the owner to walk above the filth on the street (Ewan 2011, Yeoman 1995). Ewan (2011) explains that even with the appropriate footwear, women’s long skirts would hit the street, dragging around the filth with them. In 1249 in Berwick, dust, ashes, and dung were forbidden to be thrown into the streets, the marketplace, or the River Tweed (Hall 1982). This statute gives an insight to how rubbish was commonly discarded. Towns would have been smelly from standing water, animal dung, latrines, and even dead unburied corpses (Ewan 2011). Most industries also polluted the air with smoke, which people from every social class would inhale every day (Dyer 2003). Since livestock was slaughtered in town there were carcasses, skin, and other waste lying in the streets or on nearby building's forestairs. Domestic and feral dogs and cats roamed and fouled the streets. Many people owned pigs and would allow them to wander and eat street waste, but these animals would have also added waste as well (Dyer 2003). Cattle and horses were also found in the town, also fouling the streets.

Legislation helps to indicate the conditions of the towns. For example, in 1566 the Edinburgh council ordered there be a door added to the base of the gallows so that dogs would stop dragging off bodies (Ewan 2011). Unburied corpses likely could have disseminated pathogens. Statutes in Selkirk mention orders for people to remove middens that were within 40 feet of the market cross. From the fourteenth century, some towns employed official street cleaners, but prior to that that streets were only periodically cleaned, usually for special holidays (Ewan 2011). As well as being thrown into the streets, waste was also thrown into nearby rivers and streams, which polluted the water supply, which was additionally polluted by industrial waste from dyeing and tanning.

Household rubbish, industrial waste, and soiled straw from livestock were thrown in midden heaps in the backlands. Not until the later medieval period would rubbish be carted off to the town fields (Yeoman 1995). Human waste was disposed of in cesspits in the backyards that were lined with old barrels, and moss was used as toilet paper. Excavations have found that wattle partitions were set up next to outdoor cesspits for privacy (Murray 2010, Yeoman 1995), though, streets, ditches, and streams were also used as toilets. Ditches or gutters were dug between houses to drain the human waste away from households (Ewan 2011). In the later medieval period, wealthy houses often had indoor latrines; wooden toilet seats found in situ in Perth give an indication of what these latrines looked like (Yeoman 1995).

Historical documents, although in this instance from London, again shed light on what the conditions were really like.

> "In 1301 William de Betonia complained that the cesspit of his neighbour, William de Gartone, lay so close to his cellar that the sewage dripped through the wall. This was investigated by the mayor and the aldermen, who did not accept de Gartone's argument that he was a free tenant and that his predecessors had always had a privy. Instead, the offender was given forty days to build a stone wall 2 ½ feet thick between the pit and his neighbor's cellar" (Dyer 2003: 200).

There must have been many more instances like this one in Scotland as well, especially in poor areas. If matters of cost slowed down the rate at which such problems were reported, adjudicated, and fixed, the poor would therefore had to cope with these types of hygienic problems.

Water gathered from dug wells and cisterns was often contaminated when cesspits were dug too close to a water supply (Yeoman 1995). As mentioned in section 2.4.1, Bowler and Perry (2004) discovered numerous wells and cisterns in Perth were dug too close to the water supply which resulted in contamination. Eggs of parasitic worms were also found in the cesspit material suggesting the people of Perth were infected. Other historical evidence from London mentions garderobes, or lavatories, that voided into the streets, cesspits that overflowed into the gardens, and the frequency of townspeople relieving themselves out bedroom windows at night (Hall 1982). One way we can gauge the hygiene of past communities is by analyzing parasitic remains in soil, latrines, coprolites, mummies, and bog bodies (Bouchet et al. 2003). *Trichuris trichiura*, the common whipworm and *Ascaris lumbricoides*, the large roundworm have been found in cesspits and inhumations in Scotland, indicating parasites were a daily part of life for people in medieval Scotland (Hall 1982, Yeoman 1995). Another way to assess parasite loads in past populations is with evidence of hydatid cysts, which are caused by ingesting the fertilized ova of a tape worm from the genus *Echinococcus* (Aufderheide and Rodríguez-Martín 1998). These parasites are transmitted through food or water contaminated with fecal matter, and can be found in locations with poor sanitation to this day. The parasite affects the liver or lungs by causing extreme necrosis of the tissue (Aufderheide and Rodríguez-Martín 1998). Chronic conditions calcify the originally water filled cysts which can be examined archaeologically. Skeleton 993, a middle adult female from the Isle of May, has a hydatid cyst (Figure 62). While this female was buried at the Isle of May it is possible she could have traveled from an urban environment that had poor hygienic controls.

Another indication of pathogens in past environments, including fungi, viruses, bacteria, and parasites, is from the response to skeletons with high pathogen loads. Iron deficiency anemia, which presents as cribra orbitalia or porotic hyperostosis, has been proven to be caused, or exacerbated by, intestinal parasites (Bathurst 2005). As previously mentioned, St Andrews Library suffered from statistically more porotic hyperostosis (section 5.1.3.1). Stuart-Macadam (1992) argues that porotic hyperostosis on the cranial vault and cribra orbitalia in the eye orbits are lesions that develop as an adaptation to a pathogen rich environment. The body becomes temporarily hypoferremic, or anemic, to defend the body against the pathogens, producing the lesions on the cranial vault and eye orbits. The affect mirrors the symptoms of dietary iron deficiency, which has been the long-standing explanation for porotic hyperostosis and cribra orbitalia (Stuart-Macadam 1992, Sullivan 2005, Walker et al. 2009). Several of the common causes for high pathogen loads in environments would have affected the burghs in medieval Scotland, such as high population density, agricultural subsistence which exposes soil pathogens, ground level housing, and poor sanitation (Stuart-Macadam 1992).

With further urban development, population density increases which then leads to the spread of infectious diseases. The infectious diseases that can be diagnosed through skeletal analysis include but are not limited to: tuberculosis, leprosy, syphilis, small pox, septic arthritis, and brucellosis. Many infectious diseases cannot be identified, but produce non-specific bony changes on the bones such as periostitis and osteomyelitis. When a specific infectious disease cannot be diagnosed from the pathological changes, the condition is often referred to as a ‘non-specific infection’ (Ortner 2003, Waldron 2009). DNA of bacteria or fungi can be recovered with more invasive analysis. These results can confirm a previous diagnosis or can offer new, previously unexamined, diagnoses. Redfern and Roberts (2005) studied the effects of urban development in Roman Britain and found living in squalid settlements led to higher rates of stress indicators including cribra orbitalia, enamel hypoplasia, and periostitic lesions. The infections were often chronic lasting a long period of time and often developed into osteomyelitis from exposure to bacteria-rich environments. Redfern and Roberts linked the higher rates of infectious and metabolic to contaminated water sources, sanitation issues, and parasitic remains. They explain that houses sheltered mice and rats, which could be carriers of typhus, and the poor ventilation in the houses would have predisposed individuals to respiratory diseases (Redfern and Roberts 2005).

Mary Lewis (2002) examined individuals from medieval and post medieval rural, urban, and industrial English populations to determine if there were differences in morbidity and mortality of children in the past. She found that although there were differences in urban and rural morbidity and mortality, it was industrialization that had the greatest impact on child health. She attributes this decline in child health to "environmental conditions, urban employment, socioeconomic status, and changes in weaning ages and infant feeding practices (Lewis 2002: 222)."

Living in cramped quarters found in the urban environment, especially in poorer houses, often led to infectious diseases, such as tuberculosis and leprosy, since they are highly transmittable. Tuberculosis is an infectious disease caused by *Mycobacterium bovis* and *Mycobacterium tuberculosis* and can be contracted by inhalation of droplets or ingestion (Aufderheide and Rodríguez-Martín 1998, Resnick and Niwayama 1995). Roberts (2012) lists the risk factors for contracting tuberculosis, which include: social status, poverty, animal interaction, ingestion of infected animal products, overcrowding, urban environment, poor hygiene, poor diet, iron deficiency, occupation, vitamin deficiencies, poor air quality, climate, and poor access to health care. From this list, individuals living in a rural environment would be affected by the risk factor for tuberculosis due to high animal interaction. However, those living in an urban environment, specifically poor individuals, would have had multiple risk factors for tuberculosis due to their low social status, overcrowding, poor diet, including vitamin deficiencies, poor hygiene, and poor air quality due to small cramped spaces. While all in medieval Scotland would have an equal risk for contracting tuberculosis due to the climate in Scotland and no one would have had access to antibiotics until its discovery in the late nineteenth century, the urban poor would most likely suffer more often from tuberculosis.

As previously mentioned, rural Auldhame, boasts the lowest rates of infection, (Melikian and Ives forthcoming). However, not all of the other populations with similarly low rates are rural. As previously mentioned, Glasgow Cathedral is a higher status population, potentially with better housing and hygiene, which seems to result in lower levels of infectious diseases (7%) (King 2002). Therefore, whether a population is rural or urban seems to be only one of many factors influencing rates of infectious disease. For further discussion on how status affected health, including rates of infectious disease, in lowland medieval Scotland, see section 5.2.

Hypertrophic pulmonary osteoarthropathy (HPO) is a by-product of a pulmonary infection and presents with symmetric bi-lateral periostitic lesions on the paired bones, particularly long and short tubular bones (Mays and Taylor 2002, Shneerson 1981) (section 3.1.8.1). There are two cases of HPO within the Isle of May assemblage, SK 814, an adolescent male, and SK 1030, also an adolescent (section 4.2.5.1.4). In the pre-antibiotic era, HPO typically resulted from tuberculosis while lung cancer and emphysema are typical causes today. In fact, DNA from *M. tuberculosis* was extracted from one of the skeleton at Wharram Percy that presented with lesions consistent with at HPO (Mays and Taylor 2002).

Other cases of HPO are thought to have been caused by chemical irritants, such as those found in smoke (Resnick and Niwayama 1995). Horse Cross in urban Perth had high rates of infectious disease as well as an individual with prolific periostitis on their arms and legs, diagnosed as HPO (Roberts 2007). Roberts (2007) explains Horse Cross was used for industrial activities such as tanning, dyeing and brewing. The high level of cases of periostitis, she argues, is due to exposure to chemicals used in these processes. The author claims that the chemical exposure theory corroborates the individual's diagnosis of HPO. HPO, therefore, can be seen as a poor air quality disease, whether in smoky houses or chemical exposure in urban environments. Living in the poorer houses in medieval Scotland could have caused pulmonary infections leading to HPO due to inhalation of tuberculoid droplets and also the smoky environment. The poor air circulation would have also been an issue in rural houses that generally had no chimneys and only small window openings. However, in urban environments factors such as chemicals used for industry and heavier pathogen loads would have increased the chances of suffering from HPO. It is possible the two individuals found with HPO at the Isle of May visited the Isle of May as pilgrims but originally came from urban environments. Their cases of HPO could have been caused by exposure to chemicals from industry, or from pulmonary infections due to either smoky environments or infections of tuberculosis. Further discussion on the Isle of May and pilgrimage can be found in section 5.4.

While it is possible that living with cattle, which was common in medieval Scotland, could have caused transmission of *Mycobacterium bovis* through inhalation, it is likely the transmission of the bovine bacteria was due to ingestion of unpasteurized dairy products (Roberts 2012) (section 3.1.8.1). Human-to-human transmission via inhalation was the most common way for tuberculosis to spread (Aufderheide and Rodríguez-Martín 1998). Mays et al. (2001) was expecting to find the bovine strain of tuberculosis when he analyzed the DNA from skeletons with tuberculosis at Wharram Percy since rural individuals were known to have a great deal of contact with cattle, with byres on one end of the house. Instead, they only found the human strain suggesting tuberculosis was generally transmitted from humans rather than animals. Although tuberculosis was not always transmitted from animals, living with animals within their houses both, in the rural and urban environments, would have increased the risk of other infectious diseases: bacterial, viral, and parasitic.

5.1.3.1 St Andrews

As mentioned, St Andrews Library has significantly more infectious disease than the other study populations as well as the highest rate of infectious disease of all compiled populations (section 5.1.3.1). Multiple factors may be influencing this high percentage of infectious disease. High population numbers would explain the rates of infectious disease; however, while St Andrews was considered urban, it was never a large burgh. St Andrews likely only 1,000 people (Dennison and Simpson 2000). If population size was the only factor for high rates of infectious disease, one would expect to see high rates at every site within the larger urban burghs, such as at Perth whose population size is estimated to over 5,000 people (Bowler 2004). However that is not the case (Figure 117). Therefore, population numbers alone cannot explain St Andrews Library's rates of infectious disease.

Next, trade was examined as a potential factor in spreading disease. However, as seen in section 2.3.1 St Andrews had a low status in regards to overseas trading due to poor harbor facilities (Simpson and Stevenson 1981). As mentioned in section 2.3.1, there were large numbers of pilgrims that visited St Andrews annually. In fact Campbell (2013) estimated 15,000 pilgrims could have visited St Andrews in one year alone. Visiting pilgrims could certainly have propagated the spread of pathogens throughout St Andrews. As mentioned in section 5.1.3, the urban environments often had poor hygienic controls. This was surely the case for St Andrews as well. An account of St Andrews from the eighteenth century claims "[t]he whole streets are filled with dunghills which are exceedingly noisome and ready to infect the air (Hall 1997:30)." It seems likely that although St Andrews did not boast a large population number, it still suffered from poor hygienic controls. Keene (1983) explains that population density issues do not only relate to population numbers but also housing structures being in close proximity to one another. The houses at St Andrews could be considered to be close, with burghage plots running alongside others. Simpson and Stevenson (1981) explain the average rig was nine meters wide and due to the physical position of the town there was limited land available for expansion. Keene (1983) also states that towns in early stages of development may deal with waste disposal issues and contaminated water. These issues would have also affected St Andrews rendering proximity and close quarters, poor hygienic controls, and pilgrimage all contributing factors to its significantly high infectious disease rates.

Likely related to the high pathogen load seen at St Andrews, St Andrews Library also suffered from high rates of metabolic disease (section 5.1.2). As mentioned in section 5.1.2, metabolic disease can be caused by deficiencies in the diet. It can also be caused by high pathogen loads. The body becomes temporarily hypoferremic, or anemic, to defend the body against the pathogens. Therefore, the changes that resemble metabolic disease can in fact be adaptations to a pathogen rich environment. The high infectious rate at St Andrews Library already proves it was a pathogen rich environment. The high metabolic disease at St Andrews corroborates the results.

Also related to the high pathogen load seen at St Andrews Library, males at St Andrews Library have the shortest stature of all of the compiled Scottish sites (Table 127). While heredity provides the potential for stature, many factors can affect whether the potential is met. The slightly stunted growth at St Andrews could be due to the high parasite load, or perhaps nutritional differences could be the cause of the short stature (Larsen 2000, Schweich and Knüsel 2003). Schweich and Knüsel (2003) found that individuals in a *leprosarium* population (medieval Chichester, England) that had low socio-economic and health status suffered from stunted growth in height and weight. Females in St Andrews Library are on the short side of average stature; yet they are not the shortest of all the compiled populations. Overall male and female statures are similar in the four study populations and fall well within the average stature for other Scottish medieval sites. For more on how status affects stature see section 5.2.3.5.

Table 127 Stature in centimetres for Scottish medieval sites

Study populations are in red.

Site Name	Avg. Male Stature (cm)	Avg. Female Stature (cm)	Reference
Ballumbie	**169**	**157**	**This Study**
Isle of May	**171**		**This Study**
St Andrews Library	**165**	**155**	**This Study**
Whitefriars	**168**	**155**	**This Study**
Kinnoull Street	170	153	Bruce 1995
St John's Kirk	170	154	Roberts 2005
Dundee City Churches	171	158	Roberts 2000
Kirk Ness	168	157	Henderson unpublished
The Hirsel	168	159	Anderson 2014
Whithorn (Period V)	170	156	Cardy 1997a
St Mary's Church, Kirkhill	169	159	Bruce 1997
Logies Lane	169	157	Cardy 1997b
Hallow Hill	170	160	Young 1996
Aberdeen on the Green	170	158	Cardy unpublished
St Nicholas Church Phase A	168	154	Duffy unpublished
Castle Park, Dunbar	171	157	Bruce 2000
Captain's Cabin, Dunbar	170	160	Roberts 2001
Linlithgow	170	156	Cross and Bruce 1989
Isle of Ensay	166	155	Miles 1989
Glasgow Cathedral	172	157	King 2002
St Giles (Period 2)	167	156	Henderson 2006
St Trolla's Chapel	168	159	Roberts 2003
Auldhame	170	159	Melikian and Ives forthcoming

As mentioned previously in section 5.1, the majority of people that lived in lowland medieval Scotland died between 35-45 years old. However females died earlier (25-34 years old). It was argued that women in rural environments died earlier (under 25) than their counterparts in urban environments since they had less access to health care when there were complications in childbirth or other maternal stresses. However, males in the study populations have significantly more infectious disease than females (χ^2=6.009, p=.014, df=1). And also previously mentioned in sections 4.6.3 and 5.1.3.1, males at St Andrews Library were significantly shorter than others in the region, suggesting they had poor health from high pathogen load or nutritional deficiencies. Even with these two factors, females in the study populations were still dying significantly younger than males (χ^2=13.125, p=.011, df=4). In fact, 82% of females at St Andrews Library died before the age of 35 years old (Table 130). This suggests the maternal stresses females at St Andrews Library faced made them more susceptible to the high pathogen load than males from their same locale. Another possible interpretation evaluates the data from the perspective of the osteological paradox (Wood et al. 1992) (section 1.2.2.3); the females at St Andrews were so unhealthy that they died before their bodies could develop any bony reaction to an infection. Females at Whitefriars also died young; 90% of females died before they were 35 years old. Therefore, although females living in the urban environment survived past reproductive years more often than females in the rural areas, maternal stresses on their bodies still affected their health, reducing their life expectancy compared to males in either environment. Status is another factor that could affect the health in males and females, as will be discussed in section 5.2.1.3.

Table 128 Ballumbie age at death by sex

	Age					Total
	ADL	YA	YMA	MA	OA	
Male	5	6	21	20	11	63
Female	3	9	18	22	14	66
Total	8	15	39	42	25	129

Table 129 Isle of May age of death by sex

	Age					Total
	ADL	YA	YMA	MA	OA	
Male	2	8	9	14	11	44
Female	0	0	1	1	0	2
Total	2	8	10	15	11	46

Table 130 St Andrews age at death by sex

	Age					Total
	ADL	YA	YMA	MA	OA	
Male	4	1	3	10	4	22
Female	0	3	6	2	0	11
Total	4	4	9	12	4	33

Table 131 Whitefriars age at death by sex

	Age					Total
	ADL	YA	YMA	MA	OA	
Male	0	7	7	5	2	21
Female	0	5	5	0	1	11
Total	0	12	12	5	3	32

5.1.4 Subadult mortality

In order to assess subadult mortality trends in medieval Scotland, age categories that were similar among the various skeletal reports were used, but occasionally the ranges had to be adapted for accuracy.

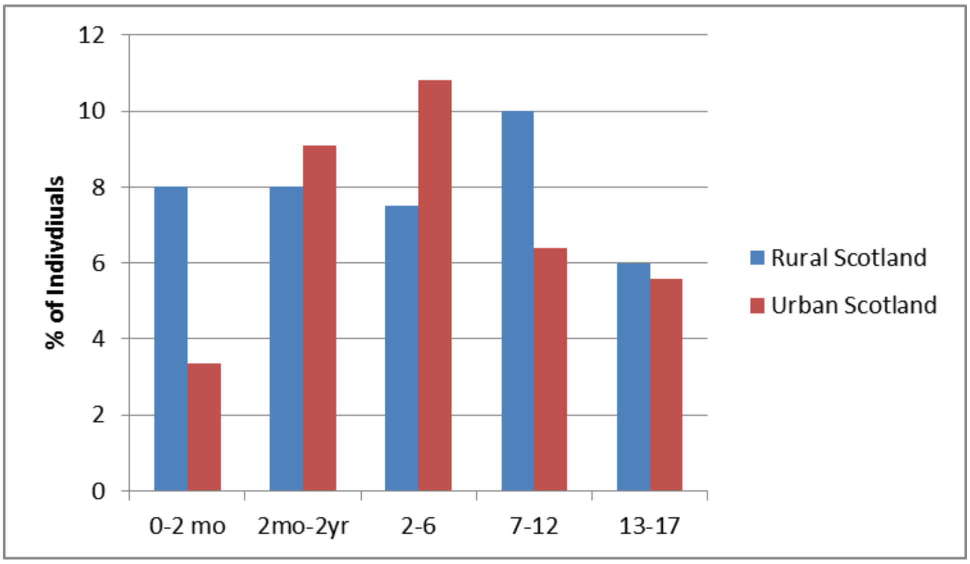

Figure 118 Urban and rural medieval Scotland subadult mortality profile

Demographic comparisons between all six rural and eighteen urban Scotland populations are shown in Figure 118. The average neonate mortality rate (0-2 months) in the compiled medieval Scottish populations was 4.8%. To put this in perspective, according to Pearce and Goldblatt (2001), who reported on neonatal mortality in the United Kingdom in the modern era, in 1971 neonatal mortality was at 1.2% and decreased since with 0.4% in 1999. There are twice as many neonates in rural populations compared to urban populations. Females living in rural areas may not have had many options if there was a complication during childbirth, as suggested in section 5.1.1. Perhaps there were better conditions for childbirth in urban areas. Sayer and Dickinson (2013) also found maternal mortality to be significantly higher in rural areas in the modern developing world. This discrepancy, however, could also indicate differential location for burials of neonates within the excavated areas. On average, infant mortality (two months to two years) in medieval Scotland was 9%. According to Pearce and Goldblatt (2001), in 1971 infant mortality in the United Kingdom was at 1.8% and has decreased since with 0.6% infant mortality in 1999.

Conversely, between the ages of 2-6 children in urban Scotland children are more likely to die than children at the same age living in rural areas of Scotland. The urban environment, likely due to population density and poor hygienic controls, affected the health of subadults by reducing their life span. In the study populations, St Andrew's Library (26%) and Whitefriars (40%) both have high rates of subadult mortality compared to the rural Ballumbie (18%). Other urban sites with similar high amounts of subadult mortality are Dundee City Churches (28%), Whithorn (32%), Aberdeen (32%), St Giles (33%), Kinnoull Street (35%), Linlithgow (59%), St Nicholas Church (51%), and St John's Kirk (79%) (Bruce 1995, Cardy 1997a, Cardy unpublished, Cross and Bruce 1989, Duffy unpublished, Henderson 2006, Roberts 2000, Roberts 2005) (Appendix 13). The urban burghs represented above include Edinburgh, Aberdeen, Perth, and Dundee, Galloway and Linlithgow. The first four mentioned are considered the "Big Four" burghs since they had the highest population sizes as well as the most overseas trade in medieval Scotland. This supports that population density is one of the factors that affects the health of those living in the urban environments. Weaning practices can also affect subadult mortality, at least for the younger children. In modern developing countries the condition kwashiorkor is caused by poor nutrition after a child is weaned, translated in some countries as the sickness one baby gets when another one comes (Dettwyler 1994, Walker 1990). Weaning practices could account for deaths at the younger part of the child age category (around 2 yrs) and exposure to infectious diseases could account for the older individuals in this group (4-6 yrs). At St Andrews and Whitefriars there are marked peaks of subadult mortality between the ages of 2-6 years. A complicating factor in subadult and neonate mortality is status. Glasgow Cathedral, a known high status cemetery, had low rates of subadult mortality (19% and low rates of neonate mortality (1%) even though it was an urban location. This indicates that the upper status individuals were shielded from the poor hygienic controls, contaminated waters, and population density issues even though they lived in the same urban environment. For further discussion on how status affects health see section 5.2.

Only one of the study populations, St Andrews, had a neonate burial (aged 0-2 months). The general absence of neonates in the other populations is most likely due to burial practices, excavation techniques, and/or taphonomy rather than a reflection of infant mortality in these populations (sections 1.2.2 and 1.3.3). Likewise, the high rates of subadult mortality seen at Whitefriars (40%) could also be related to differential burial practices. St Giles Cathedral (Henderson unpublished), Captain's Cabin (Roberts 2001), and Whithorn (Hill 1997) each had sub-cemeteries of children burials within their larger cemetery. Non-baptized neonates were often buried in different locations to the rest of the cemetery population (Gilchrist 2012). Infants, along with neonates, were sometimes buried in different locations, and if those locations were not within the purview of excavations, the demographic data may have been unintentionally skewed. An example of how this can easily happen is with the two Whitefriars excavations. In the 1982 excavation there were 21 burials excavated and none were of subadult skeletons (Cross and Bruce 1989). However, in the more recent excavations 40% of the skeletons were subadults. In fact, 10% of the burials were individuals under 2 years old. These two excavations of the same site tell a completely different picture of the population, and both of these reports may still be unrepresentative if more of the site is excavated at a later date. While the scope of an excavation is an issue in many of the interpretations of a site, nowhere is it more obvious than in interpretations of infant mortality.

St John's Kirk has an extremely high percentage of subadults (79%), a percentage explained by the authors as being due to an epidemic such as measles, diphtheria, or whooping cough. Peaks in subadult mortality at St John's Kirk were seen in infancy and childhood. The authors failed to examine the possibility that the area excavated might have been designated for the burial of children. If health is the reason for the high percentage of subadult mortality at St John's Kirk, this church has the poorest health of the lowland Scottish communities that have been compiled here.

An example of how neonate mortality is the result of local hygienic conditions is demonstrated with the Hebridean island St Kilda. In the nineteenth century the St Kilda population suffered from high amounts of infant mortality. Two thirds of the newborns born over a period of 150 years died within their first eight days of life. One woman gave birth to 14 children and only two of them survived past their eighth day of life (Stride 2008, Turner 1896). At the time the islanders called this the "eight day sickness" where newborns would stop suckling the breast and eventually get convulsions and lockjaw before passing away (Collacott 1981, Ferguson 1958, Stride 2008, Turner 1896). Doctors of the day reached contradictory conclusions such as the diet of the mothers was too oily, interbreeding led to weakening of the blood, poorly ventilated houses, and improper feeding of the baby. At the end of the nineteenth century the disease was identified as tetanus, which is caused by the microorganism *Clostridium tetani* found in soil worldwide as well as in animal feces. Soil tested from inside and outside houses on St Kilda was found positive for tetanus (Stride 2008). Post-delivery practices on St Kilda included cleaning the umbilical stump, tying the cord, and wrapping the baby tightly in dirty clothes. Babies were generally not bathed until 5 days after birth and clean clothes were not wasted on the babies since they were thought to likely die. How tetanus was transferred to the baby is unknown, but is likely to be from poor management of the umbilical cord either by an un-sanitized knife used to cut the cord, an infected ligature (such as horsehair) for the umbilical stump, or the unclean baby clothes (Stride 2008). Although tetanus does not leave traces on the skeleton, the high infant mortality rate on St Kilda due to poor sanitary practices can provide clues into the possible effects of poor hygiene in medieval Scotland.

5.2 Status: monastic/elite vs. lay/low status

Another main difference between the study populations is status. Lifestyle differences between individuals of different status affected their health. The factors that appear to influence health the greatest are housing and diet.

5.2.1 Burial location

Table 132 lists the status of the populations compiled here. Monastic cemeteries, as well as Glasgow Cathedral and St Nicholas were considered high status, while all other lay cemeteries were considered low status. Even though those in a monastic community were meant to have given up their worldly goods, section 5.2.2 will explain that they still lived in houses that were 'high status' in that they had stone floors and walls and did live in as close quarters. Monastic buildings had separate rooms or buildings for eating, working, and sleeping which was not the case in poor houses. Section 5.2.3 will explain that although the monastic diet was meant to be modest, by the end of the medieval period it was similar to the diet of the elite. Therefore, individuals considered ‘high status’ in this study include monastic communities, aristocrats, merchants, and royalty. Those of ‘lower status’ include peasants, farmers, and craftsmen. While these are generalizations, providing these distinctions allows comparisons between lifestyle and how it affected the health of the wealthier in society (as well as the monastic community) to those that are poorer individuals. The Isle of May was excluded from status analysis since it seems likely that many individuals buried there had traveled to the island for care and their burial location does not necessarily represent their status.

Table 132 Status defined for compiled populations

SiteName	Date	Type	Status
Captain's Cabin, Dunbar	9th-11th	lay	low
Castle Park,Dunbar	Early Christian-13th	lay	low
Chapelhall	10th century	lay	low
Hallow Hill	6th-9th	lay	low
Longniddry, Four Winds	5th-8th	lay	low
St. Mary's Church, Kirkhill	5th-12th	lay	low
Ballumbie	6th-17th	lay	low
Dundee City Churches	12th-15th	lay	low
Horse Cross	12th-16th	lay	low
Isle of Ensay	16th-19th	lay	low
Kirk Ness	12th-17th	lay	low
Logies Lane	15th-16th	lay	low
St. Andrews Library	15th-16th	lay	low
St. Giles, Edinburgh (Period 2)	12th-14th	lay	low
St. John's Kirk	12th-16th	lay	low
St. Trolla's Chapel	11th-17th	lay	low
The Hirsel	11th-13th	lay	low
Aberdeen on the Green	14th-17th	monastic/lay	high
Auldhame	7th-17th	monastic/lay	high
Glasgow Cathedral	14th-19th	lay	high
Jedburgh (Periods II-IV)	12th-16th	monastic	high
Kinnoull Street	13th-16th	monastic/lay	high
Linlithgow	13th-17th	monastic/lay	high
St. Nicholas Church Phase A	12th-15th	lay	high
Whitefriars	14th-17th	monastic/lay	high
Whithorn (Period V)	13th-15th	monastic/lay	high

5.2.1.1 Monastic or known high status cemetery

As mentioned in section 1.3.2 it can be difficult to determine the status of an individual, but the data may be analyzed to provide some understanding of the relationship between status and health. First, certain cemeteries are considered high status due to documentary or archaeological evidence. Glasgow Cathedral as discussed in section 1.3.2 is a known as a high status cemetery in Scotland. Documentary evidence supports its high status classification; it mentions that the cathedral enjoyed a rich endowment of lands and political power, which enabled its magnificent structural expansions (Driscoll 2002). According to Driscoll (2002) many of those buried in the cathedral would have been wealthy benefactors. The high amount of recovered coffins during excavations at Glasgow Cathedral is further evidence of the high status position of those buried there. Coffins were generally only affordable for the elite in medieval Scotland (Driscoll 2002, Stones 1989, Tarlow and Stutz 2013). Duffy (unpublished) identified the Kirk of St Nicholas as a higher status population. The parish served the increasingly wealthy burgesses of Aberdeen and increased in wealth and status in the fifteenth century when it claimed the title of the largest burgh church in Scotland (Duffy unpublished).

Burial locations within a monastic cemetery is another indication of status since the popularity of being buried in these locations after the fourteenth century increased their price and could only be afforded by the elite (Daniell 2007, Tarlow and Stutz 2013, Woodfield 2005). Jedburgh is the only population from the compiled sites that is considered to be purely monastic (Table 132). Six populations (Whitefriars, Kinnoull Street, Whithorn, Linlithgow, Aberdeen on the Green, and Auldhame) were considered monastic, but there is a possibility that lay benefactors were also buried in those cemeteries.

While it is difficult to say with certainty what proportions of the buried were monks, others buried within a monastic cemetery included wealthy benefactors who still warrant the high status classification. The type of housing and diet the monastic community often enjoyed were similar to the wealthier in the lay communities (Lowe 2009, Müldner et al. 2009, Sykes 2006, Woolgar 2006). Previous research into the status of Scottish monastic cemeteries have been completed, including Whitefriars, Kirkhill, Aberdeen, Linlithgow, Whithorn, and Jedburgh, ultimately concluding they should be considered high status (Bruce 1997, Cardy 1997a, Cardy unpublished, Cross and Bruce 1989, Grove 1995). As mentioned in section 2.4.1, the Carmelite monastery at Whitefriars was described as a ‘spacious house’ with a ‘stately chapel’ and that it was decorated with rich work (Simpson and Stevenson 1982). And although the Carmelites once led an ascetic life, by the fourteenth century, when the Whitefriars cemetery was used, Carmelite monasteries were similar to other religious orders such as the Dominicans and Franciscans (Andrews 2006).

5.2.1.2 Burial placement and grave furnishings

The burial placement within a church or monastery was also tied to status; burials closer to altars or shrines were more sacred and therefore more expensive. Burials within a church were preferred and since space was limited, generally the wealthier could afford those burial locations (Daniell 2007, Gilchrist and Sloane 2005, Tarlow and Stutz 2013). At Ballumbie there are seven individuals that are buried within a 'laird's aisle' (section 2.1.3). This mural tomb would have been a special burial location reserved for the benefactors. Conversely, those buried in the churchyard of the parish churches or even outside the churchyard can therefore be expected to be of lower status. Children of lower status parents, un-baptized infants, criminals, and those with 'sinful' diseases were often buried outside of a churchyard (Daniell 2007, Gilchrist 2012).

Grave goods or furniture can also indicate status. An example of this is the high number of coffins found at the high status cemetery Glasgow Cathedral (Driscoll 2002). While it is difficult and often impossible to determine which burials within a monastic cemetery are the monks themselves, Group 3 at the Isle of May is made up of fourteen burials from the late tenth century to the early twelfth century, which overlapped the time of the Benedictine Priory (James and Yeoman 2008). All fourteen burials in this group are male and range from 18-65 years of age. They were also buried beneath the foundations of the church, the chapter house, and in the cloister, suggesting the high status that the monks would have enjoyed. One male, SK 1211, a young-middle adult between 25-30 years old, was buried below the cloister with small red and blue naturally colored stones within the grave fill and even within the mouth of the skeleton (James and Yeoman 2008). These colored stones were unique to this burial, usually only white quartz pebbles were found with the other burials. Perhaps these colored stones denoted an important person within the community.

5.2.1.3 Complicating status assessments: Male/Female

A complicating factor to the above mentioned ways to infer status is biological sex. Another way to evaluate status within a cemetery is comparisons between males and females. As mentioned previously in section 5.1.1 females in lowland medieval Scotland died up to ten years earlier than males (Figure 113). Even though males in the study populations have significantly more infectious disease than females in the study populations, they were still dying significantly younger than males. It was suggested that maternal stresses made females more susceptible to the high pathogen load than males from their same locale. In contrast, females at Glasgow Cathedral lived until middle or old adulthood (King 2002), suggesting that higher status females are not as affected by the health problems of lower status females at other sites. This could be due to greater access to health care, improved nutrition, or better hygiene from wealthier houses (discussed further in section 5.2.2). However, the superior health of males compared to females at Glasgow Cathedral is noticeable when stature is reviewed (Table 127). Males at Glasgow Cathedral are the tallest of all compiled sites. However, females at Glasgow Cathedral fell within the normal ranges when compared to other lowland Scottish sites. This indicates that even within the high status Glasgow Cathedral cemetery, females did not enjoy the same superior health status as their counterpart males.

A further example of biological sex complicating the interpretation of status is with nunneries. While the monastic community often enjoyed a diet similar to the diet of the elite (further explored in section 5.2.3), the diet at nunneries was more similar to that of a peasant (Woolgar 2016). One complaint from a Prioress of Wroxall in 1323 explained

> they had been robbed of their customary portion of ale, meat, and fish, four nuns receiving scarcely a pint of very weak ale each day, and meat and fish and other necessaries being given in such small portions as to be scarcely enough to live on… (Woolgar 2016:162)

The differences in diet between the male and female religious institutions reflects their lower status in society. The food rations were often supplied by the monastery's resources and even the loaves of bread supplied were required to be less weight than those served to the monks (Woolgar 2016).

5.2.2 Houses

High and low status individuals in lowland medieval Scotland lived differently which eventually affected their health. One way they lived differently was the types of houses in which they lived. Even though living in an urban environment compared to a rural one increased the prevalence for infectious disease (section 5.1.3), it appears that the wealthier in society were somewhat shielded. In fact, there is a negative correlation between status and infection (r= .588, p=.013, n=17). The higher status cemeteries (Table 132) had significantly lower rates of infectious disease. Those that enjoyed a higher status during life most likely had better living conditions, which prevented the spread of pathogens.

Archaeological evidence gives us a pretty accurate picture of what the poorer urban houses would have liked like, which was similar to houses in the rural environment. Most houses were constructed from wattle and daub, which means the walls were made from woven pieces of wood, and clay, mud, and dung were covered over the wood (Perry 2010, Yeoman 1995). The majority of houses had thatched roofs made from heather and grasses, since these resources were cheap and easy to replace often (Gies 2005, Yeoman 1995). Floors were generally earthen, but sometimes clay or heather would be put down in rural environments. In urban houses sand and straw were often laid down to absorb household waste (Perry 2010). Filthy floors would be swept out to the yard and a new layer of sand and straw would be replaced. Sometimes clay, gravel or cobble stones were also used as flooring in later medieval urban houses (Perry 2010). Walls sat directly on the earthen floor and would get wood rot, which led to more sophisticated building techniques in the thirteenth century where the walls were laid down onto stone (Ewan 1990, Yeoman 1995).

The poorer houses only had one room, often without chimneys, and with only small window openings with wooden or straw coverings (Ewan 1990, Fenton 1987, Gies 2005, Perry 2010, Yeoman 1995). In the center of the house would lay the hearth, lined with clay or stone slabs, and fueled by peat or wood (Ewan 1990). The houses would have been dark, the only light coming from the fire, candles, or oil lamps (Murray 2010). Since the windows were small, the houses would have also been smoky and smelly from oil lamps, which commonly ran on fish oil (Gies 2005, Murray 2010, Yeoman 1995). More advanced hearths had a makeshift chimney that would channel the smoke (Gies 2005). The only heat came from the hearth, so houses were usually cool. Houses were commonly 10-13 feet wide and 22-26 feet long, usually rectangular in shape (Ewan 1990, Yeoman 1995). In most rural environments and in some urban ones, one end of the house would contain a byre, sheltering the livestock (Yeoman 1995). The walls were not daubed at this end of the house for better air circulation and the floor was made of stone, had drains, and would have been covered with heather so that it could be cleaned out often (Murray 2010, Yeoman 1995). Some walls were double skinned to provide more insulation (Murray 2010, Yeoman 1995). The animals provided extra body heat for the winter months, but this type of housing also demonstrates the changing social atmosphere where goods and livestock were no longer communal (Ewan 1990). Waddle hurdles were used to partition the different areas of the house such as for cooking and sleeping (Murray 2010). Even in the later medieval urban tenements, people still often kept their animals inside their houses (Murray 2010). In 1540 one lady was ordered by authorities to remove her geese from her upper storey flat in an Edinburgh house because due to the geese's feces the floorboards were completely rotten (Ewan 2011).

Houses for lower status individuals were often more cramped as well, often sharing one room. As mentioned in section 5.1.3, it was living in these poor cramped houses that often led to infectious diseases, such as tuberculosis and leprosy, since they are highly transmittable. The infections were often chronic lasting a long period of time and often developed into osteomyelitis from exposure to bacteria-rich environments. The poor often had to live with contaminated water sources, sanitation issues, and parasites (section 5.1.3). Poorer houses sheltered mice and rats, which could be carriers of diseases such as typhus. The type of flooring, the smoky atmosphere, contaminated water sources, sanitation issues, and living amongst the waste of livestock likely all contributed to the higher prevalence rate of infectious disease found in the lower status populations.

Contrary to the poorer houses that had one room where the entire family ate, worked, and slept, wealthier houses had two or more rooms. Wealthier houses had plank walls and plank or tile floors. After the fourteenth century, stone houses were being built, but only for the wealthiest individuals in the burgh. Even in the sixteenth century wooden houses were still more common than stone ones (Yeoman 1995). In these wealthier houses, the ground floor would be made from stone, and the upper floors would be made from wood (Ewan 1990). The upper floors could be reached by forestairs that ran on the outside of the building and gave access to each floor (Perry 2010). These more extravagant houses had rooms dedicated to different functions, a cellar, lofts, galleries, kitchens, and they used fireplaces instead of hearths (Ewan 2011). Wealthier craftsmen would often have their workshop on the ground floor with their living space on the upper floor, rather than working and living in the same room. As mentioned earlier the wealthy houses in the later medieval period often had indoor latrines (Yeoman 1995).

Accommodations in monastic institutions would have been similar to those enjoyed by the elite. Monasteries had multiple buildings such as what was excavated at the Isle of May including a cloister, prior quarters, chapter house, refectory, and latrine block (James and Yeoman 2008). Monasteries often included grand chapels paid by wealthy benefactors such as the 'stately chapel' at Whitefriars, described in Walter Bower's Scotichronicon. The monastic buildings were grand to attract visiting bishops and royalty (Simpson and Stevenson 1982). Even if the monks themselves slept in more humble accommodations, they still benefited from the more hygienic conditions. Many monasteries also had indoor garderrobes or a latrine block, such as the one at the Isle of May. The lime present at the latrine block at the Isle of May suggests frequent purification. Other latrines found at the Dominican friary at Kinnoul Street appeared to require occasional shoveling out (Bowler et al. 1995).

Related to the high prevalence for infectious disease is the high prevalence for metabolic disease in low status populations. On average, 15.5% of individuals that lived in low status populations suffered from metabolic disease whereas only 10.8% of individuals that lived in high status populations did. As mentioned in section 5.1.3 metabolic disease is often related to pathogen load, therefore there is a higher pathogen load found in low status populations. For example, the high status cemetery Glasgow Cathedral had low rates of metabolic disease; the individuals buried there are likely to have lived in richer houses, possibly reducing their interaction with pathogens (Figure 119). The higher status individuals most likely also enjoyed a better diet, also reducing the likelihood of being malnourished which will be further discussed in section 5.2.3. St Andrews Library serves a stark comparison, where nearly 30% of the population suffered from metabolic disease. As discussed in section 5.1.3.1, the high prevalence of metabolic disease at St Andrews was likely due to a high pathogen load.

Cribra orbitalia is also related to environmental stresses such as infection, parasitism, or iron-deficient diet (Stuart-Macadam 1989). Both infection and parasitism can be linked to housing; on average low status populations suffered from more cribra orbitalia than the high status populations (20.9% and 14.1%, respectively). Again, Glasgow Cathedral, along with other high status populations of Whitefriars, and Auldhame, has nearly no cases of cribra orbitalia (Figure 120). Conversely, 53% of individuals from Kirk Ness suffered from cribra orbitalia (Henderson unpublished), indicating a high pathogen load or that individuals there had a poor diet resulting in iron deficiency anemia. North Berwick, where Kirk Ness is located, was a larger burgh in medieval Scotland and the high population density could have influenced the spread of pathogens. Overall it appears that although living in an urban environment influenced the prevalence of infectious and metabolic disease, having a higher status shielded individuals from these diseases regardless of the type of environment in which they lived. Anomalous to this pattern is St Mary's Church, Kirkhill, a low status cemetery with low metabolic disease. There could be multiple reasons for this result. Individuals could have died before the skeletal lesions formed, there could be differential recording methods, or another factor is complicating the correlation of status and metabolic disease. Kinnoull Street is also anomalous since it is a high status location with high rates of metabolic disease. Similarly, recording methods could be influencing these results or another complicating factor that remains unknown.

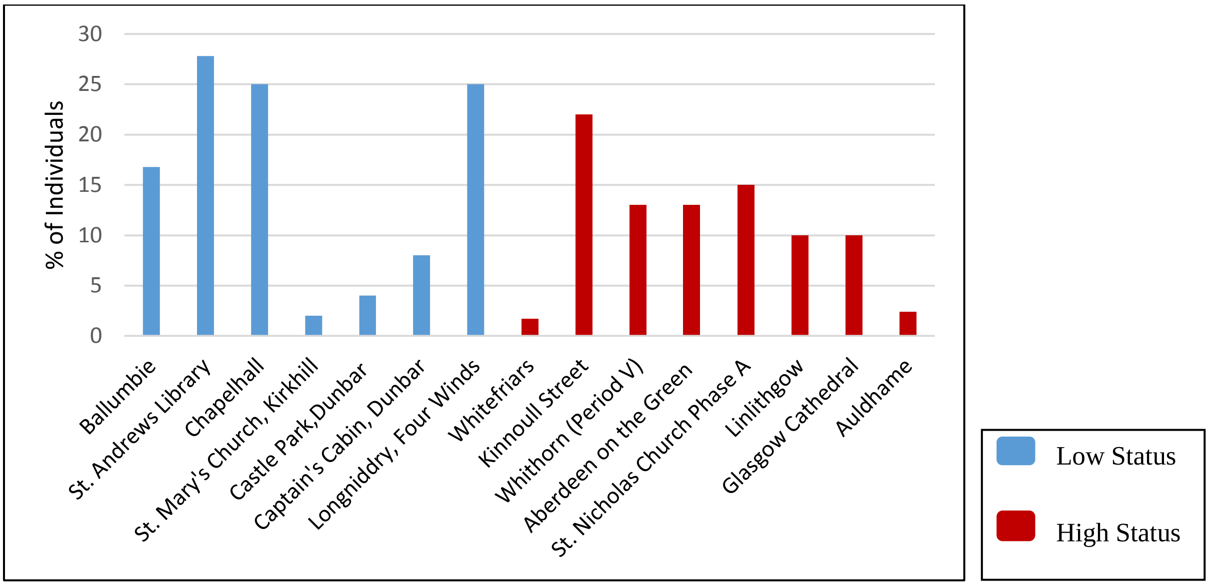

Figure 119 Prevalence rates of metabolic disease in compiled low and high status populations

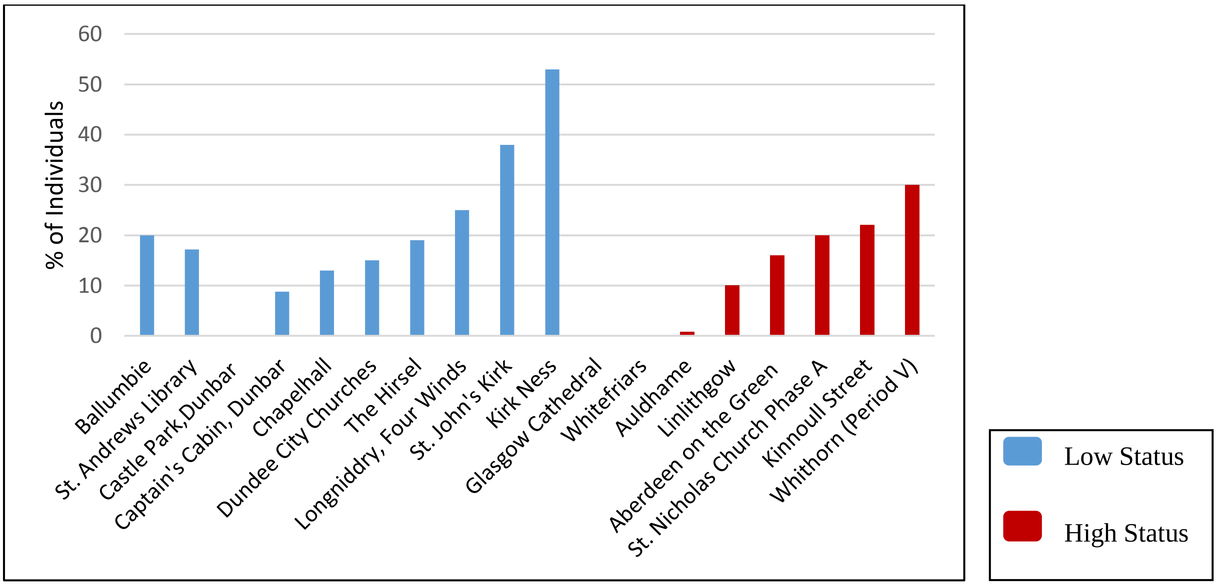

Figure 120 Prevalence rates of cribra orbitalia in compiled low and high status populations

Age at death comparisons and overall life expectancies can also help interpret status. There are twice as many deaths around birth (0-2 months) in low status populations than in high status ones (Figure 121). This is likely related to more hygienic houses but having an increased access to health care for high status individuals is likely a factor as well. There are also more deaths in the two month-two year age category in low status populations. Surprisingly, there are more individuals dying within the 25-34 age range in the high status cemeteries. Whether this means that the lower status communities were healthier or that more individuals in that age range preferred to be buried in monastic or high status cemeteries is impossible to determine. The slightly higher percentages of individuals buried within the low status cemeteries from 35 years and older suggests higher status individuals survived later in life.

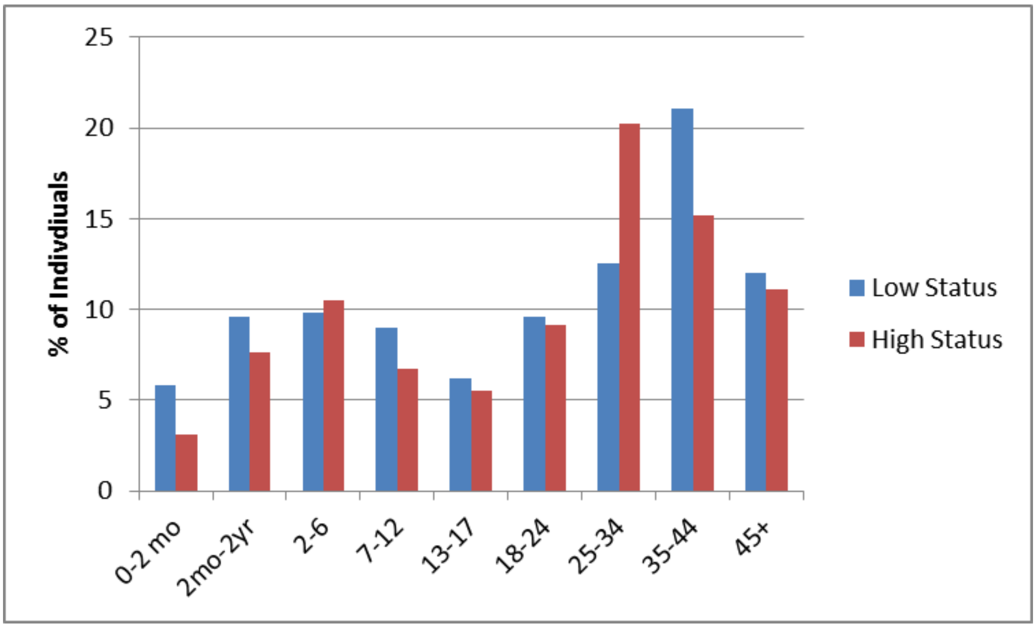

Figure 121 Age at death comparisons for compiled high status and low status sites, n=613

The connection between life expectancy and status was evaluated at Ballumbie. The seven individuals that were buried within a laird's aisle along with those buried inside the church were considered 'high status' while those buried in the churchyard were considered 'low status'. 24% of the higher status individuals lived into older adulthood, whereas only 12% of the lower status individuals did, suggesting the higher status individuals enjoyed better living conditions or an improved diet.

Individuals at Glasgow Cathedral also benefited from their high status since they outlived contemporaries (King 2002). The majority of individuals buried at Glasgow Cathedral survived into old adulthood (Appendix 13). King (2002) argues that the individuals buried at Glasgow Cathedral were not exposed to hardships of life experience. Females survived past reproductive years, a time when females tended to die in lowland medieval Scotland (section 5.1.1), indicating the living conditions for those buried at Glasgow Cathedral were superior to most. As mentioned, the individuals buried there also suffered from less infectious disease, metabolic disease, cribra orbitalia, and enjoyed fewer vitamin deficiencies (King 2002).

5.2.3 Diet

5.2.3.1 Protein eaten

Section 5.2.2 discussed that higher status individuals suffered from statistically less infectious disease which was related to more hygienic living environments. Another related factor is improved nutrition; with more fish and meat in their diet, the immune systems of high status individuals would have benefited (Woolgar et al. 2006). To determine how much and the types of protein that was ingested in high status and low status populations, stable isotope analyses were conducted.

As previously mentioned, in stable isotope analysis, the ratios of ^{13}C to ^{12}C (expressed as $\delta^{13}C$) and ^{15}N to ^{14}N (expressed as $\delta^{15}N$) can be useful in determining the diet of an individual (section 3.1.9). $\delta^{13}C$ and $\delta^{15}N$ measures where the main protein ingested by that individual came from, either from terrestrial, freshwater, or marine resources. Table 123 lists the stable isotope results for Ballumbie, St Andrews, and the Isle of May. The percentage of marine protein for these three populations were calculated and presented previously (Figures 107 and 108). Figure 122 compares the $\delta^{13}C$ and $\delta^{15}N$ values for the study populations with four other medieval populations: Auldhame from East Lothian (Lamb et al. 2012) and St Giles, Towton and Warrington from Northern England (Müldner and Richards 2005).

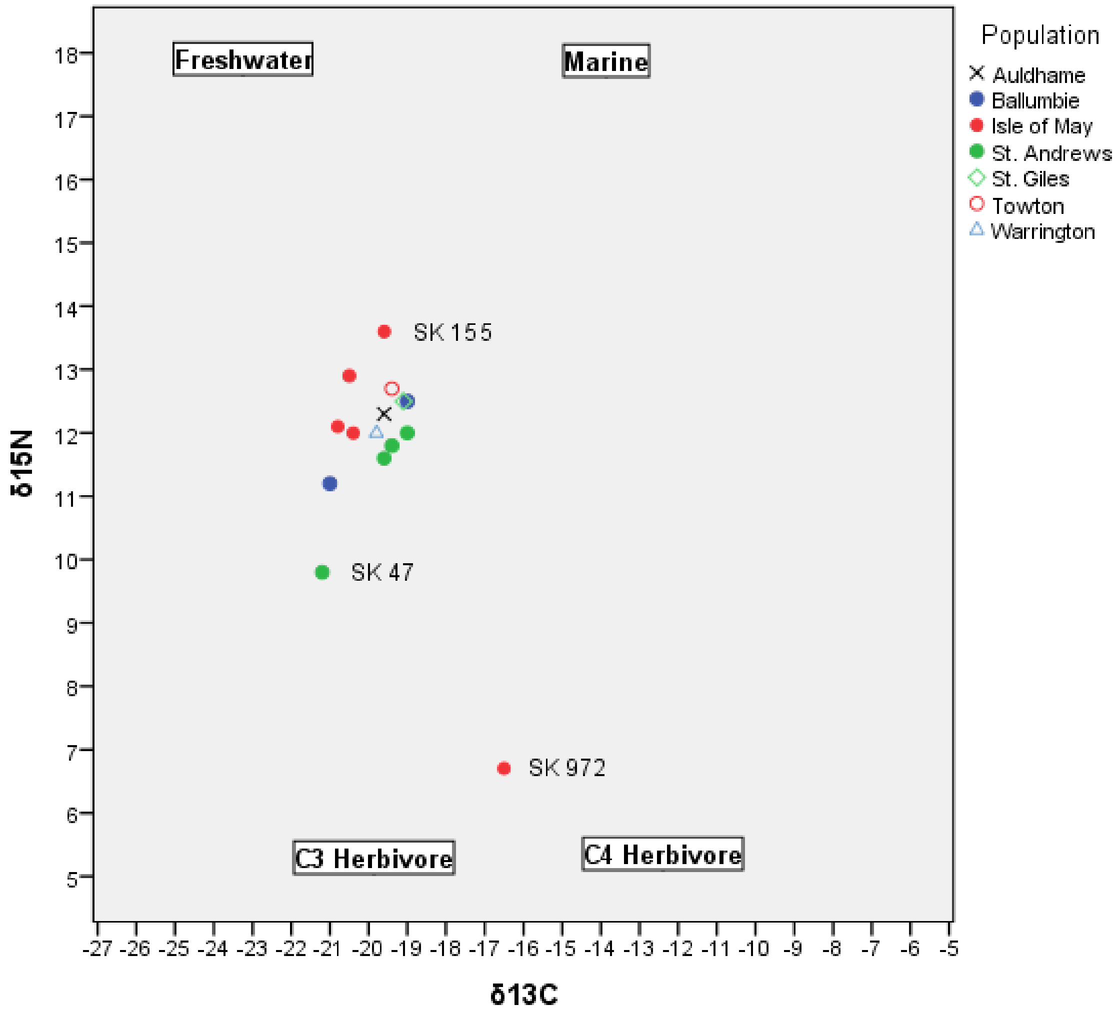

Figure 122 $\delta^{13}C$ plotted against $\delta^{15}N$ from bone collagen from individuals at Ballumbie, St Andrews, and Isle of May.

Data from Auldhame, East Lothian are from Lamb et al. (2012). Data from St Giles, Towton, and Warrington are from Müldner and Richards (2005).

The $\delta^{13}C$ and $\delta^{15}N$ values for Ballumbie suggest these individuals had similar diets, predominately terrestrial protein with a smaller component of marine resources (Schoeninger 1995). However, the values suggest a further distinction. There are two groupings at Ballumbie (Figure 123): individuals with 5-16% marine resources in their diet (Group 1), and individuals with 21-29% marine resources in their diet (Group 2).

According to the lighter $\delta^{13}C$ values skeletons 092, 153, 207, 279, 501, 682, and 747 ate less marine resources, constituting around 5-16% of their diet (Table 123). Conversely, skeletons 467, 512, 630, 725, and 832 ate diets with a slightly larger marine component (between 21-29%); however their diet was still mainly terrestrial protein. An independent-samples t-test was conducted to compare the percentage of marine resources between these two groups. There was a significant difference between Group 1 (M= 10.80, SD= 4.39) and Group 2 (M=25.74, SD=2.98; t(10)=-6.556, p=.000). These results suggest that the individuals in Group 1 ate less marine resources than those in Group 2. All of the Ballumbie diets corroborate what is known about the medieval diet, one that abstains from meat on Fridays or religious holidays and instead eats fish on these days. However, why are there two groups of individuals? Are the individuals in the different marine protein groups from different social classes or is there another reason for this division? Eighty percent of the individuals with the higher percentage of marine resources in their diet (Group 2) are buried in higher status locations such as inside the church or in the 'laird's aisle', which suggests the groupings are based on social status. Another explanation for the differing marine percentages could be an indication of inclusion of freshwater protein, since shellfish such as mussels and oysters can mimic terrestrial values (Cook et al. 2001). Diets can also change at a site over time; however in this case individuals from the different marine protein groups overlap in date, so chronology should not be included as a possible explanation.

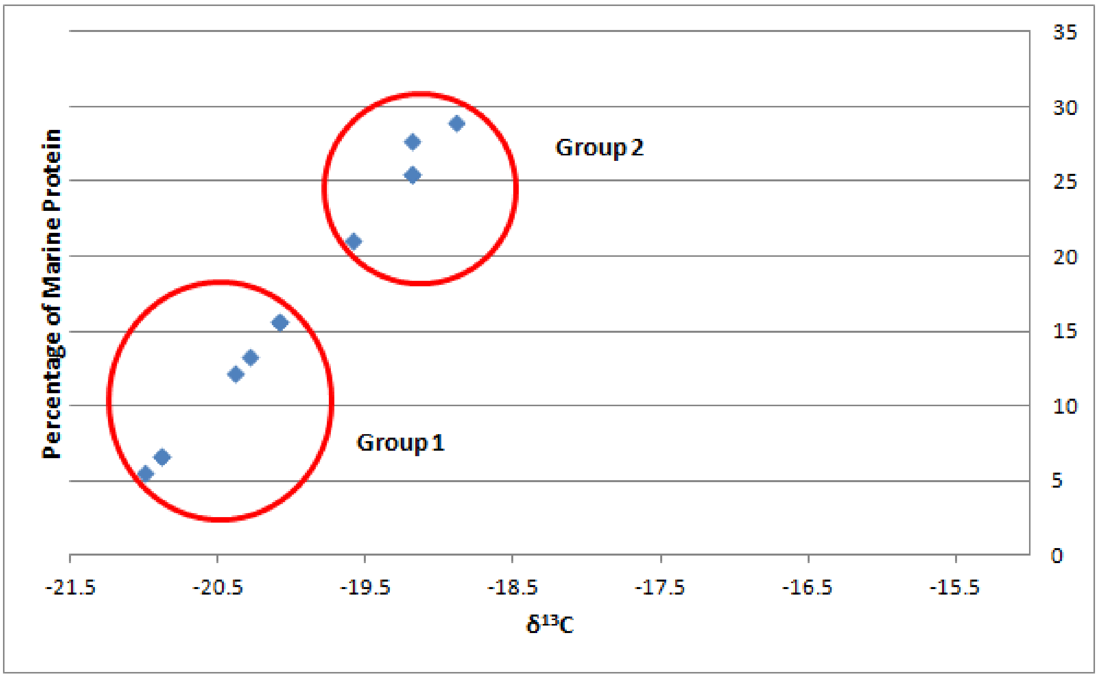

Figure 123 Percentage of marine protein at Ballumbie showing two groupings

From historical and archaeological evidence we know the diets of urban and rural poorer people in the Middle Ages were very similar (Ewan 1990), dominated by the use of oats, barley, and rye to make both bread and ale (Ewan 2011, Yeoman 1995). Occasionally, cheese, butter, and eggs were also eaten. On most days, the majority of poorer individuals in lowland medieval Scotland were vegetarian; however, fish and shellfish supplemented their diet. Beans, nuts, mushrooms, and peas grown in the gardens were also common, along with fruit, such as apples and berries, grown in both urban and rural gardens (Stevens 2003).

Although the diet for the urban and rural poor was very similar, the diet of the wealthy, including those at religious institutions, did differ in many ways. For the wealthy, diverse foods could be purchased. Fenton (2007) shares an example of the diversity of food enjoyed by the wealthy in 1529, when James V and his mother visited John Stewart, the 2nd Duke of Albany, for a hunt in the forest of Atholl:

> The drinks included ale, beer, wine both white and claret, malvery, muskadel, Hippocras, and aquavitae. To eat there was wheat bread, main-bread and ginge-bread, with fleshes, beef, mutton, lamb, veal, venison, goose, grice, capon, coney, cran, swan, partridge, plover, duck, drake, brussel-cock and prawnies, black-cock and muir-fowl, cappercailles. Fish were placed in the moat to be available for dining on as well including 'salmonds, trouts, pearches, pikes, [and] eels', (Fenton 2007:38).

This account offers an example of the provision on offer to those of great wealth, and the majority of even the wealthiest did not dine on such a diverse group of foods. Largely, the wealthy diet more commonly differed from the diet of the general population by a greater consumption of fresh meat. Wealthy individuals could afford to have meat more often in their diet, and could afford the better cuts. The poor often could only afford tripe or haggis (Ewan 2011).

Different types of meat were also status symbols. The general population ate beef, but the elite could also afford venison, pork, rabbit, and poultry (Fenton 1987). In rural areas sheep were kept for their wool; most people could not afford to kill their sheep until they could no longer produce their main product (Sykes 2006). Cattle were kept for their hides, and meat was sold or used to pay rent, rather than being eaten (Gies 2005). However, the elite did not have these economic restrictions, and it became a status symbol to eat young animals such as lambs and suckling pigs (Fenton 2007, Sykes 2006). For poor individuals any meat that was eaten was often not fresh, but smoked or preserved, as was most fish. For both the elite and the poor, meat was avoided on religious holidays and Fridays, and poultry fish or other seafood was consumed instead (Fenton 2007). Archaeological and isotopic evidence demonstrates that fish was a significant component of the medieval diet, a trend that drastically changed in post-Reformation Britain (Serjeantson and Woolgar 2006). According to archaeological evidence, the animal eaten most often was cattle, followed by sheep, then pig, goat, horse, and deer. Domestic chickens and geese were eaten as well (Yeoman 1995). Sheep and goats milk were used to produce cheese and butter whereas cow's milk was only used for raising calves (Yeoman 1995).

Along with the greater amount and variety of meat in their diet, the elite also dined on imported luxuries, such as figs, walnuts, grapes, exotic spices, and wine (Ewan 2011, Fenton 2007, Yeoman 1995). Wheat was more expensive than oats or barley because it did not grow as easily in Scotland, therefore, it was mostly restricted to the upper classes (Yeoman 1995). Another main difference in the diet of the elite versus the poor is the amount of vegetables eaten. Vegetables were seen by the elite as a peasant food and generally avoided. For example, at a royal feast in 1590 for James VI and Anne of Denmark the dishes were almost entirely of flesh, with no fruits or vegetables (Fenton 2007). Geddes (1994) argues this was the fashion until at least the seventeenth century where fresh beef and wheaten bread were upper-class foods, and fruits and vegetables were little regarded. The poor sustained themselves by the food produced in their gardens, including kale, cabbage, turnips, swedes, and peas (Ewan 1990 and 2011, Fenton 1987, Stevens 2003). Despite this, even the amount of vegetables eaten by poor individuals in the Middle Ages was still likely insufficient, relative to modern health standards (Dyer 2006). In fact, Gies (2005) claims medieval diets were often lacking in protein, lipids, calcium, and vitamins A, C, and D. However, as mentioned in section 5.1.2 there is no indication from this research of insufficient vitamin C or D in the lowland medieval diet.

At St Andrews Library skeletons 28, 69, and 75 have similar diets to the Ballumbie individuals with the slightly larger proportion of marine components (Table 123; Figure 122); here the marine protein ranges between 21-28% of the diet. The larger marine protein intake in the majority of individuals at St Andrews Library is consistent with their coastal location. However, St Andrews SK 47, a middle adult male, has unique $\delta^{13}C$ and $\delta^{15}N$ values that suggest a diet that was solely terrestrial with very little or no marine resources in their diet (Figure 122). In the absence of associated faunal remains it is impossible to definitively state how much meat was in his diet; however there is unlikely to have been a significant component of aquatic resources in the diet. This would have been a very unusual diet for individuals that lived in medieval Scotland. Perhaps the abstinence from meat and fish was a choice. Several monastic orders abstained from eating meat, but generally fish was acceptable. Did this individual follow Christianity's fasting rules, which required no meat on Fridays? Or perhaps this male just did not like the taste of fish or shellfish.

At the Isle of May, $\delta^{13}C$ and $\delta^{15}N$ values from contexts 997, 814, and 859 all imply mostly terrestrial diets with small marine components of between 8-12% (Table 123; Figure 122). These correspond to the amounts of marine resources eaten in the lower status group within the Ballumbie population (Group 1). This diet with small amounts of marine protein is surprising since the Isle of May was a monastic site and is coastal. There was an expectation of higher marine resources in their diets, similar to that found at St Andrews Library. Perhaps these results suggest the individuals that were buried there were pilgrims that possessed a lower status, or that they originated from a non-coastal location. Another possibility is that the monks living there did not abstain from meat on fast days. SK 155, a male between the ages of 20-25. This male had heavier $\delta^{13}C$ and $\delta^{15}N$ values suggesting a diet with a higher percentage of marine protein, consisting of around 21% of his diet. The percentage of aquatic resources can also be calculated from $\delta^{15}N$ values (Cook et al. 2001). Based on the enriched $\delta^{15}N$ value for SK 155, aquatic resources could have consisted up to 52% of his diet. Perhaps he enjoyed a higher social status than the others, suggested by his carbon and nitrogen values.

It is likely that SK 155 was a pilgrim since he was buried with a scallop shell in his mouth, associating him with the way of St James where the scallop shells were given to pilgrims at the shrine in Santiago de Compostela in Galicia, Spain (Clyne 1990) (Clyne 1990, Cramp 1980, Hildburgh 1942). Natural scallop shells were sold in booths near the cathedral at Compostela and pilgrims brought the shells back with them as mementos and were eventually buried with them (Clyne 1990). Two scallop shells were found in association with two different burials at St Mary's Cathedral, Tuam in Galway. In these cases the shells were perforated, thought to have been attached to a bag (Clyne 1990). There was also an individual buried with a scallop shell at The Hirsel (Cramp 1980) as well as Perth High Street (Perry et al. 2010) in Scotland. Similarly, a pilgrim's burial with a scallop shell was also found at the medieval hospital cemetery of St Mary Magdalen in Winchester, England (Roffey and Tucker 2012). SK 155 was a male, probably between 20-25 years old, based on epiphyseal fusion. He suffered from a childhood illness or poor nutrition since he had healed cribra orbitalia, healed porotic hyperostosis, and linear enamel hypoplasia on 28 out of 30 teeth present. SK 155 was buried under the high altar of the chapel, an area usually reserved for the more important individuals. His burial location, his higher status diet, and the inclusion of a scallop shell all indicate he enjoyed a high status among his community at the time of his death.

Müldner and Richards (2007) analyzed skeletal remains from Fishergate, a late medieval priory, and found no difference in the carbon and nitrogen levels between different groups (monks and benefactors). Their interpretation is that the diet of the monastic community was no different to that of the high status individuals in the community (Müldner and Richards 2007). High status individuals were also able to afford to be buried within the religious house (Tarlow and Stutz 2013). The authors did find that there were more males of the lay community buried in high status locations and that those males also ate more marine foods than females (Müldner and Richards 2007). Eating fresh fish was a mark of status, many elite dishes included salmon cooked in expensive spices (Woolgar 2016). A license was also required to fish, making it prohibitive for some. Fresh fish was held in such esteem during the medieval period that fishermen often made it as an offering to monasteries (Woolgar 2016). Conversely, preserved fish and shellfish were often viewed as food for the poor (Woolgar 2016).

Similar results were found at Whithorn, a monastic cemetery where the bishops of the community have been identified. Muldner et al. (2009) conducted stable isotope analyses on clergymen and high status lay benefactors and compared them to lower status individuals. The diet of the bishops contained more marine resources than the lay community; a higher marine component is suggested by the authors to correspond with a higher status (Lowe 2009, Müldner et al. 2009). Surprisingly, opposite results were discovered at Portmahomack. While there was still a change in diet between the monastic and lay individuals,

> $\delta^{13}C$ and $\delta^{15}N$ values from the monastic groups (phases 1-3) suggest a diet consisting of C_3-based terrestrial foods, including a significant proportion of animal protein but no marine protein. In contrast to their predecessors, the late medieval lay community (phase 4) had higher $\delta^{13}C$ and $\delta^{15}N$ values, suggesting both terrestrial and marine protein was consumed (Shirley Curtis-Summers, pers.comm.).

It appears there is cultural variation in what was considered the diet of high status at different sites in Scotland. Higher status diets at Whithorn and Ballumbie were indicated by more marine resources, whereas at Portmahomack it was denoted by more meat and less marine resources. Portmahomack was an earlier medieval monastery, dating to the sixth century, so the isotopic results may be showing changes to the monastic diet from early to later established monasteries.

The earlier monastic diet was based on the Rule of St Benedict of Nursia (c.480-c.550), which was similar to a Mediterranean diet (Woolgar 2016). As mentioned in section 2.4.1, the early Carmelites led an ascetic life, abstaining from meat on most days (Andrews 2006). As part of this ‘earlier monastic diet,’ the main meal would have two cooked dishes made of cereals and vegetables, occasionally with the addition of eggs and fish. A third dish was of fresh fruit or vegetables along with a loaf of bread and drink. By the end of the twelfth century additional dishes (called pittances) were added including meaty dishes made with offal, but not the actual flesh of the meat (Woolgar 2016). Birds were not usually considered meat, but more similar to fish since they both appeared on the fifth day of Creation. Each feast day was a celebration and additional dishes were added. In the monastery of

Bury St Edmunds in the mid twelfth century there were 35 occasions where pittances were expected (Woolgar 2016).

In between the feast days were days of abstinence where the original diet based on the Rule St Benedict was eaten and meat was prohibited. By the thirteenth century meat from quadrupeds was avoided on Wednesdays, Fridays, and Saturdays and during Lent it extended to eggs and dairy products (Woolgar 2016). Other days of abstinence included Advent, saints' days or days preceding a feast day. Fish could be eaten on abstinence days, but only by those who could afford it. Each order also observed different rules for meals; however generally the meat of quadrupeds were prohibited to all except the sick (Woolgar 2000). After 1336, Pope Benedict XII relaxed the rules on eating meat, however it could only be eaten in certain locations, and at least half of the monks on that day should eat regular food (without meat) (Woolgar 2016). At this this point, monks consumed cheese and fruit regularly.

Around 1300 AD in an elite lay household in England meat would be avoided up to half of the days of the year (Woolgar 2016). A religious household, and religious institutions, might avoid meat for a further two or more months. Most Christian, lay households would avoid meat on Fridays and Lent, but provisions were made for the sick, young, elderly, pregnant women, pilgrims, and those that had heavy manual labor. The ideas of the seven deadly sins and their role in damaging the soul, in particular of lust and gluttony, were deeply believed by most, inspired their eating practices (Woolgar 2016). Though, there was a degree of variation in practice, as some people would only avoid meat for one meal on abstinence days, while others would abstain from meat, eggs, and cheese.

Later in the medieval period the monastic orders started to relax their dietary restrictions: offal was no longer considered meat and salted or pre-cooked meat could be eaten (Sykes 2006). Sykes (2006) describes that by the thirteenth century, fetal animals were classified as fish because of the 'watery' environment of the uterus. These later medieval monastic orders, such as the Augustinians, enjoyed an elite lifestyle, benefiting from lands endowed to the monasteries (Woolgar 2006). Their diets were similar to, or even more extravagant than, that of the wealthy townspeople (Rogers and Waldron 2001), as has been demonstrated by isotopic evidence at Whithorn, Fishergate, and this research (Lowe 2007, Müldner et al. 2009, Müldner and Richards 2007).

The wealthier monasteries, such as Westminster Abbey, had more extravagant dishes, however this would not have been the case for every monastery. Westminster Abbey, had a daily allowance on non-fast days of 6,200 calories (Harvey 1995). Although Westminster was an English monastery, the more wealthy Scottish monasteries could have had similar diets, but perhaps not quite on the same scale. Even though flesh was prohibited on Wednesdays, Fridays, and Saturdays at Westminster, the diet of the monks, according to their records, included fish, capons, chicken, ducks, geese, egret, herons, pheasant, partridge, pigeons, quail, teal, and swan (Gasquet 1922). In 1372, the abbot at Westminster Abbey gave a dinner to his tenants at Denham where he served beef, mutton, four small pigs, five ducks, one swan, six geese, six capon, nine fowl, two woodcock, and a milk cream cheese (Gasquet 1922). This would have been accompanied by wine or ale. Within the monastery, the abbot was allotted more and richer dishes, since he would often entertain visitors (Woolgar 2016). More refined loaves of bread were also enjoyed by the abbot. The abbot and his guests enjoyed a separate menu with varied sauces, such as ginger, pepper sauces, and cumin, and were served on the nicest dishes the monastery owned (Woolgar 2016). The level of cleanliness was also ensured for the abbot.

SK 972 at the Isle of May, a 7-9 year old child with tuberculosis, has unusual $\delta^{13}C$ and $\delta^{15}N$ values (section 5.4.2.1). When evaluating the $\delta^{13}C$ value only, it suggests a diet rich in marine protein (56%), however the $\delta^{15}N$ value does not correspond (Figure 122). In a diet rich in marine protein, an enriched $\delta^{15}N$ value is expected (Schoeninger 1995). Katzenberg and Lovell (1999) investigated whether carbon and nitrogen values could be affected by illness. They found that stable isotope values could be affected in pathological bone. They found the bone samples that had pathology had an increase in nitrogen, compared to normal bone from the same individual, due to protein being usurped for tissue maintenance. Conversely, in SK 972 the $\delta^{15}N$ is not elevated, so it seems unlikely the tuberculosis in the bone samples is responsible for the unusually light $\delta^{15}N$ value. The $\delta^{13}C$ in Katzenberg and Lovell's samples (1999) was also affected in the pathological bone samples with an even more negative value. Yet again, it appears unlikely to be the case here since the $\delta^{13}C$ value is heavy. Even if the bone was affected, the $\delta^{13}C$ and $\delta^{15}N$ values would most likely only be affected by one trophic level, which would mean the $\delta^{13}C$ and $\delta^{15}N$ values from ingested protein would still be unusual in Medieval Scotland (Catriona Pickard, pers. comm.).

One possible explanation for the $\delta^{13}C$ and $\delta^{15}N$ values found in SK 972 is the type of plants eaten. As mentioned in section 3.1.9 there are two main types of plants based on the pathway by which they photosynthesize CO_2: C_3 and C_4 plants. These unique $\delta^{13}C$ and $\delta^{15}N$ values suggest a diet consisting of both C_3 and C_4 plants, or animals that consumed them. This is surprising since C_4 plants only grow naturally in warmer climates. Lightfoot et al. (2012) compared three time periods in Croatia (Iron Age, Roman, and early medieval), and found a shift in $\delta^{13}C$ and $\delta^{15}N$ values that they attribute to the addition of millet, a C_4 plant, in the diet. They link the new cultivation of millet to an influence of the Slavic diet and food was a way to create and maintain cultural identity (Lightfoot et al. 2012).

Müldner et al. (2011) examined stable isotope results from Romano-British burials at Driffield Terrace in York and found two of their individuals had similar values to SK 972, also implying a diet of C_3 and C_4 plants. Since C_4 plants were not cultivated in Britain, and the only place where millet was found in antiquity was at military sites in London, they conclude that the two individuals were immigrants. However, at the Isle of May, SK 972 seems to be local to areas near the Isle of May, revealed by strontium and oxygen values (Table 123 and Figure 109). It is possible this child enjoyed a diet of millet or another C_4 plant, even though millet was not yet cultivated in medieval Scotland. Perhaps this special diet was fed to this child specifically because the child was ill, indicating a form of medical treatment (Weber and Fuller 2007; see section 5.4.2.1). Furthermore, a unique imported diet suggests this child and its relations enjoyed a high status. Even with the quicker collagen turnover in children, this child was probably receiving this special diet for a while (Catriona Pickard, pers. comm.). It is unclear how long the child was at the Isle of May while receiving the special diet. It is possible that this child received this special diet from its parents at home, and when the diet, and whatever other treatment the parents gave, failed, the child was brought to the Isle of May for a last chance of a cure. In either of these scenarios it is clear that this individual, who was a sick child with tuberculosis, had an unusual diet compared to the rest of the Isle of May and also the rest of medieval Scotland. The $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values could also potentially indicate SK 972 originated from other areas in much of England or even central Continental Europe (Evans et al. 2012, Bentley and Knipper 2005, Darling 2003, Lykoudis and Argiriou 2007) which could suggest a much lengthier travel to reach the Isle of May.

5.2.3.2 Carious lesions

One of the most obvious skeletal changes related to diet are those associated with dental disease. The presence of dental caries generally indicates a diet of cariogenic foods such as quickly fermentable carbohydrates (Hardwick 1960). Refined sugar is the biggest cause of carious lesions; however sugar was not easily accessible in medieval Scotland since it was first introduced to England in the twelfth century (Hardwick 1960). There is a positive correlation between status and the number of caries per individual ($r=.579$, $p= .030$, $n=14$). The wealthier populations suffered from more caries per individual. This correlation is likely related to differential access to sugars. The high status lay populations as well as the monastic populations both suffered from more carious lesions. This indicates both types of populations had the same access to refined sugars, dried fruits, and other cariogenic foods (Hardwick 1960). As discussed in section 5.2.3.1 other similarities in the monastic and elite diets include the amount and types of protein eaten (Harvey 1995, Rogers and Waldron 2001).

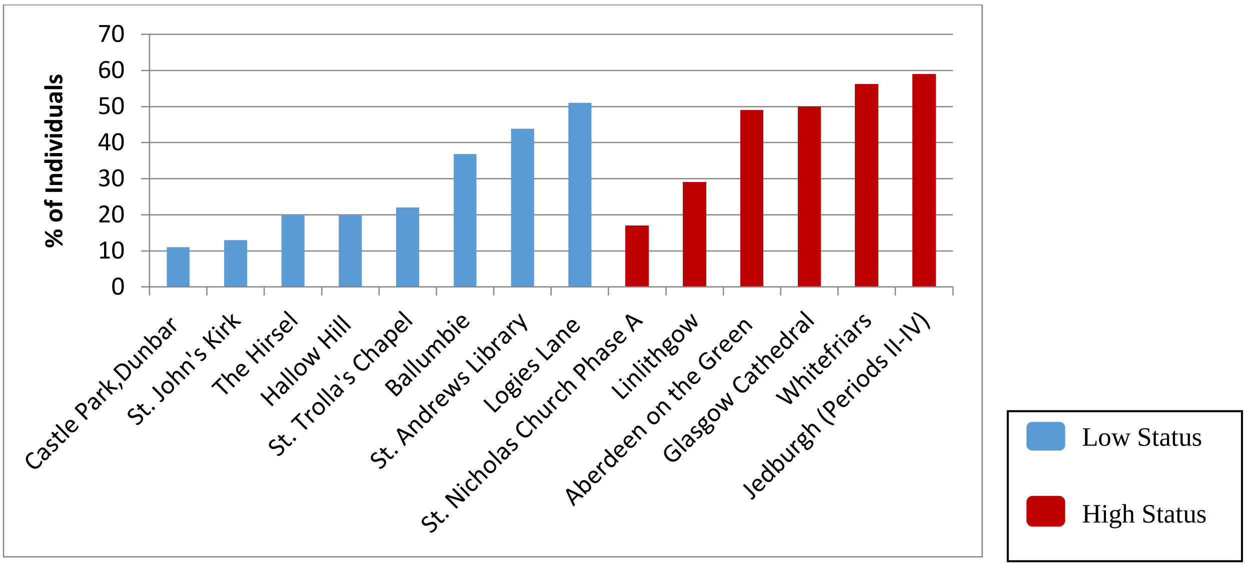

Figure 124 Prevalence of caries per individual in compiled high status and low status populations.

Glasgow Cathedral, a known high status site, has one of the highest prevalence rates of carious lesions (50%) per individual (Figure 124), consistent with a more refined diet (King 2002). The monastic populations of Jedburgh and Whitefriars had the highest prevalence rate of caries (59% and 56%, respectively) both consistent with higher status populations (Grove 1995). Prevalence rates for carious lesions range from 11% (Castle Park) to 59% (Jedburgh), indicating populations had differential accessibility to carbohydrates or refined sugars (Hardwick 1960). This suggests that Whitefriars is a higher status population, whereas Ballumbie and St Andrews Library are lower status. While sugar was first introduced to England in the twelfth century (Hardwick 1960), it could have been more difficult to access it in Scotland until later. Another interpretation of varying rates of caries between populations could be varying dental hygiene practices, such as the use of chewing sticks (Cook et al. 2012). Carious lesions are generally age-related, so if individuals in high status populations have longer life expectancies they would also have more opportunity to develop carious lesions.

As mentioned, refined sugar is the biggest cause of carious lesions; however sugar was not easily accessible in medieval Scotland since it was only first introduced to England in the twelfth century (Hardwick 1960). Dried fruit is also highly cariogenic as is refined flour since it tends to remain around the teeth. Sugar, dried fruit, and refined flour were expensive, mostly consumed by higher classes; therefore the presence of carious lesions in skeletal populations is indicative of status (Ewan 2011, Fenton 2007, Yeoman 1995). In addition, raw foods, mostly consumed by lower classes seem to have a protective factor against the development of carious lesions (Hardwick 1960). More frequent eating can also produce an increase in carious lesions (Thylstrup and Fejerskors 1986). Eating the more luxurious foods such as sugar, dried fruit, and wine, eating less raw foods, as well as more frequent eating all would have contributed to the high prevalence rate of carious lesions in the high status populations.

Males are four times more affected by caries than females at St Andrews Library, which suggests there is differential access to resources at this site, men having more access to carbohydrates or refined sugars. It is worth noting the findings of Walker and Hewlett (1990) albeit in a different location and a different time period. Their oral health survey of African pygmies and Bantu revealed differences in diet, social status, and oral hygiene between the men and women of the groups. The men had fewer carious lesions and less tooth loss than the women. The authors attribute these results to differences in eating habits and access to cariogenic foods between the men and women. In these groups the men go away on hunts and eat meat and nuts where the women stay behind and eat carbohydrates such as fruit, tubers, maize, and rice (Walker and Hewlett 1990).

5.2.3.3 Metabolic disease

As mentioned in section 5.2.3, there is a higher prevalence for metabolic disease in low status populations compared to high status ones (15.5% and 10.8%, respectively). Low status populations also suffered from more cribra orbitalia than the high status populations (20.9% and 14.1%, respectively). While hygienic housing and parasite load influenced these rates, a diet deficient in iron and other vitamins can also cause these conditions (Stuart-Macadam 1989). The higher status populations of Glasgow Cathedral, Whitefriars, and Auldhame have nearly no cases of cribra orbitalia suggesting a better diet as well as lower pathogen (likely from more hygienic housing) were contributing factors (Figure 120). The higher rates of metabolic disease seen in St Andrews (Figure 119) is argued in section 5.1.3.1 to be caused by a higher pathogen load rather than deficiencies in diet, however both are likely contributing factors.

For poorer individuals, the amount of food available was directly tied to the harvests. June and July before the harvest were often hungry months: in Ireland this period was called “the bitter six weeks” (Fenton 2007). Wealthier individuals would not usually feel the changes in the harvest cycle in the quantity of food, except in years of famine, which would have even affected the wealthy, although not as severely. From 1290 to 1325 there were major crises of subsistence, which led to many deaths from starvation (Bartlett 2013). Dyer (2006) argues that poor individuals with no access to gardens were the worst affected by famines. According to today’s standards, the wealthier peasantry would have had the best diet (Woolgar et al. 2006). They would have owned cattle and chickens to supply them with milk, cheese, and eggs, they would have had access to a garden and would have grown fruits and vegetables, and they would have been able to afford fish and meat on occasion. They would not have been able to afford refined sugar, dried fruit, and often ate more raw foods, all contributing to fewer dental caries. However, in times of poor harvest, their diet and health could have been negatively affected. Overall there were few cases of rickets (Vitamin D deficiencies) in the study populations. The rate of rickets is also tied to sun exposure, therefore the higher rates found in St Giles in Edinburgh (13%) and Glasgow Cathedral (8%) where tenement buildings blocked the sun in late medieval Scotland is expected. There were no cases of scurvy (Vitamin C deficiencies) in the study populations and it was also rare in compiled populations, indicating the diet of most individuals in lowland medieval Scotland was sufficient.

As mentioned in section 5.1.2 deficiencies in diet can also lead to linear enamel hypoplasia (LEH), a metabolic condition where normal enamel production is halted in favor of vital functions. LEH can occur in individuals due to trauma or hereditary conditions; however individuals with multiple bands of LEH is typical in systematic metabolic disruptions (Goodman and Rose 1990). Metabolic disturbances can be caused by infections, hormonal changes and malnutrition (Goodman and Armelagos 1985a). Low status populations suffered from more LEH (42%) than the high status populations (34%) suggesting the higher status individuals had a better nutritional status and were less tied to the harvest cycle (Figure 125). Diet is certainly an important factor in health, and it appears the higher status individuals had a higher nutritional status evident from lower rates of metabolic disease, cribra orbitalia, and linear enamel hypoplasia.

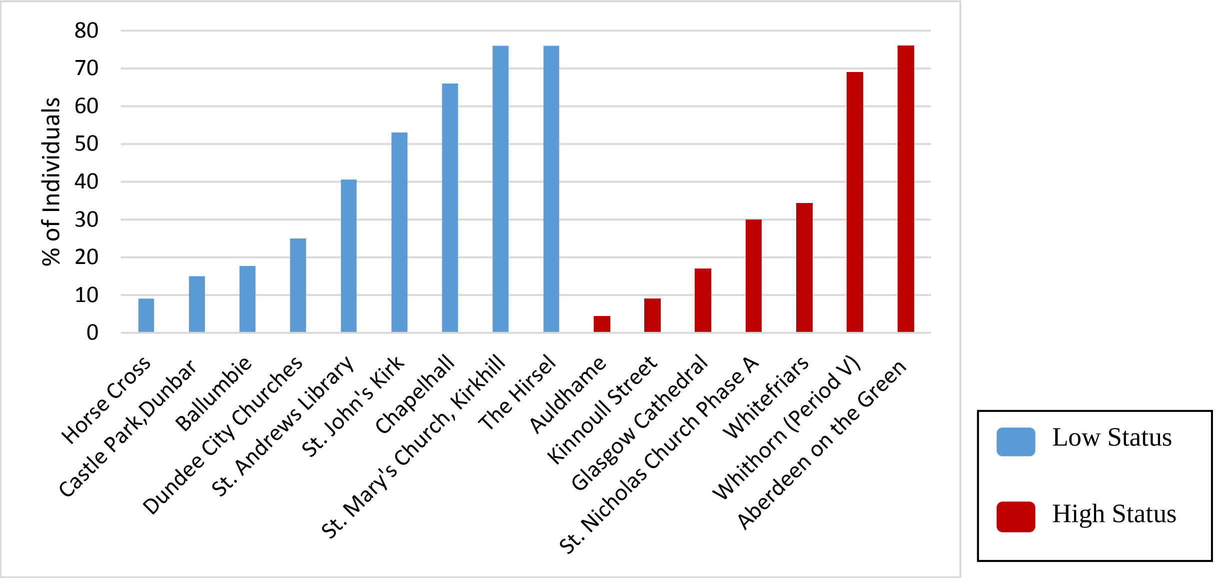

Figure 125 Prevalence of LEH per individual in compiled high status and low status populations

5.2.3.4 DISH and eDISH

Another condition that could be influenced by diet is diffuse idiopathic skeletal hyperostosis or DISH (section 3.1.8.5). DISH has been associated with obesity and type II diabetes (Rogers and Waldron 2001). There are only two possible cases (3.4% of total population) of eDISH in the Isle of May assemblage and one in the St Andrews Library assemblage. DISH is characterized by extensive calcification of ligaments, cartilage, or muscle attachment sites, also known as entheses. In particular, the right side of the thoracic region along the anterior longitudinal ligament tends to ossify in cases of DISH, typically in more than four contiguous vertebrae (Waldron 2009). DISH and the propensity to form bone are correlated with age and sex where men over the age of forty are more likely to suffer from these conditions (Rogers and Waldron 2001). Rogers and Waldron (2001) argue the etiology of DISH is a multisystem hormonal disorder and that obesity and type II diabetes could be contributing factors. The authors found high prevalence rates of

DISH among monastic populations; therefore they suggest that the 'monastic way of life' predisposed individuals to DISH (Rogers and Waldron 2001).

To diagnose a proper case of DISH, four contiguous vertebrae must be fused with candlewax-like exostoses, along with other symptoms (Waldron 2009). While the three cases in the study populations mentioned have some vertebral fusion, none has four contiguously fused vertebrae, and therefore cannot have a secure diagnosis of DISH. However, it is likely that these cases are early onset DISH (or eDISH). A statistically higher percentage of individuals buried at the Isle of May were also 'bone formers' (χ=76.959, p=.000, df=3) (Table 133). Waldron (2009: 72) defines 'bone formers' as those that have

> "a tendency to ossify soft tissues, especially in the entheses, that is the point at which tendons insert into bone, probably in response to minimal repetitive trauma…Bone formers are probably more likely than others to produce heterotopic ossification and to calcify or ossify costal cartilages, thyroid cartilage and other soft tissues."

Waldron (2009) argues that 'bone forming' is associated with type II diabetes, abnormal vitamin A metabolism, high levels of serum uric acid, higher levels of growth hormone and IGF-I serum levels. 'Bone forming,' Waldron (2009) suggests, should be viewed on a scale with DISH at the extreme end.

Table 133 Bone formers in the study populations

			Bone Former		Total
			no	yes	
Population	Ballumbie	Count	189	8	197
		% within Population	95.9%	4.1%	100.0%
	Isle of May	Count	33	25	58
		% within Population	56.1%	43.9%	100.0%
	St Andrew's	Count	61	11	72
		% within Population	84.7%	15.3%	100.0%
	Riggs Road	Count	58	0	58
		% within Population	100.0%	.0%	100.0%
Total		Count	341	44	385
		% within Population	88.5%	11.5%	100.0%

Since 'bone forming' is a pre-curser to DISH, and DISH is associated with conditions related to obesity, the high prevalence of bone forming at the Isle of May appears to indicate a 'monastic way of life' (Rogers and Rogers and Waldron 2001). As mentioned previously (5.2.3.1 and 5.2.3.2), the diet of monks, especially in later monastic orders, was similar to that of the wealthy townspeople (Rogers and Waldron 2001, Woolgar 2016), which was demonstrated by isotopic evidence at Whithorn, and Fishergate and further supported with the high prevalence for carious lesions in this research (Lowe 2007, Müldner et al. 2009, Müldner and Richards 2007). While there was variation, with wealthier monasteries eating more extravagantly, it appears that most late medieval monastic diets were similar to elite diets in amount and types of protein and the amount of cariogenic foods like sugar and carbohydrates. Therefore it seems the rich diet of the monks likely contributed to their rates of obesity, type II diabetes, and also DISH. Higher rates of DISH were seen at the English monastic site of Merton Priory where there are 30 cases, or 4% of total population (WORD 2011). However, Whithorn, a Scottish monastic site, only has three possible cases (0.06%) of eDISH. The high status population of St Nicolas in Aberdeen had a prevalence rate of DISH (3%), suggesting individuals buried there enjoyed an elite diet. Mays (2007) reports the English lay population Wharram

Percy has a percentage of 4% of DISH. In this case, DISH is not related to an elite diet, the author instead suggests it is only due to a genetic predisposition to form bone (Mays 2007). The one case at of eDISH St Andrews Library could be an individual that enjoyed a higher status and therefore richer diet; however he could have also had a genetic predisposition for the condition. 'Bone forming' and its connection with obesity has been a recent discovery (Waldron 2009), therefore early skeletal reports often do not present results or discuss this condition making it difficult for comparative purposes.

5.2.3.5 Stature

Nutritional status can be easily assessed by how tall the males and females are within a population. Section 5.1.3.1 mentions that while heritable traits provide the potential for stature, multiple factors can affect whether the potential is met. At St Andrews, males were shorter than any contemporary males (section 5.1.3.1) indicating stunted growth from either pathogen load or nutritional status. Conversely, males at the Isle of May are on the upper end for height compared with other compiled lowland populations (Table 127). The height for males at the Isle of May could also suggest a higher nutritional status. Of the compiled populations, Glasgow Cathedral have the tallest males, further evidence of their higher nutritional status (King 2002). Schweich and Knüsel (2003) found English monastic populations who enjoyed a higher nutritional status also had an increase in stature.

5.3 Best health status in lowland Medieval Scotland?

Reviewing prevalence of disease Auldhame appears to be one of the healthiest populations in lowland medieval Scotland since they had low rates of infection, metabolic disease, trauma, linear enamel hypoplasia, antemortem tooth loss, and caries by tooth. It is likely that because there was better childhood health (low rates of cribra orbitalia and linear enamel hypoplasia) the resulting adult population was also more robust (Melikian and Ives forthcoming). The rural coastal environment that Auldhame was situated in appears to have contributed to this healthy lifestyle. While lower rates of infectious disease was significantly less in rural environments, rural populations were more affected by metabolic disease, signifying those in rural areas were more susceptible to food shortages in poor harvest years.

Urban environments suffered from more infectious disease due to poor hygienic controls, contaminated waters, and population density. Not only did urban environments have more pathogens, they also had to contend with chemical exposure from industrial activities such as tanning, dyeing and brewing, as seen in cases of Hypertrophic Pulmonary Osteoarthropathy at Horse Cross. Urban populations also had more caries per tooth than the rural populations, though in this case, these rates are related to increased access to refined sugars in the burghs.

Individuals at Auldhame had low rates of infectious disease as well as low rates of metabolic disease, suggesting they not only benefited from low population density in the rural environment but they also were not as affected by the harvest cycle as most rural environments were. Auldhame not only benefited from its rural environment, but it also is considered higher status, since it was once an ecclesiastical settlement. The site of Auldhame was only used as an ecclesiastical settlement for half of its occupation (650-900 AD). However, the status of the majority of those buried there appears to have benefited their health. However, in regards to diet, the isotopic evidence from Auldhame suggests that although there was some ecclesiastical use at the site, the average diet at Auldhame was not a typical high status diet (Lamb et al. 2012). Instead of high percentages of marine protein found in monastic and elite diets from the inclusion of fish on fast days (Lamb et al. 2012), Auldhame individuals ate the amount of protein seen within lower status sites such as Ballumbie (Figure 119). Portmahomack was also an early monastic settlement where the monastic diet had similarly low amounts of protein (Curtis-Summers 2009) (section 5.2.3.1), therefore the isotope results from Auldhame could indicate the earlier monastic diet prior to the relaxation of the Rule.

This complicating picture of status at Auldhame is futher demonstrated with the life expectancy of individuals buried there. Individuals at Auldhame still tended to die between 25-44 years of age, whereas those from the high status population of Glasgow Cathedral died over 45 years of age. So, even though those living in Auldhame appeared ‘healthy,’ they still died earlier, shedding light on the definition of health and the osteological paradox (Wood et al. 1992) (section 1.2.2.3). If dying at older ages is an indicator of 'health,' then those buried at Glasgow Cathedral were healthiest. However, when contextualized with other high status cemeteries, life expectancy appears to be complicated in nature. Individuals that were buried in the other high status cemeteries were not more likely to live into older age, instead the majority died between the ages of 25-44 (Figure 121).

If stature indicates superior health, males at Glasgow Cathedral were taller than all others in lowland medieval Scotland, including Auldhame, again conveying good health at Glasgow Cathedral. Though, as mentioned in section 5.2.1.3, females at Glasgow were of average stature compared to the rest of medieval Scotland, indicating that good health, or good nutrition, was not equal between the sexes. The females within Glasgow Cathedral did survive past reproductive years, so although their stature may have been stunted their longer life span corroborates that having a higher status was the primary factor in health.

While, there were cases of rickets at Glasgow Cathedral, the low rates of other vitamin deficiencies as well as cribra orbitalia suggests the development of rickets was related to low sun exposure rather than vitamin D deficiencies. Significantly lower rates of infectious disease in high status populations is a trend maintained throughout lowland medieval Scotland, including Glasgow Cathedral and Auldhame. Those that enjoyed a higher status during life most likely had more hygienic living conditions in both rural and urban environments, which prevented the spread of pathogens. High status individuals could afford better housing, which had plank or tile floors, had fireplaces instead of hearths, and fewer people living in cramped spaces. This type of housing would have provided better hygienic conditions, resulting in lower rates of infectious diseases.

The nutrition of most high status individuals was better, with more protein in their diet, which helped boost the immune system as well as increase their stature. High status individuals did not feel the effects of a poor harvest, instead their rich diet produced dental caries and some developed obesity or diabetes. The lower rates of metabolic disease in the high status populations further supports their health benefited from their improved housing and more nutritional diet. While access to health care improved in the urban environments, it was likely the high status that also benefited.

High status individuals in medieval Scotland enjoyed lower rates of infectious disease and metabolic disease; however, they were not spared from joint disease, dental disease or trauma. Additionally, they suffered from more carious lesions and eDISH than lower status individuals. So, while their childhood stress was lower, indicated from lower rates of linear enamel hypoplasia, taller stature, and higher life expectancy, they still had some difficulties in life. Overall, it appears that location did affect health, though it was the status they enjoyed in society that had the greatest effect on health.

5.4 Health and Disease at the Isle of May

Complicating the factor of status is pilgrimage, which is why the Isle of May was removed when discussing status above. Most monastic cemeteries have been considered high status in this research due to the more hygienic accommodations as well as an improved diet from lower status individuals. This has been corroborated with historical, isotopic, and archaeological research (sections 5.2.2, 5.2.3.). While some that went on pilgrimage might have been considered higher status (diet and burial location of SK 155), it is usually difficult to discern the status of most pilgrims. As will be discussed in section 5.4.2, many people went on pilgrimage because they were already unhealthy and they were hoping for a cure. These pilgrims may have even infected others along the way, including other pilgrims or those in the locations they visited. In many cemeteries it is impossible to separate which individuals are visiting pilgrims and could therefore make the entire population appear unhealthy in a skeletal study. In the case of the Isle of May, many of individuals buried there were likely pilgrims since few burials were contemporary with the life of the priory (section 2.2.3). The high prevalence for disease corroborates that the Isle of May burials represent sick pilgrims. As mentioned in section 5.2.3.1, SK 155 was buried with a scallop shell in his mouth, indicating he was a pilgrim. Cases of individuals with rare and late stage disease further supports that many of the burials represent visiting pilgrims who perished on their journeys.

5.4.1 Prevalence of disease at the Isle of May

Previous research into the burials at the Isle of May noted that there were many sick individuals; however they suggested statistical tests in future studies to see whether the prevalence rates were significant (James and Yeoman 2008). Therefore, one of the goals for this research was to perform these tests. To test whether the individuals buried at the Isle of May did in fact have statistically more disease than the other study populations, the number of types of pathology each skeleton had during their life was compared. Section 4.6.4 presented rates for each study population in the general categories of pathological conditions: infection, congenital, trauma, metabolic, joint, dental, and miscellaneous. For example, if an individual had joint disease and dental disease, their count is 2. The results found that the majority of the Isle of May population had between two and five diseases during their life (Table 73). Nearly a quarter of individuals at the Isle of May had five or more diseases during their life. The mean number of types of pathology individuals at the Isle of May have is 3.29. In comparison with the study populations, individuals buried at the Isle of May suffered from statistically more pathologies during their life (χ^2=54.724, p=.000, df=3). The unusually high prevalence of disease across all categories, specifically trauma, and infectious, metabolic, and joint diseases, as well as individuals with rare and late-stage diseases further suggests that individuals traveled to the Isle of May for healing purposes (Willows 2015, Willows forthcoming).

While St Andrews boasts the highest prevalence for infectious disease in all compiled populations (discussed in section 5.1.3.1), individuals at the Isle of May also suffered from high rates of infectious disease (49%) (Figure 126). Though in the case of the Isle of May the high rate is related to sick individuals that traveled to the Isle of May rather than the pathogen load found there. Compared to the compiled populations, the Isle of May also had one of the highest rates of congenital disease (Figure 127). The Isle of May has a higher prevalence of metabolic disease including cribra orbitalia, porotic hyperostosis, and osteopenia compared to all compiled populations (Figure 128). The difference in the amount of metabolic disease between the four study populations is statistically significant (χ^2=30.134, p=.000, df=3). The individuals buried at the Isle of May also had significantly more joint disease (χ^2=59.041, p=.000, df=3) than the study populations. The prevalence rate of joint disease is higher at the Isle of May (81%) than any other compiled population (Figure 129).

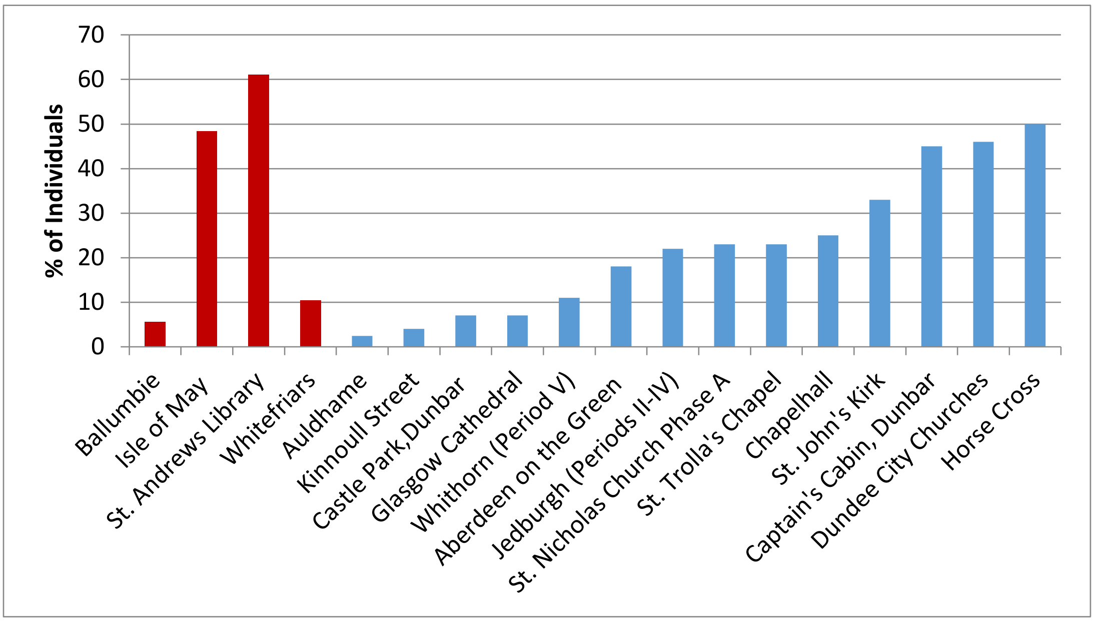

Figure 126 Prevalence rates of infection in lowland medieval Scotland.
Study populations are in red.

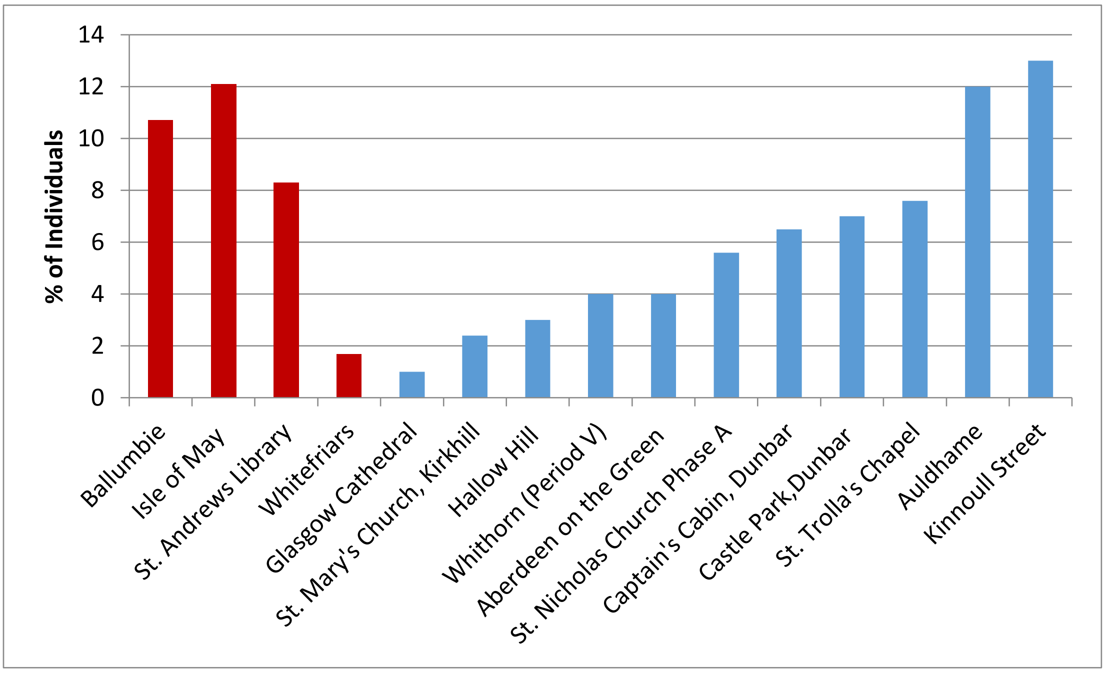

Figure 127 Prevalence rates for congenital disorders in lowland medieval Scotland.

Study populations are in red.

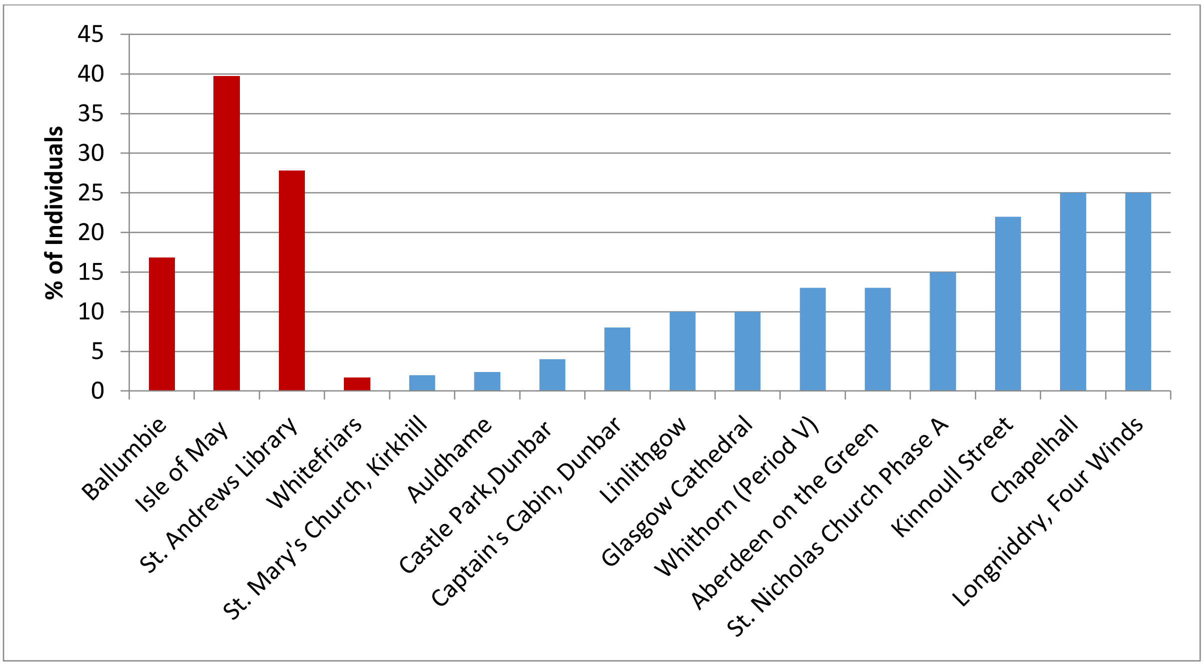

Figure 128 Prevalence rates of metabolic disease in lowland medieval Scotland

Study populations are in red**.**

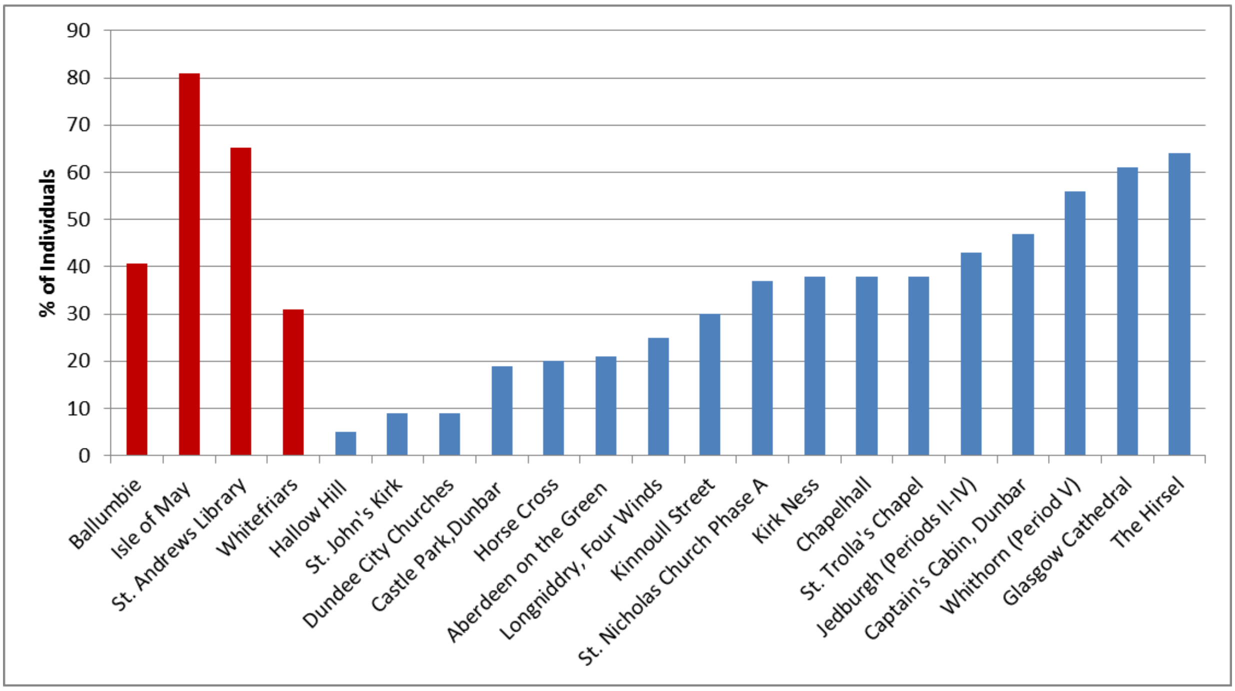

Figure 129 Prevalence rates for joint disease in medieval Scotland

Study populations are in red.

The prevalence rate of trauma at the Isle of May is striking (38%) (Figure 130), it is statistically higher than the other study populations (χ^2=28.577, p=.000, df=3). This rate is also higher than any other compiled population. Were individuals prone to more traumas at the Isle of May, or were individuals with trauma traveling to the Isle of May? Many of these injuries included healed fractures as well as compression fractures of the vertebrae. Compression fractures of the vertebrae are common in the archaeological record and tend to be caused by accidental falls (Ortner 2003). Age related bone loss or osteoporosis also increases the risk of compression fractures to the vertebrae (Roberts and Manchester 2007).

Osteochondritis dissecans is an osteochondral fracture and can be caused by direct trauma or repetitive microtrauma (Waldron 2007) (section 3.1.8.3). The condition occurs more often in younger athletic males (Waldron 2007). The Isle of May, again, has a statistically higher prevalence of osteochondritis dissecans (15.5%) (χ^2=25.094, p=.000, df=3). The condition is not present only in younger individuals at the Isle of May: four middle adult individuals were also affected. The reason for such high rates of this condition could possibly be caused by microtrauma from long pilgrimages. In fact, the high rate of all traumatic lesions at the Isle of May is likely related to the pilgrimage nature of the site, people with traumatic lesions could have been traveling to the island for healing, also pilgrims that were traveling could have injured themselves along their route. Another explanation is that since the age profile Isle of May demonstrated many older males, the traumatic lesions could have been age-related and not necessarily a by-product of pilgrimage.

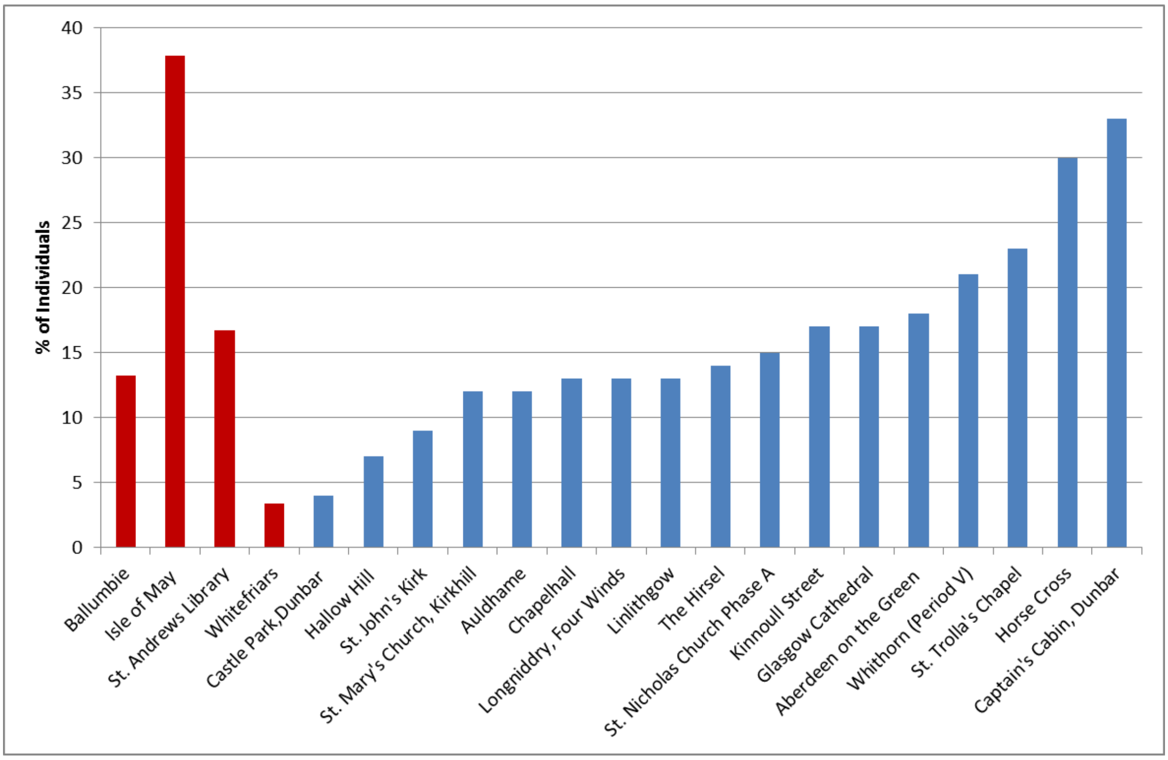

Figure 130 Prevalence rates for trauma in lowland medieval Scotland

Study populations are in red.

5.4.2 Pilgrimage and treatment of the sick

A pilgrimage is a journey with a religious purpose. Visiting one's parish church generally did not count as a pilgrimage, the term is only applied when some distance is involved (Bartlett 2013). There was no minimum distance travelled for it to be considered a pilgrimage, however. The distance traveled often related to how grave the sin to be purged was (Bartlett 2013). Major offences could result in distances of more than 500 miles away from their home (Bartlett 2013).

There were perpetual pilgrims, who left their homes for good and traveled around to foreign lands visiting shrines. In fact, goal-less wandering was a common feature of early medieval Irish religious life. Most pilgrimages occurred in the spring and summer when the weather was more accommodating. Originally there was no distinction between a pilgrim and crusader, crusaders were just armed pilgrims (Bartlett 2013). A distinction was made with the name 'palmer' from the twelfth century onwards for a pilgrim that visited the Holy Land and received a memorial palm there. The term 'palmer' then became synonymous with 'pilgrim'. A 'Rome-farer' or 'Rome-seeker' was used to describe those that had traveled or was on their way to Rome. A pilgrim on their way to Santiago was called a 'James-seeker', since St James's remains are thought to be buried there (Bartlett 2013). The three most prominent places to travel to during the medieval period were the Holy Land, Santiago, and Rome (Bartlett 2013). People traveled to the Holy Land for the burial and birthplace of Jesus, Santiago for the burial of St James, and Rome for the burial of the apostles Paul and Peter, and other notable saints.

The earliest recorded pilgrimage to Santiago was in 950 AD and the current cathedral was constructed in 1075 AD (Bartlett 2013). In the fourteenth century more than 300 English pilgrims visited Santiago (Bartlett 2013). Pilgrimage became formalized with its own distinctive garb and paraphernalia, like the shoulder bag and staff, so pilgrims could be identified. Pilgrims had a special status and there were specific privileges and protections they could enjoy. Badges or tokens were often purchased near the shrines as souvenirs of their journey and perhaps act as a talisman (Bartlett 2013). Each shrine usually had its own symbol or badge, for Rome it was crossed keys and for Santiago it was a scallop shell. The earlier souvenirs at Santiago were actual scallop shells, however in the twelfth century more of the souvenirs were made from metal with a symbol emblazoned on it.

In fact, as discussed previously (section 5.2.3.1), SK 155, a male between 20-25 years of age, was buried with a scallop shell (*Pecten maximus*) in his mouth (James and Yeoman 2008). Since his strontium and oxygen values are consistent with the Eastern part of Scotland it is likely he was originally from Eastern Scotland, left on pilgrimage to Santiago de Compostela, and then returned to the Isle of May after his journey (Willows 2015). This individual had healed cribra orbitalia, porotic hyperostosis, and hypoplasia on almost all of his teeth signaling an illness while he was a child (Lewis 2007). He also had osteoarthritis, Schmorl's nodes on almost all of his thoracic vertebrae, and compression fractures on three lumbar vertebrae. Schmorl's nodes are related to an athletic lifestyle where extra stress is placed on the lower spine and sufferers can have severe and progressive back pain (Peng et al. 2003) (section 3.1.8.5). The osteoarthritis and Schmorl's nodes are consistent with a more active lifestyle, one a pilgrim's journey could produce, as indicated in skeletons of other pilgrims (Clyne 1990). However, his compression fractures are indicative of a trauma such as a fall, and the Schmorl's nodes could be related to the compression fractures. Whether or not he suffered this trauma during his pilgrimage is not possible to determine, but if he did, it is likely he would have been in pain during his long journey.

Pilgrimage could be traumatic and dangerous, many drew up wills prior to their journeys (Bartlett 2013). Pilgrims often stayed at monasteries; however from the eleventh century onwards hospitals and hostels were erected to house the increasing number of pilgrims. The hostels and hospitals also provided burials for pilgrims if they died there. A cemetery on route to Santiago was built in 1168 solely for pilgrims (Bartlett 2013). It is less surprising, then, to have a cemetery at the Isle of May in which many of the burials are pilgrims that perished during or at the end of their journey.

Pilgrims had various motives for their journeys, though most pilgrims had religious intentions. A law code from France distinguished three types of pilgrimage: some were voluntary, some were as a consequence from a vow, and others were out of penance (Bartlett 2013). Ronald Finucane researched the miracle records of many British shrines and found the reasons for visiting shrines varied between pilgrims: shrines were visited to express piety, to carry out a penance, to receive an indulgence, to collect free alms from monasteries, to have a holiday from work, to ask a favor from the saints, or to thank them for favors received, but by and large people went to shrines to be cured of physical or mental conditions (Finucane 1995). Robert Bartlett (2003, 2013) reviewed miracle records of the Scottish shrines St Aebbe of Coldingham and St Margaret of Scotland and also found seeking a miraculous cure was one of the best documented aspects of the cult of the saints.

Disease in the middle ages was often associated with sin; repentance and prayer were required for healing (Daniell 1997, Durkan 1962, Hamilton 2003). Pilgrimage to the shrines of saints to repent for sins was seen as normal part of healing and maintaining health (Oram 2011). Touching or just being near the relics of saints had the power to cure (Finucane 1995).

Finucane's review of the miracle records claim the causes of illness and death were demons, sin, sleeping outdoors, or the will of God. An illness or even crop failure could be a punishment from God for working on a Sunday, or from a slighted saint if a vow was not kept (Finucane 1995). The miracle record of St Aebbe also often tied misfortune to demonic activity (Bartlett 2003). Bartlett describes people possessed by demons were tied to crosses and left overnight and in the morning they were either dead or 'cured.' One example from the miracle records of St Margaret demonstrates a miraculous cure of the saint.

> While a miller was sleeping by his mill, lizards entered his body through his mouth, giving him great pain and suffering. Within the space of a year they had multiplied to such an extent that his belly swelled up and he looked like a pregnant woman just about to give birth. […] When he was brought to the place where her most holy body fist lay buried, he tasted some of the water from the well next to the tomb and went to sleep. While he was sleeping St Margaret came to him, lightly touched his belly and suddenly, as it seemed to him, disappeared into heaven. Within the next three days the wretched man vomited up an incredible number of lizards mixed with a mass of blood and stinking indescribably. So, with his health restored, he returned to his own country, praising God and St Margaret, never afterwards feeling anything from this accident (Bartlett 2003: 123).

While this is an extravagant account, the word 'cure' was very flexible; sometimes even a slight improvement of a condition would be considered a 'miraculous cure'. Also, if a pilgrim improved a week or a month later at home, it was attributed to the healing power of the saint (Bartlett 2003, Finucane 1995). The miracle records also provide examples of cures of typical conditions.

> A monk called Lambert was so severely troubled with a toothache that he swore on oath that he was almost out of his mind. He really did not know what to do, but he reflected that, through the merits of St Margaret, the Lord had very often cured sufferers from this ailment and countless other illnesses. Therefore he ran like a madman to the queen's tomb and touched with his finger the stone in which her most holy relics rest, then put the finger in his mouth and rubbed both the front and the back of his teeth with it. At once he soothed the pain and, once it had gone, never afterwards, as he asserted, did seem to suffer the slightest trace of toothache. (Bartlett 2003:129)

Shrines often looked like modern day trauma wards where people waited for healing, sometimes for days, weeks, or even months (Finucane 1995, Scott 2010). During this long wait some minor afflictions improved on their own, such as headaches, indigestion, rotten teeth that would fall out, or fractures that started to mend. Symptoms of chronic conditions, such as arthritis (in which sufferers were often considered cripples) could abate in warmer months. Finucane (1995) explains that even acute inflammations could rupture and then start to heal on their own. All of these examples would have been considered miraculous cures by a saint's hand, and the stories of the cures encouraged more sick pilgrims to visit (Ewan 2011, Oram 2011). If the individual was cured of their disease, they often continued to other shrines in order to maintain their health care regimen. If they were not cured of their disease, they would also continue on to other shrines so that they might have better success with a different saint (Ewan 2011). Bartlett (2003) explains one woman went to the Shrine of Thomas the martyr in London and the saint was 'not willing to grant her the healing she requested,' so she then went to Coldingham on the advice of her friends where she was then healed. If a cure was not attained, or the condition relapsed, explanations included that the pilgrim neglected a vow, he lacked a sufficient belief in the saint, he was sinful, or he had also visited a physician or used human medicines (Finucane 1995). In fact, visiting a physician before visiting a shrine was considered vain and foolish since physicians were expensive and often left their patients in a worse condition (Bartlett 2003).

5.4.2.1 Healing at the Isle of May

Due to its location and religious significance, the Isle of May was a popular pilgrimage destination throughout the medieval period (Duncan 1956, Eggeling 1960, James and Yeoman 2008, Yeoman 1999). The Aberdeen Breviary dated to AD 1510 describes frequent miracles that occurred at the church, specifically 'barren women, coming in the hope of thereby becoming fruitful, were not disappointed' (Eggeling 1985:21, Macquarrie 2012, Stuart 1868:xli). Not only could women drink from the pilgrim's well and become fruitful, even animals were improved by living on the island. John Stuart in his *Records of the Priory of the Isle of May* (1868:liii) explained that the sheep with the coarsest of wool, after one season on the island, had fleece as 'fine as satin'. Even their meat improved in flavor after living on the Isle of May.

Stuart (1868) also regales the fable of the life of St Kentigern, born around AD 550, whose pregnant mother, Theneu, was thrown off a mountain by her father because the baby was illegitimate. As the fable goes, the fish that lived where she entered the water saw that she was injured and accompanied her near the Isle of May and “there they remained” (Forbes 1874:lxxxiii, Stuart 1868:vii). St Kentigern’s pregnant mother then arrived safely near Culross, where Kentigern was later born. This story implies that Theneu’s plight was the reason why the waters near the Isle of May continue to be so fruitful with fish (Duncan 1956, Forbes 1874). Macquarrie (2012) explains Theneu’s origin story may suggest she was created as a fertility goddess and that she may not be a real historical figure.

It is interesting that St Kentigern, also called St Mungo, was later known for bringing a bird back to life and that water from St Mungo’s well was once thought to cure rickets (Forbes 1874). It could be argued that many of the saints were thought to have healing miracles associated with them, and St Kentigern was just one among them. Though, these fables do seem to suggest that the embellishments of the story of St Kentigern’s life reflect an awareness on the part of these writers of some kind of association between the island and healing. Since the majority of the burials and use of the Isle of May date to prior to St Kentigern’s birth, the association itself would have been much older than the 12th century, and the Kentigern record incorporated this association of the Isle of May and healing into Kentigern’s story. In fact, due to the early dates of the burials, the Isle of May could have had a healing tradition as early as the 6th-8th centuries. The peak of burials and the inclusion of younger adults as well as some females in the seventh to tenth century suggest this was the peak pilgrimage period at the island. This also corresponds to the more pronounced pathological conditions including the rare and late-stage diseases, the majority date to the seventh to tenth century.

Although there is no known historical evidence that the Isle of May had a ‘healing centre’, as previously mentioned, the Aberdeen Breviary, claims that by drinking the water from the pilgrims’ well would cure infertility (Eggeling 1985:21, Macquarrie 2012, Stuart 1868). The Breviary continues to say the island was the “scene of many reputed miracles” (in Eggeling 1960). Healing wells were common in medieval Scotland, many allegedly blessed by saints such as St Columba and St Ninian (Hamilton 2003). The miracle records of St Aebbe mention individuals that washed their eyes or affected body parts in the fountain, or drank from the fountain, and then were cured (Bartlett 2003). The healing tradition at the Isle of May appears to be connected to the island itself rather than the Benedictine priory, since the majority of the burials are outside the dates of the foundation and abandonment of the priory. The tradition instead predates the priory and is more likely tied to the earlier Celtic or pagan occupations at the site (James and Yeoman 2008, Willows 2015).

Examination of the environmental material on the Isle of May revealed two types of plants with medicinal properties used during the medieval period: *Hyoscyamus niger*, commonly known as black henbane, and *Chelidonium majus*, or greater celandine (James and Yeoman 2008). Black henbane has anesthetic properties and has been used medicinally for five millennia in ancient civilizations such as Egypt, Babylon, Greece, and Rome. According to Moffat (1992:4) henbane was found at the medieval Scottish hospital at Soutra and was used in recipes to put a patient to sleep so "he will be able to suffer cutting in any part of the body without feeling it or aching." In an ointment henbane could be used for inflammation, burns, wounds, toothaches, earaches, and bruising (Gruenwald *et al.* 2000, Moffat 1992). Greater celandine was also used during the middle ages medicinally and was found in other monastic gardens (Barker 1961, Harvey 1992, Van Arsdall 2002). It is a mild analgesic and was used to treat warts, inflammation, toothaches, gout, stomach, liver, gallbladder and intestinal problems (Barker 1961, Gruenwald *et al.* 2000, Van Arsdall 2002).

As mentioned, the individuals at the Isle of May suffered from statistically more disease (section 5.4.1). There were also many cases of individuals with rare and late stage diseases. An example of an individual with late stage disease is SK 972, a child whose dentition places age at death at 8 years (+/- 2 yrs), while the length of the humerus and femur places this skeleton younger at 4.5-5.5 years old. It is likely that this child was eight years old but was so sickly that the rest of the body was under-developed. The pathology of the spine indicates tuberculosis; there is fusion and resorption of the bodies of many cervical and thoracic vertebrae as well as a severe curvature of the spine (sections 3.1.8.1, 4.2.5.1.2). The spinal destruction of Skeleton 972 is so severe that the child would likely have been crippled (Turgut 2001, Waldron 2009). It is extremely unlikely that this child traveled to the Isle of

May for any purpose other than for a chance to be cured of this debilitating disease, and, due to the young age of the child, most likely a parent or other family member accompanied them on their journey (Willows 2015). The carbon and nitrogen values (δ^{13}C of -16.5 and δ^{15}N of 6.7) imply a terrestrial diet that was supplemented with C_4 plants, such as millet. Section 5.2.3.1 posited since C_4 plants were not cultivated in medieval Scotland, whether it was possible this child was from a rich family that imported millet for a special cure for their sickly child. While it remains uncertain, what is clear is that this individual, who was a sick child with tuberculosis, had a unique diet compared to the rest of the Isle of May and also the rest of medieval Scotland. Millet does have a higher nutritional value than other cereal crops and has been used for medicinal and ritual purposes in other populations (mostly in the East) in the past (Weber and Fuller 2007).

Another individual with a late stage disease is Skeleton 997, a 15-17 year old probable male with a pathological diagnosis that is still under debate; differential diagnoses include tuberculosis and congenital syphilis (section 4.2.5.1.3). If this individual did suffer from congenital syphilis, it may be one of the earliest cases in the UK. Recent radiocarbon information dates this skeleton to 640-710 AD. There are many active periostitic lesions throughout the body, but the legs bear the brunt of the disease, both femora are extremely thin from atrophy, both tibiae are swollen with osteomyelitis, and the lower legs and feet contain no trabecular bone at all, rather they are sheaths of cortical bone. Congenital syphilis is an infectious disease caused by *Treponema pallidum* passed down to the fetus by its mother in utero (Aufderheide and Rodríguez-Martín 1998, Ortner 2003) (section 3.1.8.1). Tibiae are the bones most affected in congenital syphilis, with periostitis and osteomyelitis. Dactylitis of the finger and toes is also frequently observed in congenital syphilis with a "formation of a thin and bony shell" (Aufderheide and Rodríguez-Martín 1998, 296). Syphilitic dactylitis is often bilateral and symmetrical (Resnick 2002) and in Skeleton 997 both right and left metatarsals are affected (Figure 46). However, except for a lesion on the mandible, the skull is unaffected and the skull is often affected in cases of congenital syphilis (Aufderheide and Rodríguez-Martín1998, Ortner 2003). The severity of this individual's disease would have been crippling, again indicating a parent or other family member accompanying them to the Isle of May for healing purposes. Survival of both Skeleton 972 and Skeleton 997, at least until this point in their lives, concurs with Tilley and Oxenham (2011)'s argument that survival of the disabled in the past indicates continuous care by the community.

Skeleton 859, an old adult male between the ages of 45-59 year, provides another example of a rare and late stage disease. As mentioned in section 4.2.12, his right innominate has a 23.2 mm x 17.1 mm proliferative lesion on the iliac fossa, which pierces through the bone to the other side (Figures 60 and 61). There are also proliferative lesions on much of both ischia and superior to the auricular surface on both ilia. These osteoblastic, or bone-forming, lesions are typical of metastatic prostate carcinoma (Aufderheide and Rodríguez-Martín 1998, Ortner 2003, Waldron 2009) (section 3.1.8.7). There are also lytic, or bone-destroying, lesions on the distal humerus, 1st cervical vertebra, 12th thoracic vertebra, distal femur, and the right 1st metatarsal. Metastatic carcinoma is often expressed with a mixture of both blastic and lytic lesions (Ortner 2003, Tkocz and Bierring 1984); these other lytic lesions may indicate a venous transmission of the disease. Radiocarbon information reveals this man lived between 655 and 773 AD, designating this as one of the earliest recorded cases of prostate cancer in Great Britain. In fact, there have been only a few cases of prostate cancer found in archaeological contexts in Great Britain (Anderson et al. 1992, Ortner 2003, Waldron 1997).

There are two probable cases of metastatic carcinoma of the prostate at St Nicholas Church; one from phase A (12th-15th century) and one from phase B (15th-18th century) (Duffy unpublished). One of the skeletons appears to have similar changes to Skeleton 859: "osteoblastic and sunburst in appearance and visible at multiple sites including the spine, scapula, ribs, sternum, pelvis and sacrum, potentially suggesting a prostate origin (Duffy unpublished:94)." Anderson et al. (1992) diagnose a 45-55 year old male from fourteenth century Canterbury with metastatic carcinoma of the prostate. At the time the article was published, the authors claimed this was the first example of the disease in medieval England (Anderson et al. 1992). There are two skeletons with probable metastatic carcinoma of the prostate at Barton-upon-Humber. One of these also had increased vascularity affecting many bones (Waldron 2007), a condition noticed in Isle of May Skeleton 859. A 30-50 year old male from Wharram Percy (11th-16th century) was diagnosed with metastatic carcinoma with an origin of the prostate due to both blastic and lytic lesions (Mays et al. 1996). Reviewing the reported cases of probable prostate cancer from Britain, it appears that Skeleton 859 from the Isle of May is the earliest case known (Anderson et al. 1992, Brothwell 1967, Ortner 2003, Tkocz and Bierring 1984). There are, however, possible cases of prostate cancer dating to the first century AD in Italy (Grévin et al. 1997) and in Neolithic Spain (De La Rúa 1995).

As mentioned in section 4.7, SK 859 has the highest $^{87}Sr/^{86}$ Strontium value of 0.713271, along with the lightest $\delta^{18}O$ value (-8.9) among the Isle of May individuals, which signify that this individual was not local to the Eastern Scotland area. Instead, his strontium and oxygen values are consistent with Central Scotland, possibly suggesting he traveled up to 150 miles to the Isle of May for the purpose of healing.

A further example of an individual at the Isle of May with a rare condition is SK 971. SK 971 is a young adult male with multiple congenital disorders including lumbarization of the 1st sacral vertebra as well as an unfused neural arch in the 1st cervical vertebra (sectin 4.2.6.3). The skull of Skeleton 971 has the longest maximum length, the widest maximum breadth, the longest basion to bregma measurement, the widest minimum frontal breadth, and the longest total facial height among all the skulls from the Isle of May. Skeleton 971 is also an outlier for the minimum frontal breadth measurement, although the difference is not statistically significant. The deviation from normal basion-bregma measurements is also substantial (Figure 48); however, the trend is likewise not statistically significant. Possible differential diagnoses suggested in section 4.2.6.3 is an acrocephalopolysyndactyly disorder such as Apert's Syndrome, or Carpenter's Syndrome (Aufderheide and Rodríguez-Martín 1998, Daroff et al. 2012). There is one possible case of hydrocephaly at St Helen-on-the-Walls (Dawes 1980). Other examples are three skulls from Cannington, Somerset (Brothwell et al. 2000), a child from Eccles, Kent (Manchester 1980), as well as an affected child from Doonbought Fort, Co. Antrim, Northern Ireland (Murphy 1996).

It appears likely that the pilgrims visited the Isle of May because the island had a healing cult associated with it, supported by historical, environmental, and skeletal evidence (James and Yeoman 2008, Willows 2015). The high prevalence of disease as well as rare and end-stage diseases supports the conclusion of a possible hospice-like center at the Isle of May (Willows 2015, Willows forthcoming). Interestingly, 23% of the population is under 25 years of age. Since the Isle of May is more isolated, it was likely not a typical monastery where children could be left to join the brotherhood. Instead, the young individuals who died on the Isle of May were likely brought there for the purpose of healing. This theory is supported by the high prevalence of disease amongst these young individuals. The treatment offered to the sick pilgrims was most likely medicine in the form of henbane and greater celandine to ease their pain and water from the healing well as a tonic, also likely a bed, meals, and a prayer for their soul, like other medieval hospitals. Strontium and oxygen results for SK 859 suggest he was an immigrant from the Highlands, possibly coming to the Isle of May for treatment for his prostate cancer. Carbon and nitrogen results display a unique diet for SK 972; was millet or another C_4 plant imported specifically to treat this child's tuberculosis? This child would have required a parent or other relation to assist them to the Isle of May. This journey would have been costly and arduous, but a possible cure must have been more important. How long the child was treated at the Isle of May before its death remains uncertain.

Perhaps the Isle of May had a reputation for curing specific diseases, and attracted individuals with those conditions. In Bartlett's review (2003) of the miracle records of the Scottish shrines St Aebbe and St Margaret he found that certain saints and their shrines were associated with curing specific diseases and ailments. For example, there was a higher than usual amount of individuals seeking a cure to 'dumbness' at the shrine at St Aebbe, and the shrine at St Margaret included 'moral miracles'.

Another possibility is that the Isle of May catered to wealthy individuals who could afford to travel with a sick child to the island. Bartlett (2003) also found that each shrine attracted different clientele; for example at the shrine for St Aebbe, 62%

of the individuals healed were poor females, whereas the shrine of St Margaret attracted more males, monks, and few poor individuals.

The sick either traveled to the Isle of May, or were brought there by a parent because of its healing tradition, or the burial ground was sacred and a preferable place to bury the dead. The historical accounts, the environmental evidence, and now the skeletal evidence all conclude that the Isle of May had a healing tradition during the medieval period. How these individuals were treated at the Isle of May is only alluded to, but it seems to have been worth the effort for the medieval Scottish community.

6. Conclusion

This thesis has examined the health of those living within the lowland, east coast region of Scotland from 500-1500 AD utilizing historical, archaeological, and skeletal material. The analysis of four medieval populations in the study area has illustrated that although they were close geographically, each population had unique aspects to their skeletal health due to differences in their location and status.

This study first presented the osteological analysis of skeletal remains of four medieval populations (385 individuals) from eastern, lowland Scotland, before moving into a contextualized discussion of these four lowland populations. By focusing on the broad themes of location (rural/urban) and status (high/low), and by statistical comparison of prevalence rates of disease, this discussion highlighted some of the key similarities and differences between the standards of health in this region of medieval Scotland. The discussion of health from the perspectives of location was framed within the context of access to health care, population density/pathogen load, diet, and subadult mortality. The differences in housing conditions and diet in upper and lower status populations were evaluated in respect to effects on skeletal heath. This conclusion seeks to draw out the major trends and findings, in order to provide a basis for future research.

6.1 Main Findings

6.2.1 Rural/urban

While the majority of individuals that lived in the compiled lowland, medieval populations died between the ages of 35-45 years old, females tended to die between 25-34 years of age. Peak mortality occurred between 18-24 years of age in females in rural environments, suggesting an inferior access to health care throughout pregnancy, childbirth, and post-childbirth. Likewise, there were twice as many neonates deaths in rural populations compared to urban populations. Females living in rural areas may not have had many options if there was a complication during childbirth reducing both the mother and offspring’s life expectancy.

Rural populations were more affected by metabolic disease, signifying those in rural areas were more susceptible to food shortages in poor harvest years. However, since urban areas had higher rates of LEH (Linear Enamel Hypoplasia), it appears that poorer individuals living in lowland, medieval Scotland in either environment would have suffered from malnutrition sometime during their lives, especially during the winter months and times of famine. And, since there were no cases of scurvy and rickets was rare, it appears individuals were able to receive enough vitamins C and D before their skeletons were affected.

Those living in the urban sites had statistically more dental caries per tooth than those at the rural sites indicating easier access to refined sugar, refined flour, dried fruit, and other cariogenic foods.

Comparing the compiled sites, those in urban environments have more infectious disease overall than those in the rural ones. Among the study populations, urban St Andrews has significantly more infectious disease than rural Ballumbie. The high rates of infectious disease in urban environments are likely related to population density, close quarters, poor hygienic standards, and poor living environments. Through previous archaeology research, eggs of parasitic worms found in urban Perth confirms contaminated water supplies (Bowler and Perry 2004). Not only did urban environments have more pathogens, they also had to contend with chemical exposure from industrial activities such as tanning, dyeing and brewing, as seen in cases of HPO (Hypertrophic Pulmonary Osteoarthropathy) at Horse Cross. In urban environments, children between the ages of 2-6 were more likely to die than children at the same age living in rural areas of Scotland, further corroborating the effects of population density and poor hygienic controls on health.

The high rates of metabolic and infectious disease found at St Andrews was likely due to multiple factors including proximity and close quarters, poor hygienic controls, and sick pilgrims spreading pathogens. Males at St Andrews Library also have the shortest stature of all of the compiled Scottish sites; the slightly stunted growth could be due to the high parasite load.

6.1.1 Status

6.1.1.1 Housing

Living in an urban environment increased the prevalence for infectious disease; nevertheless, it appears that the wealthier in society were somewhat shielded from such diseases. There is a negative correlation between status and infection; the higher status cemeteries had significantly lower rates of infectious disease. Similarly, there were low rates of metabolic disease at higher status sites suggesting a reduction in their interaction with pathogens. Those that enjoyed a higher status during life most likely had better living conditions, which prevented the spread of pathogens. High status individuals could afford better housing, which had plank or tile floors, had fireplaces instead of hearths, and fewer people living in cramped spaces. This type of housing would have provided better hygienic conditions, resulting in lower rates of infectious diseases. Living in the poorer houses in medieval Scotland could have caused pulmonary infections leading to HPO due to inhalation of tuberculoid droplets and also the presence of a smoky environment. Poor air circulation would have also been an issue in the rural houses that generally had no chimneys and only small window openings.

There are twice as many deaths around birth (0-2 months) in low status populations than in high status ones. This is likely related to more hygienic houses but having an increased access to health care for high status individuals is likely a factor as well. High status individuals in the compiled populations also outlived contemporaries. Within the study populations, twice as many higher status individuals at Ballumbie lived into older adulthood suggesting the higher status individuals enjoyed better living conditions or an improved diet.

6.1.1.2 Diet

High status individuals benefitted from improved nutrition with more protein in their diet. Two groupings at Ballumbie were identified from isotope analysis: Group 1 – those eating less marine resources (5-16%), and Group 2 – those eating more marine resources (21-29%). Since the majority of Group 2 were also buried in higher status locations such as inside the church and in the ‘laird’s aisle,’ the differing diets in these two groups were likely based on social status. The scallop-shell pilgrim's dietary protein (SK 155), consisted of up to 52% marine resources, indicating his higher status. His high status, likely due to being a pilgrim who journeyed to Galicia, Spain, likely contributed to his favorable burial location.

Similar results were found at Whithorn, where a higher marine component corresponds with a higher status according to the authors (Lowe 2009, Müldner et al. 2009). However, the opposite was true at Portmahomack (Curtis-Summer 2009) where the higher status individuals ate no marine protein, which suggests a cultural variation in what was considered the diet of high status at different sites in Scotland. Portmahomack was an earlier medieval monastery, dating to the sixth century, so the isotopic results may be indicative of changes to the monastic diet from early to later established monasteries.

While the earlier monastic diet was a Mediterranean one (that is, abstaining from meat on most days), later in the medieval period the monastic orders started to relax their dietary restrictions. Their diets became similar to, or even more extravagant than, that of the wealthy townspeople. There is a positive correlation between status and the number of caries per individual; the wealthier populations, including monastic ones, suffered from more carious lesions. This suggests both types of populations had the same access to refined sugars, dried fruits, and other cariogenic foods. The higher rates of eDISH and DISH, which is associated with obesity and type II diabetes, further suggest that the diet of those from the upper class was similar to those living in religious institutions.

Diet is certainly an important factor in health, and it appears the higher status individuals had a higher nutritional status evidenced by lower rates of metabolic disease, cribra orbitalia, and linear enamel hypoplasia. The above average stature seen at the Isle of May and Glasgow Cathedral could also suggest a higher nutritional status in these populations.

6.1.2 Best health status in lowland medieval Scotland

Two populations within the sampled area were identified as the healthiest. They were high status, rural Auldhame and high status, urban Glasgow Cathedral. Both populations had low rates of infection, metabolic disease, and linear enamel hypoplasia. Status appears to be complicated at Auldhame since the individuals buried there ate a low status diet (Lamb et al. 2012). Additionally, the richer diet at Glasgow cathedral is demonstrated through increased rates of carious lesions and eDISH. Life expectancy was also lower at Auldhame (25-44 years) compared to Glasgow Cathedral (45+ years) and individuals at Auldhame did not reach the taller stature that males at Glasgow Cathedral did. Therefore it appears the low rates of infectious and metabolic disease seen at both populations are due to different factors. At Auldhame, the low rates can be attributed to its rural location with low population density and pathogen load. At Glasgow Cathedral, however, the low rates are tied to status with improved housing and nutrition.

While high status individuals at Glasgow Cathedral benefited from lower rates of infectious disease, metabolic disease, linear enamel hypoplasia, taller stature, and higher life expectancy, they were not spared from joint disease, dental disease, trauma, or eDISH.

Those that were buried at Auldhame benefited from its rural location. However, it appears the housing conditions and nutrition of those buried at Glasgow Cathedral had a greater effect on health. Even though low population density is an important factor for health, improved nutrition afforded better immune systems to respond to the pathogen load.

6.1.3 Health and disease at Isle of May

Pilgrimage complicated the factor of status, therefore the Isle of May was discussed separately. We know that the Isle of May was a pilgrimage location from historical research as well as from SK 155, the male buried with a scallop shell in his mouth. From his isotopic values and his burial we can conclude that he was originally from Eastern Scotland, left on pilgrimage to Santiago de Compostela, and then returned or traveled to the Isle of May after his journey.

The unusually high prevalence of disease across all categories, specifically trauma, infectious, metabolic, and joint disease, as well as individuals with rare and late-stage diseases indicates that individuals/pilgrims traveled to the Isle of May for healing purposes. The sick child with tuberculosis (SK 972) possibly received a special diet that included millet, suggesting a form of medical treatment. This special diet could have been fed to this child as a form of medical treatment and that this special, imported diet suggests this child and its relations enjoyed a high status. The fact that their relations brought them to the Isle of May, which is associated with pilgrimage, indicates they were searching for treatment.

SK 997 possibly suffered from one of the earliest cases of pre-Columbian congenital syphilis known in Great Britain. The severity of this individual's disease would have been crippling, again indicating a parent or other family member accompanying them to the Isle of May for healing purposes. SK 859 possibly suffered from the earliest recorded case of prostate cancer in Great Britain. The isotopic results concluded that this individual was not local to the Eastern Scotland area indicating he also traveled up to 150 miles to the Isle of May for the purpose of healing.

It appears likely that the pilgrims visited the Isle of May because the island had a healing cult associated with it, and possibly a hospice-like center, all supported by historical, environmental, and skeletal evidence.

6.2 Limitations

Every effort was made to construct a thoughtful and systematic study. However, with every project there is always opportunity for further development. One very disappointing limitation to this research was the Whitefriars population. The cemetery in its entirety was supposed to be excavated. However, due to financial reasons, Whitefriars was only partially excavated in 2008. It appears that Whitefriars may be excavated again in the near future; however that material will remain for others to incorporate into the present analysis. Another limitation with Whitefriars was the poor preservation of the skeletal remains, which surely prevented observing abnormal bone, and likely obscured accurate diagnoses. Due to the poor preservation of bone in the Whitefriars assemblage and in order to ensure the accuracy of the statistical results, chi-square tests for each type of disease were run with and without the inclusion of Whitefriars to see if the outcome changed. With the removal of Whitefriars, none of the outcomes for any of the chi-square tests changed.

Only macroscopic research methods were utilized in this research. Future research could incorporate radiographic or microscopic analyses to aid in diagnoses. A list of skeletal elements was prepared that would have been useful to radiograph, but such work fell outside the scope of this research.

Comparing osteological data recorded by different researchers, potentially with inter-observer bias, is an unavoidable limitation. Every attempt was made to mitigate the impact by using standardized recording guidelines and widely recognized operational definitions for pathology.

6.3 Future Research

Due to time and funding constraints, only a few isotope analyses could be completed. However, future research into diet and migration through stable isotope analysis on each of the populations could yield interesting results. For example, it would be interesting to see how far each person buried at the Isle of May traveled to get there. Additionally, it would be interesting to determine if anyone else at the Isle of May received a special diet of C_4 plants. Migration patterns could not be identified within the Ballumbie or St Andrews Library populations in the current study, but could be an avenue for future research. As ancient DNA analyses become less expensive, such studies could yield interesting results: for example, it would be interesting to see if those buried in the 'laird's aisle' at Ballumbie were all related. Ancient DNA could also be used to aid in sex determination for those left in the 'undetermined' category. This would be especially useful at St Andrews Library where sexual dimorphism was low. Ancient DNA could also be useful in confirming differential diagnoses in the case of infectious diseases (Donoghue et al. 2005, Mays and Taylor 2002, Mays et al. 2001).

Potential research avenues could include comparing Scotland with more countries such as Ireland and Wales, and even other parts of Northwest Europe (e.g. Scandinavia, Germany) to place Scotland in a wider context, and to explore how differences in culture, landscape, and climate affected patterns of health in medieval Britain and Europe.

This study has extended previous research on health in lowland medieval Scotland incorporating historical, archaeological, and osteological research to provide a more informed discussion of regional health. Location and status both influenced health. However, it appears that it was the status one enjoyed in society that had the greatest effect on personal health. This research had contributed to making the everyday lives of the ‘historically invisible’ (Funari et al. 2003), including peasants, farmers, craftsmen, women, and children, become visible.

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Appendices

Appendix 1 Cranial and postcranial measurements

Bone	**Measurements (after Bass 1995)**
Cranium	maximum length; maximum breadth; basion-bregma height; minimum frontal breadth; total facial height; upper facial height; bizygomatic breadth; nasal height; nasal breadth; orbital height; orbital breadth
Maxilla	maximum alveolar height; maximum alveolar breadth; palatal length; palatal breadth
Mandible	bicondylar breadth; bigonial breadth; ramus height; minimum ramus breadth; height of mandibular symphysis
Atlas	maximum width
Sacrum	width 1st body; maximum anterior breadth (a); maximum anterior height (b); sacral index (a × 100 / b):
Sternum	length mesosternum; length manubrium
Scapula	maximum length (a); maximum breadth (b); length spine; supraspinous length; infraspinous length; length glenoid cavity; scapular index (b × 100 / a)
Clavicle	maximum length (a); circumference (b); claviculohumeral index (a × 100 / maximum length humerus); robustness index (b × 100 / a)
Humerus	maximum length; maximum diameter of head; epicondylar width; maximum diameter midshaft; least circumference
Radius	maximum length; radiohumeral index (length × 100 / length humerus)
Ulna	maximum length; physiological length; least circumference; caliber index (least circumference × 100 / physiological length):
Metacarpals	maximum length
Pelvis	maximum height; maximum breadth; pubis length (a); ischium length (b); ischium-pubis index (a × 100 / b)
Femur	maximum length; bicondylar length; antero-posterior diameter; mediolateral diameter; diameter head; circumference shaft; subtrochanteric antero-posterior diameter (a); subtrochanteric mediolateral diameter (b); bicondylar width: platymeric index (a × 100 / b)
Patella	maximum width; maximum height
Tibia	maximum length; proximal breadth; antero-posterior diameter nutrient foramen; mediolateral diameter nutrient foramen; circumference at nutrient foramen; distal breadth, platycnemic index
Fibula	maximum length
Calcaneus	maximum length; maximum breadth
Metatarsals	maximum length

Appendix 2 Example of recording spreadsheet

Population	Context	Skeletal Area	Identified Bone	Side	Description	Condition	Age	Likely Age
IOM	431	pelvis	sacrum		complete 1-5, 5 broken off but present	good		12+
IOM	431	pelvis	coccyx		complete bone	good		
IOM	431	pelvis	innominate	R	complete bone	good	YA	14-22
IOM	431	pelvis	innominate	L	complete bone slight post mortem damage	good	YA	14-22
IOM	431	lower limb	femur	R	complete bone taped together	good	AD	over 18
IOM	431	lower limb	tibia	R	complete bone	good	YA	
IOM	431	lower limb	fibula	R	complete bone taped together	good		
IOM	431	foot	calcaneus	R	complete bone	good	AD	over 18
IOM	431	lower limb	patella	R	complete bone	good		

Ageing Criteria	Sex	Sexing Criteria	Measurements	Stature	Pathology Summary
fusion almost complete of sacral 1-5	M	curved profile	width 1st body:49.7; maximum anterior breadth (a): 101.4; maximum anterior height (b):106.3; sacral index (ax100/b): 95.39		
iliac crest fusing, ischial tuberosity fusing, pubic symphysis phase 1, auricular surface phase 1	M	narrow greater sciatic notch, no ventral arc, no sharp ischiopubic ramus, no subpubic concavity, subpubic angle, ischium-pubis index	maximum height: 205; maximum breadth:162; pubis length(a): 83.2; ischium length(b): 98.2; ischium-pubis index (ax100/b): 84.73		
iliac crest fusing, ischial tuberosity fusing, pubic symphysis phase 1, auricular surface phase 1	M	narrow greater sciatic notch, no ventral arc, no sharp ischiopubic ramus, no subpubic concavity, subpubic angle, ischium-pubis index	maximum height: 210; maximum breadth: 160; pubis length(a): 85.9; ischium length(b):99.2; ischium-pubis index (ax100/b): 84.73		
epiphyses fused	M	diameter head, bicondylar width	maximum length: 431; bicondylar length: 428; antero-posterior diam: 75.4 ; mediolateral diameter: 26.4; diameter head:48.0; circumference shaft: 81;subtrochanteric antero-posterior diam (a):28.1;subtrochanteric mediolateral diameter (b): 28.8; bicondylar width:78.7; platymeric index (ax100/b):97.56	163.98 +/- 3.27	
epiphyses fused	?		maximum length:338; proximal breadth:73.6; anterior-posterior diameter nutrient foramen (b):28.1; mediolateral diameter nutrient foramen(a):23.7; circumference at nutrient foramen:88;distal breadth:44.2; platycnemic index (ax100/b):23.7*100/28.1=84.34		
			length:331		
fused			length:74.2, breadth: 39.9		
			length:40.2, breadth: 44.2		

Infection	Growth	Trauma	Metabolic	Joint Disease	Dental Disease	Other Pathology	Comments
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	eurymeric
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	
absent	absent	absent	absent	absent	absent	absent	

Appendix 3 Decision table for sexing skeletons

Score	0	1	2	3	4	5
Size						
Frontal						
Supraorbital ridge						
Supraorbital margin						
Mastoid process						
Nuchal crest						
Greater sciatic notch						
Ventral arc						
Ischiopubic ramus ridge						
Subpubic concavity						
Subpubic angle						
Preauricular sulcus						
Ischium-pubis index						
Sacrum						
Length glenoid cavity						
Diameter head humerus						
Epicondylar width						
Diameter head femur						
Circumference femur						
Bicondylar width						
Circumference tibia-						
Breadth proximal tibia						
Breadth distal tibia						

Sexing Key

0	unobservable
1	female
2	probable female
3	indeterminate
4	probable male
5	male

Comments:

Appendix 4 Dentition recording forms

SITE **SK#** **SEX** **AGE**

Adult

Left	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3	**Right**
	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3	

Deciduous

Left	m2	m1	c	i2	i1	i1	i2	c	m1	m2	**Right**
	m2	m1	c	i2	i1	i1	i2	c	m1	m2	

Key to Status of Dentition

0	not known/unclear
1	unerupted
2	erupting
3	present
4	present but damaged
5	missing post mortem
6	missing ante mortem
7	congenitally absent
a	dental abscess
c	carious lesion
h	socket healing

Hypoplasia Recording Form

Left	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3	**Right**
	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3	

Hypoplasia Key

1	linear horizontal grooves
2	linear vertical grooves
3	linear horizontal pits
4	nonlinear pits
5	single pits

Location: Distance from CEJ:

Comments:

Caries Recording Form

Left	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P1	M1	M2	M3	**Right**
	M3	M2	M1	P2	P1	C	I2	I1	I1	I2	C	P1	P2	M1	M2	M3	

Caries Key

1	occlusal
2	interproximal
3	buccal/labial or lingual
4	cervical
5	gross

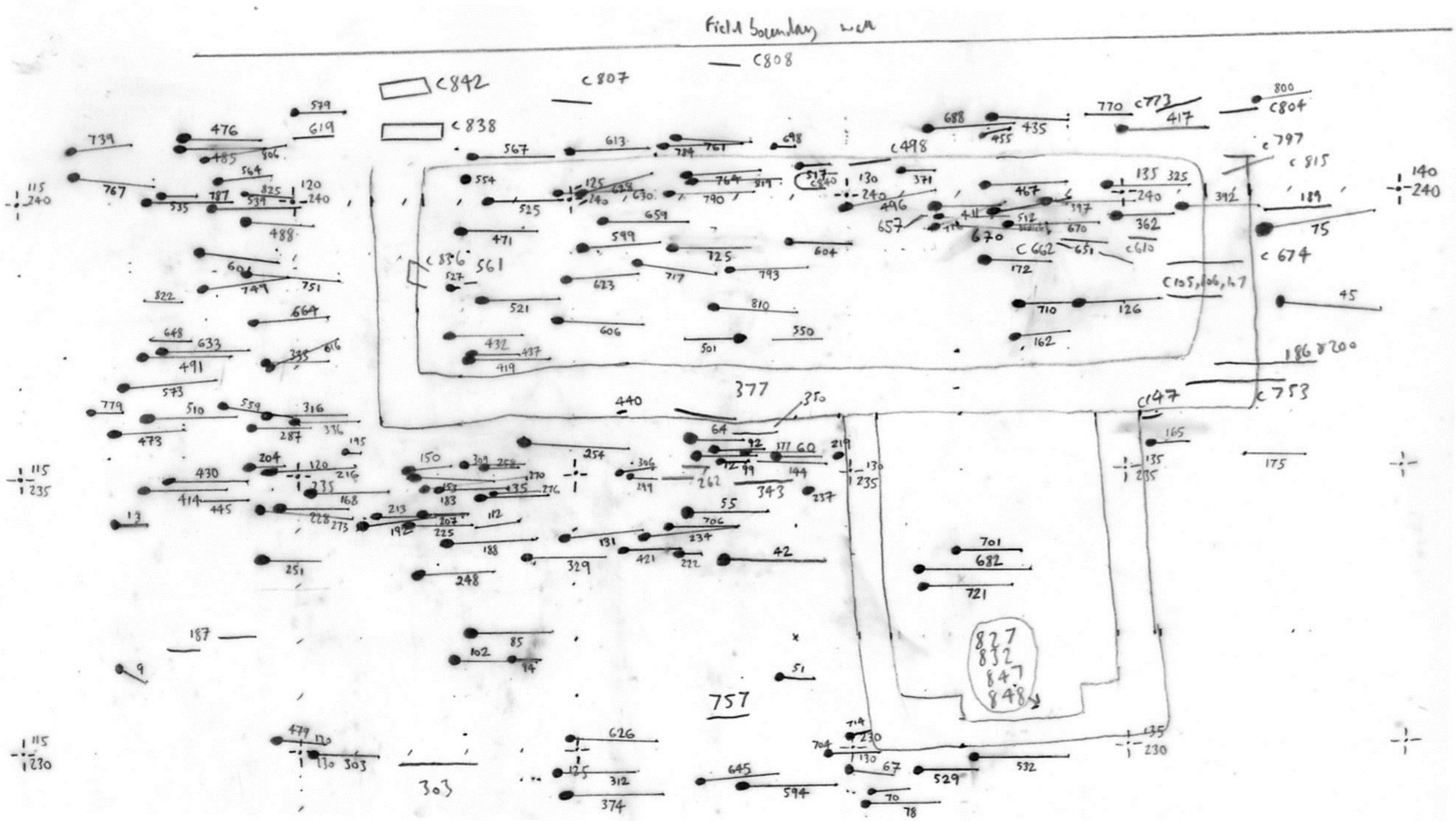
Comments:

Appendix 5 Example of summary spreadsheet

Population	Context	Condition	Age	Likely Age	Ageing Criteria	Sex	Sexing Criteria
IOM	832	good	YA	19-25	dental wear, pubic symphysis, auricular surface, epiphyseal fusion, rib end	M	cranial and pelvis morphology and post cranial measurements

Stature	Pathology	Comments	Burial Group	Burial Type
167.56 +/-3.27	2/27 carious lesions, hypoplasia on maxilla and mandible, antemortem tooth loss and healed alveolar bone, porotic hyperostosis, healing lytic lesion on base of both 1st proximal phalanges, 5/12 thoracic and 4/5 lumbar Schmorl's nodes, T11, T12, and L1 with squaring and disc degeneration- Scheuermann's Disease? porosity and periostitis on many bones	rhomboid fossa, cortical defect	3	Extended inhumation

Appendix 6 Ballumbie burial plan (Hall unpublished)



Appendix 7 Ballumbie burial location and phases (after Hall n.d)

Skel No	Age	Sex	Location	Phase
SK 09	AD	Undet.	burial ground	phase 2
SK013	MA	Male	burial ground	phase 2
SK042	MA	Female	burial ground	phase 2
SK045	YMA	Female	burial ground	phase 2
SK051	MA	Female	burial ground	phase 2
SK055	ADL	Male	burial ground	phase 2
SK060	YMA	Male	burial ground	phase 2
SK064	MA	Male	cist	phase 1
SK067	MA	Male	burial ground	phase 2
SK070	AD	Male	burial ground	phase 2
SK072	MA	Male	cist	phase 1
SK075	YMA	Female	burial ground	phase 2
SK078	ADL	Non-Adult	burial ground	phase 2
SK085	ADL	Non-Adult	burial ground	phase 2
SK092	MA	Male	non-cist but pre-church	phase 1
SK099	IN	Non-Adult	burial ground	phase 2
SK102	YMA	Female	burial ground	phase 2
SK112	AD	Female	burial ground	phase 2
SK112A	AD	Undet.	burial ground	phase 2
SK126	MA	Male	cist	phase 1
SK131	MA	Female	burial ground	phase 2
SK135	YA	Female	burial ground	phase 2
SK144	AD	Undet.	burial ground	phase 2
SK150	MA	Female	burial ground	phase 2
SK153	YA	Female	burial ground	phase 2
SK162	ADL	Non-Adult	inside church	phase 2
SK165	AD	Male	cist	phase 1
SK168	OA	Male	burial ground	phase 2
SK172	OA	Female	inside church	phase 2
SK175	AD	Undet.	cist	phase 1
SK183	MA	Male	cist	phase 1
SK187	AD	Undet.	burial ground	phase 2
SK188	AD	Male	burial ground	phase 2
SK192	OA	Female	burial ground	phase 2
SK195	OJ	Non-Adult	burial ground	phase 2
SK204	OJ	Non-Adult	burial ground	phase 2
SK207	MA	Male	burial ground	phase 2
SK213	YA	Female	burial ground	phase 2
SK216	OA	Female	burial ground	phase 2
SK222	YJ	Non-Adult		
SK225	YMA	Male	burial ground	phase 2
SK228	ADL	Male	burial ground	phase 2
SK231	AD	Female	burial ground	phase 2
SK234	YMA	Male	burial ground	phase 2

Skel No	Age	Sex	Location	Phase
SK237	MA	Male	burial ground	phase 2
SK248	YMA	Male	burial ground	phase 2
SK251	AD	Undet.		
SK254	OA	Female	burial ground	phase 2
SK258	OA	Male	burial ground	phase 2
SK261	IN	Non-Adult	burial ground	phase 2
SK262	OJ	Non-Adult	burial ground	phase 2
SK270	AD	Male	burial ground	phase 2
SK273	MA	Female	burial ground	phase 2
SK276	MA	Female	burial ground	phase 2
SK279	AD	Undet.	non-cist but pre-church	phase 1
SK303	YMA	Male	burial ground	phase 2
SK306	MA	Male	burial ground	phase 2
SK309	MA	Female		
SK316	OJ	Non-Adult	burial ground	phase 2
SK325	AD	Female	cist	phase 1
SK326	AD	Female	inside church	phase 2
SK329	YMA	Male	burial ground	phase 2
SK333	ADL	Male	burial ground	phase 2
SK336	OJ	Non-Adult	burial ground	phase 2
SK341	MA	Male	inside church	phase 2
SK343	ADL	Male	burial ground	phase 2
SK350	AD	Undet.	non-cist but pre-church	phase 1
SK353	YA	Undet.	burial ground	phase 2
SK356	AD	Undet.	burial ground	phase 2
SK362	MA	Male	cist	phase 1
SK365	YMA	Female	burial ground	phase 2
SK368	OA	Female	burial ground	phase 2
SK371	IN	Non-Adult	inside church	phase 2
SK374	YMA	Male	burial ground	phase 2
SK377	YMA	Female	non-cist but pre-church	phase 1
SK380	MA	Undet.	burial ground	phase 2
SK392	YMA	Male	cist	phase 1
SK397	OA	Female	cist	phase 1
SK411	OJ	Non-Adult	inside church	phase 2
SK414	YA	Male		
SK417	OA	Female	inside church	phase 2
SK419	MA	Male	inside church	phase 2
SK421	MA	Female	burial ground	phase 2
SK430	AD	Female	burial ground	phase 2
SK432	YMA	Female	inside church	phase 2
SK435	MA	Female	inside church	phase 2
SK437	OA	Female	inside church	phase 2
SK440	OA	Female	burial ground	phase 2
SK445	AD	Female	burial ground	phase 2
SK447A	YMA	Male	inside church	phase 2
SK447C	MA	Female	inside church	phase 2
SK453	YJ	Non-Adult		

Skel No	Age	Sex	Location	Phase
SK464	YA	Undet.		
SK467	MA	Female	cist	phase 1
SK471	ADL	Male	inside church	phase 2
SK473	YA	Male	burial ground	phase 2
SK476	YMA	Male	burial ground	phase 2
SK479	OA	Male	burial ground	phase 2
SK485	AD	Female	burial ground	phase 2
SK488	YMA	Female	burial ground	phase 2
SK491	YMA	Female	burial ground	phase 2
SK496	ADL	Non-Adult	cist	phase 1
SK501	MA	Female	inside church	phase 2
SK510	OA	Male	burial ground	phase 2
SK512	YMA	Female	inside church	phase 2
SK517	AD	Undet.	cist	phase 1
SK519	MA	Male	burial ground	phase 2
SK521	YA	Male	inside church	phase 2
SK525	MA	Female	inside church	phase 2
SK527	YMA	Female	inside church	phase 2
SK529	YMA	Female	burial ground	phase 2
SK532	MA	Male	burial ground	phase 2
SK535	OJ	Non-Adult	burial ground	phase 2
SK539	YMA	Male	burial ground	phase 2
SK546	IN	Non-Adult	inside church	phase 2
SK550	MA	Female	inside church	phase 2
SK559	ADL	Female	burial ground	phase 2
SK561	YMA	Female	inside church	phase 2
SK562	AD	Undet.	burial ground	phase 2
SK564	OJ	Non-Adult	burial ground	phase 2
SK567	OA	Male	inside church	phase 2
SK579	OJ	Non-Adult	burial ground	phase 2
SK586	YMA	Female	burial ground	phase 2
SK594	MA	Female	burial ground	phase 2
SK599	OA	Female	inside church	phase 2
SK601	OA	Female	burial ground	phase 2
SK604	OJ	Non-Adult	inside church	phase 2
SK606	MA	Male	inside church	phase 2
SK613	YA	Male	inside church	phase 2
SK616	MA	Female	burial ground	phase 2
SK619	OJ	Non-Adult	burial ground	phase 2
SK623	YMA	Male	inside church	phase 2
SK626	MA	Female	burial ground	phase 2
SK628	YMA	Male	inside church	phase 2
SK630	OA	Male	inside church	phase 2
SK633	YMA	Male	burial ground	phase 2
SK642	YMA	Male	inside church	phase 2
SK645	YA	Female	burial ground	phase 2
SK648	YA	Male	burial ground	phase 2
SK651	AD	Undet.	inside church	phase 2

Skel No	Age	Sex	Location	Phase
SK654	AD	Female	inside church	phase 2
SK657	YMA	Male	inside church	phase 2
SK659	YA	Female	inside church	phase 2
SK664	ADL	Female	burial ground	phase 2
SK670	OA	Male	inside church	phase 2
SK672	YMA	Male	inside church	phase 2
SK677	AD	Male	inside church	phase 2
SK682	MA	Male	aisle	phase 3
SK686	OA	Undet.	cist	phase 1
SK688	YMA	Female	inside church	phase 2
SK693	AD	Undet.	burial ground	phase 2
SK696	OJ	Non-Adult	burial ground	phase 2
SK698	YJ	Non-Adult	inside church	phase 2
SK701	YMA	Male	aisle	phase 3
SK704	YJ	Non-Adult	burial ground	phase 2
SK706	YMA	Female	burial ground	phase 2
SK710	AD	Undet.	cist	phase 1
SK714	YJ	Non-Adult	burial ground	phase 2
SK716	YA	Female	inside church	phase 2
SK717	MA	Female	inside church	phase 2
SK721	YMA	Female	aisle	phase 3
SK725	OA	Male	inside church	phase 2
SK728	AD	Female	burial ground	phase 2
SK739	ADL	Non-Adult	burial ground	phase 2
SK742	AD	Male	inside church	phase 2
SK747	AD	Male	cist	phase 1
SK749	MA	Male	burial ground	phase 2
SK751	YMA	Male	burial ground	phase 2
SK755	AD	Undet.		
SK757	AD	Female		
SK761	MA	Male	inside church	phase 2
SK764	MA	Female	inside church	phase 2
SK767	AD	Female	burial ground	phase 2
SK784	OA	Male	inside church	phase 2
SK787	YMA	Female	burial ground	phase 2
SK790	OA	Female	inside church	phase 2
SK793	MA	Female	inside church	phase 2
SK800	ADL	Female	burial ground	phase 2
SK806	MA	Male	burial ground	phase 2
SK810	YMA	Female	inside church	phase 2
SK819	YMA	Male	inside church	phase 2
SK822	ADL	Non-Adult	burial ground	phase 2
SK825	ADL	Non-Adult	burial ground	phase 2
SK827	OA	Female	aisle	phase 3
SK830	YA	Female	burial ground	phase 2
SK832	OA	Male	aisle	phase 3
SK833	MA	Female	burial ground	phase 2
SK835	AD	Undet.	non-cist but pre-church	phase 1

Skel No	Age	Sex	Location	Phase
SK836	YA	Female		
SK838	AD	Undet.		
SK839	MA	Undet.	cist	phase 1
SK841	OA	Male	inside church	phase 2
SK843	YA	Female	cist	phase 1
SK844	YMA	Male	non-cist but pre-church	phase 1
SK845	OA	Female	non-cist but pre-church	phase 1
SK847	YA	Male	aisle	phase 3
SK848	MA	Female	aisle	phase 3

Appendix 8 Isle of May burial groups, type, and locations (after James and Yeoman 2008)

Context	Age	Sex	Burial Group	Burial Type/Location
155	YA	M	5	Dug (beneath altar)
376	AD	Undet.	3	Dug (beneath cloister)
379	AD	M	3	Dug (beneath church)
385	AD	M	3	Dug (beneath church)
386	YA	M	3	Dug (beneath church)
431	YA	M	3	Dug (beneath chapter house)
435	MA	Undet.	3	Dug (beneath chapter house)
440	AD	M	3	Dug (beneath chapter house)
444	OA	M	3	Dug (beneath chapter house)
814	ADL	M	1	Long cist
815	MA	M	1	Long cist
820	MA	M	1	Long cist
830	MA	M	3	Extended inhumation
831	MA	M	3	Extended inhumation
832	YA	M	3	Extended inhumation
833	AD	M	3	Extended inhumation
834	AD	Undet.	3	
837	MA	M	1	Long cist
846	OA	M	1	Long cist
848	OA	M	1	Long cist
853	YMA	M	1	Long cist
859	OA	M	2	Long cist
864	MA	M	1	Long cist
868	OA	M	1	Long cist
869	OA	M	1	Long cist
872	OA	M	4	Extended inhumation
885	OA	M	1	Long cist
887	OA	M	1	Long cist
888	YMA	M	1	Long cist
924	MA	M	4	Dug (cemetery area)
955	YMA	M	2	Cist
957	YMA	M	2	Cist
959	MA	M	2	Cist
961	YMA	M	4	Cist
967	YMA	M	2	Cist
970	OJ	Non-Adult	2	Cist
971	YA	M	2	Cist
972	OJ	Non-Adult	4	Dug (cemetery area)

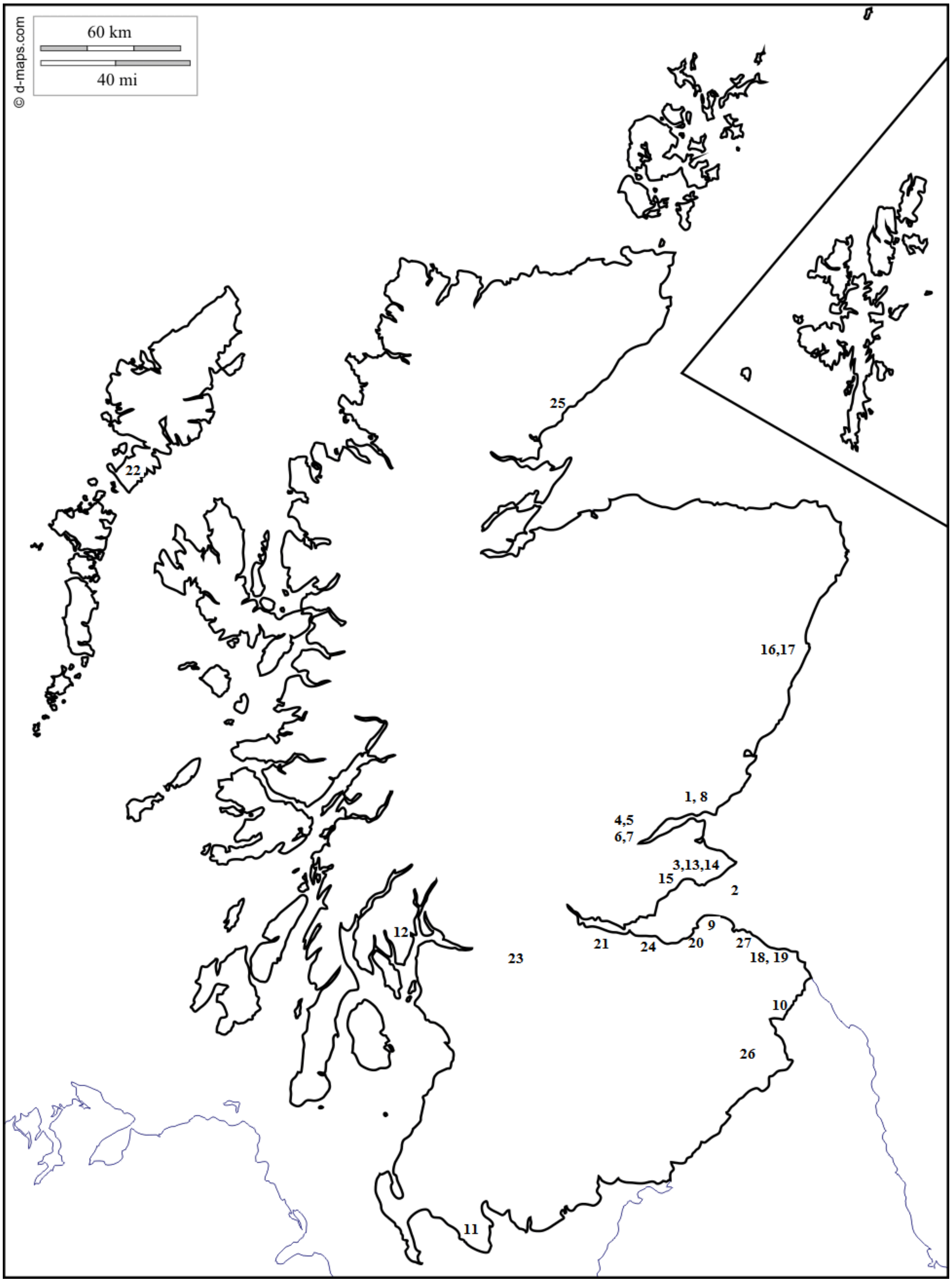
Context	Age	Sex	Burial Group	Burial Type/Location
980	YA	M	2	Cist
981	OA	M	2	Cist
982	AD	M	2	Cist
985	YMA	M	2	Cist
987	OA	M	2	Cist
993	MA	F	2	Cist
995	MA	M	2	Cist
997	ADL	M	2	Cist
999	MA	M	2	Cist
1022	YA	M	2	Cist
1023	YMA	Undet.	2	Cist
1025	YMA	M	2	Cist
1030	ADL	Non-Adult	2	Cist
1033	YMA	F	4	Cist
1039	MA	M	2	Cist
1042	MA	M	4	Dug (cemetery area)
1120	MA	M	6	Dug (trench V)
1137	MA	M	5	Dug (trench V)
1138	YA	M	5	Dug (trench V)
1211	YMA	M	3	Dug (beneath cloister)

Appendix 9 St Andrews Library burial layers (after Rees 2003)

Context	Age	Sex	Burial Layer
10	AD	Female	21.70m to 20.82m OD (Layer 1)
11	AD	Male	21.70m to 20.82m OD (Layer 1)
12	MA	Male	21.70m to 20.82m OD (Layer 1)
13	YMA	Female	21.70m to 20.82m OD (Layer 1)
14	IN	Non-Adult	21.70m to 20.82m OD (Layer 1)
15	ADL	Non-Adult	21.70m to 20.82m OD (Layer 1)
16	AD	Undet.	21.70m to 20.82m OD (Layer 1)
17	YMA	Female	20.81m to 20.61m OD (Layer 2)
18	ADL	Male	21.70m to 20.82m OD (Layer 1)
19	MA	Male	21.70m to 20.82m OD (Layer 1)
20	OA	Undet.	21.70m to 20.82m OD (Layer 1)
22	OA	Undet.	21.70m to 20.82m OD (Layer 1)
23	YMA	Male	21.70m to 20.82m OD (Layer 1)
24	MA	Male	21.70m to 20.82m OD (Layer 1)
25	IN	Undet.	21.70m to 20.82m OD (Layer 1)
26	YA	Female	20.81m to 20.61m OD (Layer 2)
27	YMA	Female	20.81m to 20.61m OD (Layer 2)
28	YMA	Male	21.70m to 20.82m OD (Layer 1)
29	AD	Male	21.70m to 20.82m OD (Layer 1)
30	YJ	Non-Adult	20.81m to 20.61m OD (Layer 2)
31	MA	Male	20.81m to 20.61m OD (Layer 2)
32	AD	Undet.	20.81m to 20.61m OD (Layer 2)
33	MA	Male	20.81m to 20.61m OD (Layer 2)
34	YJ	Non-Adult	21.70m to 20.82m OD (Layer 1)
35	MA	Male	20.81m to 20.61m OD (Layer 2)
36	YA	Female	20.81m to 20.61m OD (Layer 2)
38	AD	Female	20.60m to 19.72m OD (Layer 3)
39	AD	Undet.	20.81m to 20.61m OD (Layer 2)
40	YJ	Non-Adult	20.60m to 19.72m OD (Layer 3)
41	YA	Female	20.60m to 19.72m OD (Layer 3)
42	MA	Female	20.81m to 20.61m OD (Layer 2)
43	AD	Female	20.81m to 20.61m OD (Layer 2)
44	OJ	Non-Adult	20.81m to 20.61m OD (Layer 2)
45a	AD	Male	20.81m to 20.61m OD (Layer 2)
45b	AD	Undet.	20.81m to 20.61m OD (Layer 2)
46	OA	Male	20.81m to 20.61m OD (Layer 2)
47	MA	Male	20.81m to 20.61m OD (Layer 2)
48	MA	Undet.	20.81m to 20.61m OD (Layer 2)
49	ADL	Male	20.81m to 20.61m OD (Layer 2)
50	ADL	Male	20.81m to 20.61m OD (Layer 2)

Context	**Age**	**Sex**	**Burial Layer**
51	MA	Undet.	20.81m to 20.61m OD (Layer 2)
52	AD	Male	20.81m to 20.61m OD (Layer 2)
53	MA	Female	20.60m to 19.72m OD (Layer 3)
54	AD	Male	20.81m to 20.61m OD (Layer 2)
55	ADL	Male	20.81m to 20.61m OD (Layer 2)
56	YMA	Female	20.60m to 19.72m OD (Layer 3)
57	YMA	Female	20.60m to 19.72m OD (Layer 3)
58	MA	Male	20.60m to 19.72m OD (Layer 3)
59	AD	Undet.	20.60m to 19.72m OD (Layer 3)
60	YA	Male	20.60m to 19.72m OD (Layer 3)
61	YMA	Female	20.60m to 19.72m OD (Layer 3)
62	MA	Male	20.60m to 19.72m OD (Layer 3)
63	AD	Undet.	20.60m to 19.72m OD (Layer 3)
64	OJ	Non-Adult	20.60m to 19.72m OD (Layer 3)
65	AD	Male	20.81m to 20.61m OD (Layer 2)
66	YJ	Non-Adult	20.81m to 20.61m OD (Layer 2)
68	IN	Non-Adult	20.60m to 19.72m OD (Layer 3)
69	OA	Male	20.60m to 19.72m OD (Layer 3)
70	AD	Male	20.60m to 19.72m OD (Layer 3)
71	AD	Female	20.60m to 19.72m OD (Layer 3)
72	AD	Female	20.60m to 19.72m OD (Layer 3)
73	YMA	Male	20.60m to 19.72m OD (Layer 3)
74	YJ	Non-Adult	20.60m to 19.72m OD (Layer 3)
75	OA	Male	20.60m to 19.72m OD (Layer 3)
76	ADL	Non-Adult	20.60m to 19.72m OD (Layer 3)
79	YJ	Non-Adult	21.70m to 20.82m OD (Layer 1)
80	IN	Non-Adult	21.70m to 20.82m OD (Layer 1)
81	AD	Male	20.81m to 20.61m OD (Layer 2)
82	OA	Male	20.60m to 19.72m OD (Layer 3)
83	MA	Male	20.81m to 20.61m OD (Layer 2)
84	YJ	Non-Adult	20.60m to 19.72m OD (Layer 3)
85	OA	Undet.	21.70m to 20.82m OD (Layer 1)

Appendix 10 Map of Scottish medieval sites compiled (after d-maps.com)



Map Key

1	**Ballumbie**
2	**Isle of May**
3	**St Andrews Library**
4	**Whitefriars**
5	Kinnoull Street
6	St. John's Kirk
7	Horse Cross
8	Dundee City Churches
9	Kirk Ness
10	The Hirsel
11	Whithorn
12	Chapelhall
13	St. Mary's Church, Kirkhill
14	Logies Lane
15	Hallow Hill
16	Aberdeen on the Green
17	St. Nicholas Church
18	Castle Park, Dunbar
19	Captain's Cabin, Dunbar
20	Longniddry, Four Winds
21	Linlithgow
22	Isle of Ensay
23	Glasgow Cathedral
24	St. Giles
25	St. Trolla's Chapel
26	Jedburgh
27	Auldhame

Appendix 11 All compiled populations date, location, reference, sample size

Site Name	Date cents. AD	Location	Reference	Sample Size
Ballumbie	6th-17th	Rural, Angus	This study	197
Isle of May	5th-16th	Island, Firth of Forth	This study	58
St Andrews Library	15th-16th	Urban, St Andrews	This study	72
Whitefriars	14th-17th	Urban, Perth	This study	58
Kinnoull Street	13th-16th	Urban, Perth	Bruce 1985	23
St. John's Kirk	12th-16th	Urban, Perth	Roberts 2005	33
Horse Cross	12th-16th	Urban, Perth	Roberts 2007	10
Dundee City Churches	12th-15th	Urban, Dundee	Roberts 2000	35
Kirk Ness	12th-17th	Urban, North Berwick	Henderson unpublished	24
The Hirsel	11th-13th	Rural, Berwickshire	Anderson 2014	331
Whithorn (Period V)	13th-15th	Urban, Galloway	Cardy 1997	1605
Chapelhall	10th century	Rural, Argyll	Roberts 2000	8
St. Mary's Church, Kirkhill	5th-12th	Urban, St Andrews	Bruce 1997	282
Logies Lane	15th-16th	Urban, St Andrews	Cardy 1997	121
Hallow Hill	6th-9th	Rural, Fife	Young 1996	145
Aberdeen on the Green	14th-17th	Urban, Aberdeen	Cardy unpublished	193
St. Nicholas Church (Phase A)	12th-15th	Urban, Aberdeen	Duffy unpublished	478
Castle Park, Dunbar	Early Christian-13th	Urban, East Lothian	Bruce 2000	27
Captain's Cabin, Dunbar	9th-11th	Urban, East Lothian	Roberts 2001	76
Longniddry, Four winds	5th-8th	Rural, East Lothian	Lorimer 1992	8
Linlithgow	13th-17th	Urban, Linlithgow	Cross and Bruce 1989	201
Isle of Ensay	16th-19th	Island, Hebrides	Miles 1989	416
Glasgow Cathedral	14th-19th	Urban, Glasgow	King 2002	79
St. Giles (Period 2)	12th-14th	Urban, Edinburgh	Henderson 2006	78
St. Trolla's Chapel	11th-17th	Rural, Sutherland	Roberts 2003	13
Jedburgh (Period II-IV)	12th-16th	Urban, Jedburgh	Grove 1995	23
Auldhame	7th-17th	Rural, East Lothian	Melikian and Ives forthcoming	242

Appendix 12 Information on compiled populations

Study populations

Ballumbie is a rural sixth to seventeenth century parish church cemetery, and the Isle of May assemblage is a monastic and lay island population from the fifth to sixteenth century. The fifteenth to sixteenth century Holy Trinity Church in St Andrews was excavated twice: first in 1991, when it was known as Logies Lane, and the second in 2003, when it was called St Andrews Library (which is one of the four study populations).

The burials from the Logies Lane excavations are shown separately in Table 8. Whitefriars Street in urban Perth was also excavated twice, once in 1982 (Cross and Bruce 1989), and again in 2008; the remains from the 2008 excavations form one of the four study populations. Whitefriars is an urban monastic and lay assemblage and dates from the fourteenth to seventeenth centuries.

Other Scottish medieval sites

Kinnoull Street is an urban assemblage from a thirteenth to sixteenth century Dominican monastic and lay cemetery in Perth (Bruce 1995). St. John's Kirk (Roberts 2005) and Horse Cross (Roberts 2007) are another two assemblages from Perth, both dating from the twelfth to sixteenth centuries. St. Mary's Church, Kirkhill from urban St Andrews is a lay assemblage dating from the fifth to twelfth centuries (Bruce 1997). The urban Carmelite friary at Aberdeen on the Green, with monastic and lay burials dating from the fourteenth to seventeenth centuries, was excavated twice, in 1980 (Cross and Bruce 1989) and 1994 (Cardy unpublished). The report by Cardy (unpublished) combines results from both excavations, which will be used here. St. Nicholas Church in urban Aberdeen dates from the twelfth to eighteenth centuries (Duffy unpublished); phase A (12^{th}-15^{th} centuries) only will be used in this discussion.

Two long cist cemeteries are included, Chapelhall, from tenth century rural Argyll (Roberts 2000b), and Four Winds, Longniddry from East Lothian from the fifth to eighth centuries (Lorimer 1992). The lay cemetery in urban Dunbar dating from the ninth to the thirteenth centuries produced two excavations, Castle Park in 1993 and Captain's Cabin in 1998 (Roberts

2001). For Castle Park, data from burials from two watching briefs, DB09 and DB10 (Bruce 2000) were combined here. The Isle of Ensay, in the Outer Hebrides, was a lay cemetery used between the sixteenth to nineteenth centuries (Miles 1989).

The urban assemblage from Glasgow Cathedral is a lay community from the fourteenth to nineteenth century (King 2002). Period 2 of St. Giles Kirk in urban Edinburgh is a lay community, dating from the twelfth to fourteenth century (Henderson 2006). St. Trolla's Chapel is a rural lay assemblage from Sutherland dating from the eleventh to seventeenth centuries (Roberts 2003).

Monastic and lay burials at urban Whithorn in Galloway covered a long period of time, therefore for comparative purposes, only skeletons from Period V (Cardy 1997a) from the thirteenth to fifteenth century are used here. Auldhame is a recent excavation in rural East Lothian of a monastic and lay assemblage from the seventh to seventeenth centuries (Melikian and Ives forthcoming). Linlithgow is an urban monastic and lay cemetery used between the thirteenth and seventeenth centuries (Cross and Bruce 1989). Period II-IV of Jedburgh Abbey represent the twelfth to sixteenth centuries of an urban monastic assemblage (Grove 1995). Focusing only on the monastic burials at Jedburgh Abbey allows for a better comparison with other heavily monastic sites like the Isle of May.

Appendix 13 Number of sexed individuals, number of males/females and percentage of sexed individuals, number of subadults/adults; sudadults = < 18 adults= >19

Site Name	**No. Sexed**	**Males**	**% Males**	**Females**	**% Females**	**No. Subadults**	**% Subadults**	**No. Adults**	**% Adults**
Ballumbie	169	70	0.41	77	0.46	36	0.18	161	0.82
Isle of May	52	49	0.94	3	0.06	5	0.09	53	0.91
St Andrews Library	46	30	0.65	16	0.35	19	0.26	53	0.74
Whitefriars	34	22	0.65	12	0.35	23	0.40	35	0.60
Kinnoull Street	17	8	0.47	9	0.53	8	0.35	15	0.65
St. John’s Kirk	8	5	0.63	3	0.38	26	0.79	7	0.21
Horse Cross	8	4	0.50	4	0.50	2	0.20	8	0.80
Dundee City Churches	22	11	0.50	11	0.50	10	0.29	25	0.71
Kirk Ness	16	7	0.44	9	0.56	6	0.25	18	0.75
The Hirsel	173	85	0.44	88	0.56	150	0.45	181	0.55
Whithorn (Period V)	670	314	0.47	356	0.53	512	0.32	1093	0.68
Chapelhall	4	1	0.25	3	0.75	3	0.38	5	0.63
St. Mary’s Church, Kirkhill	148	44	0.30	104	0.70	56	0.20	226	0.80
Logies Lane	52	28	0.54	24	0.46	31	0.26	90	0.74
Hallow Hill	40	17	0.43	23	0.58	22	0.15	58	0.40
Aberdeen on the Green	106	60	0.57	46	0.43	62	0.32	131	0.68
St. Nicholas Church (Phase A)	189	110	0.58	79	0.42	243	0.51	235	0.49

Site Name	No. Sexed	Males	% Males	Females	% Females	No. Subadults	% Subadults	No. Adults	% Adults
Castle Park, Dunbar	20	11	0.63	9	0.45	7	0.26	20	0.74
Captain's Cabin, Dunbar	38	16	0.42	22	0.58	37	0.49	39	0.51
Longniddry, Four winds	7	1	0.14	6	0.75	1	0.13	7	0.88
Linlithgow	49	31	0.54	18	0.37	119	0.59	82	0.41
Isle of Ensay	186	86	0.46	100	0.54		0.00	186	0.45
Glasgow Cathedral	61	35	0.57	26	0.43	15	0.19	64	0.81
St. Giles (Period 2)	51	32	0.63	19	0.37	26	0.33	52	0.67
St. Trolla's Chapel	8	6	0.75	2	0.25	4	0.31	9	0.69
Jedburgh (Period II-IV)	18	18	1.00	0	0.00	0	0.00	23	1.00
Auldhame	100	58	0.58	42	0.42	81	0.33	161	0.67
Wharram Percy	351	211	0.60	140	0.40	327	0.48	360	0.52
St. Helen-on-the-Walls	732	338	0.46	394	0.54	291	0.27	777	0.73
Merton Priory	538	485	0.90	53	0.10	33	0.05	643	0.95
Barton-upon-Humber	1422	747	0.53	675	0.47	849	0.31	1875	0.68
Knowe of Skea	28	16	0.57	12	0.43	20	0.49	21	0.51

Appendix 14 Plague in medieval Scotland

Since sufferers from the bubonic or pneumonic plague died before the disease could affect their skeleton, this study did not include discussion of these diseases. However, since historical information records up to 1/3 of people in medieval Scotland died from the plague, a brief discussion is included here.

When the plague first arrived in Scotland in 1349 it was initially thought to be caused by sin, as other diseases were. In fact, when the plague was first seen by the Scottish armies in the Borders, it had infected English armies, and this was attributed to God's punishment (Hamilton 2003). However, it is thought that these same Scottish men later disseminated the plague throughout Scotland when returning home from war (Dingwall 2003, Hamilton 2003). According to Oram (2011), most people believed the plague was caused by divine wrath and saints such as the Virgin Mary, St. Sebastian, and St. Roch were prayed to for protection. Even after outbreaks had been occurring for over two hundred years, the first medical text printed in Scotland in 1568, which was about how to prevent and cure the plague, still listed repentance of sin and prayer as preventative measures. Therefore, when cases such as that at St Andrews Cathedral in 1362, where 24 canons died from the plague occurred, people were shocked, since the canons were 'men of ample education, circumspect in spiritual and in temporal matters, and upright and honourable in their way of life,' (Bower in Oram 2011) and should have been protected (Oram 2011). This tragedy was explained by some as an evil force that was attacking the Church and others thought it could be explained by God being unhappy with the Church (Oram 2011). And since the plague was thought to be caused by God's intervention or even evil forces it was not thought of as a disease that could be treated. However, after several outbreaks of the plague, views started changing about the cause and how it spread (Dingwall 2003, Hamilton 2003). Since most of the people that were affected, especially in the first outbreaks of the plague, were the poor, it was assumed it was their living arrangements and their poor hygiene that caused the plague and their goods, baggage, and clothes spread it. Although now we know that it is spread through by the bacterium *Yersinia pestis* carried by the fleas on rats and the housing situations for the poor as well as their usual malnourishment led to the high percentages of cases of the plague amongst the poor (Dingwall 2003, Roberts and Cox 2003,). We also know that there are two forms of the plague, bubonic and pneumonic. Bubonic requires the flea to bite the victim for transmission whereas the pneumonic form can transmit from infected humans to others by droplets from coughs or sneezes. The pneumonic form was virulent in Scotland in the winter since people generally crowded together indoors in these colder months (Fitch 1987).

In the fifteenth century the burghs attempted to take measures against the plague with prevention and containment by uses of quarantine, regulating the movement of people and goods, and the cleaning and fumigation of infected areas (Oram 2011). People infected with the plague were quarantined within their own houses, or sent to other quarantined areas. Their houses would then be cleansed and fumigated by burning herbs to cleanse the air (Ewan 2011). In 1452 an Act of Parliament allowed the burning down of any house that was infected with the plague (Hamilton 2003). Edinburgh, along with most other burghs as well, had regulations that prohibited people or goods from entering the burgh, stray dogs and cats were killed, schools and markets were closed, and the sale or even shaking out of second hand clothes was illegal (Comrie 1932). Those infected with the plague, or sometimes those who lived with infected family members, were taken to Burgh Muir for isolation and were forbidden to return into town unless they had a license from the Bailles (Comrie 1932, Ferguson 1948). Individuals who broke the burgh laws on quarantine were severely punished; some people were banished, and others were hung at gallows outside of the burgh to discourage from breaking the laws or trying to enter the burghs unlawfully. Dauid Duly, a tailor, had harboured his sick wife for two days in his house until she died from the plague, and without telling officers, went to mass at St. Giles Kirk on that Sunday, potentially infecting others. He was convicted and sentenced to be hung in front of his own door, but when the rope broke, the sentence was commuted to banishment from the town for life (Comrie 1932).

Unfortunately, the measures taken to prevent the spread of the plague were not effective, and could not have been with their lack of knowledge about contagions, and the plague still spread into the burghs with disastrous effects (Hamilton 2003). Sources claim that up to a third of the population of Scotland died from the plague, however other epidemics, such as typhoid, could have been misdiagnosed as the plague and included in these counts (Comrie 1932, Hamilton 2003, Oram 2011). The east coast of Scotland was affected the worst because its population was more densely settled and also due to overseas trade to Europe, where the plague was even more catastrophic. Vessels were put into quarantine for forty days where they were washed with sea water; for example, vessels arriving in Leith were sent to Incholm, Inchkeith, or the Isle of May for quarantine (Hamilton 2003). More heavily populated towns were affected particularly harshly, due to the close and unhygienic living arrangements that encouraged rat infestations. Oppositely, the Highlands of Scotland were hardly affected because of the more dispersed population (Hamilton 2003). There were similar efforts to isolate and quarantine syphilis in Scotland in 1497.