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A Stable Isotope Analysis Study for Dietary Reconstruction at the Multi-Period Site of Mesembria on the Black Sea.

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Supervisor: Dr Kath McSweeney/Dr Catriona Pickard

Abstract

Diet in historic populations has traditionally been reconstructed using ancient literary sources and artistic depictions and the focus has often been on elite banquets and religious restrictions surrounding food. According to these sources the diet from Classical times through to the Medieval period was centred around a 'Mediterranean triad' of grain, oil and wine, with the wealthy gaining access to a more varied diet, including meat and fish, and the men often getting preferential access to certain foods. It was also suggested that with the transition to Christianity, the fasting rules resulted in a change of diet towards a vegan diet or with the replacement of meat with fish, as meat was associated with sinfulness. Stable isotope analysis provides a more reliable means of determining what people were actually eating, and the study of dental pathology supplies useful supporting evidence as the teeth can be directly affected by the foods that are being consumed. The isotopic results indicate a predominantly C_3 terrestrial diet, as would be provided by the aforementioned triad of foods, primarily in the form of bread, but also including a significant terrestrial animal component, either in the form of meat, eggs or dairy, and a significant and variable marine element. The dental evidence demonstrated high levels of both caries and calculus, in accordance with this diet high in both carbohydrates and proteins. There was little difference in diet over time, although the Byzantine-Medieval period had elevated isotopic values indicating a slight increase in marine food consumption, presumably due to Christian fasting rules, as well as improvements in fishing technologies and food preservation techniques. The small Byzantine cemetery demonstrated elevated isotopic values and worse dental health compared to the main multi-period cemetery demonstrating a diet with increased proportions of seafood and cariogenic foods, possibly in the form of sweeteners such as dates and honey, and indicating a degree of exclusivity about the individuals buried there. There were no significant differences in diet identified between the sexes, age groups or burial types. These results and dietary reconstruction are comparable to those from similar sites that have undergone stable isotope analysis, including other Greek colonies and coastal Byzantine sites, indicating a general 'Mediterranean diet' over time and space.

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Chapter 1: Introduction

The study of past diets has always been of interest to scholars due to its inherent centrality to the everyday lives of all people as a means of subsistence, illustrating the availability of resources and technologies to various populations, as well as being a means of expression whether it be in celebratory banquets or in abstinence, by fasting from specific foodstuffs. The need for food has affected the formation of human society in its most integral components, such as settlement locations and distributions, population sizes, social (and later political and economic) organisation and the development of technology (Bonsall et al., 1997).

Overview

This study focuses on the population of Mesembria on the Black Sea, using skeletal material from two cemeteries to carry out stable isotope analysis for dietary reconstruction. The main cemetery (AHM), located on the mainland and now incorporated into the New Town of Nessebar (A on Fig.1), features burials from the Classical, Hellenistic, Early Byzantine and Medieval periods. Despite the continued occupation of the site under the Roman Empire there were no Roman burials excavated from this cemetery. Additionally there were some burials which could not be assigned dates due to their lack of artefacts, which will need to be analysed for ^{14}C dating, but are known to be non-modern and are referred to as Antiquity. The cemetery site was excavated during three seasons (2008-2010) by the National Institute of Archaeology and Museum, Sofia, and the Museum of Ancient Nessebar and the analysis of the skeletal material is ongoing by the team from the University of Edinburgh. There was also a small cemetery (OT) excavated in 2011 on Kraibrezna Street in the Old Town of Nessebar on the island (B on Fig.1). These burials were of Byzantine date and associated with the Basilica of the Holy Mother Eleusa.

Figure 1: Map of Nessebar indicating the cemetery sites. https://maps.google.co.uk/

History of Mesembria

Mesembria was originally a Thracian settlement from the 12th to 6th centuries BC, located on the Black Sea coast of modern Bulgaria, which is now the modern town and World Heritage Site of Nessebar. The site was established as a Greek colony towards the end of the 6th century BC by Megaran Greeks, who maintained the basic etymology of the Thracian name for the city, thought to have been derived from the eponymous founder of Mesembria, Melsas (Hind, 1983-1984, 1992-1993; Nawotka, 1994; Chiekova, 2007; Petropoulos, 2008). The site remained in continuous occupation throughout the Hellenistic period and Roman Empire, becoming a religious centre under the Byzantine Empire, with its numerous churches for which it is now protected as a centre of world culture, and afterwards through the Medieval and modern times to the present day (Hind, 1992-1993). Mesembria was a busy port town which came under the control of a variety of different powers, as a Greek colony, then incorporated into the Roman Empire and later as a part of the Bulgarian state, and would undoubtedly have had immigrants and various influxes of newcomers at times (Ballard et al., 2001; Boyan, 2008). Despite this influx of new peoples and cultures, it is likely that the majority of the people remained constant, with the new cultural practices being smoothly integrated with the local ones as was observed by the continuation of Thracian culture alongside Greek, observed in the extant artefacts and even in the adoption of Thracian imagery, with what is presumed to be Melsas, on the Greek coinage minted in Mesembria (Hind, 1992-1993; Nawotka, 1994; Chiekova, 2007). Mesembria did, however, forge close ties with Athens as exhibited by the large quantities of red and black figure ware discovered and the city's inclusion in the Delian League, as testified by a silver coin from the late 5th century BC (Petropoulos, 2008). In the Late Roman and Early Byzantine periods Mesembria both flourished as a religious centre, illustrated by the vast numbers of churches constructed, and came under threat from 'barbarian' tribes, alongside much of the rest of the Roman Empire (Boyan, 2008). Mesembria became a military port in the 7th century AD during the Byzantine-Bulgarian wars and possession of the city switched back and forth until the 10th century falling under the Bulgarian kingdom but all the time remaining an important cultural and religious centre forging contacts between Byzantium and Bulgaria (Boyan, 2008).

Aims and Objectives

This is a diachronic study of diet in the population of Mesembria using stable carbon and nitrogen isotopes. There have not been many studies of stable isotopes for dietary reconstruction carried out in the Western Black Sea region, with the few examples including the Copper Age study at Varna and Durankulak (Honch et al., 2006) and another of the Greek colony site at Apollonia (Keenleyside et al., 2006), south of Mesembria and also on the coast. Besides Apollonia, the only other Greek colony site that has previously undergone stable isotope analysis to investigate diet is Metaponto in Italy (Henneberg et al., 1999; Henneberg and Henneberg, 2003). This study will therefore be of interest to determine how much the diet of Greek colonies was influenced by their location, native culture, available resources and links of trade and cultural communications with Athens, Megara and the rest of the Greek world. There are also relatively few studies of change in diet over time within populations due to the lack of materials, either as a result of poor preservation or because cemeteries did not remain in use (Vika, 2011; Fuller et al., 2012). This study has the potential therefore to illustrate interesting changes over time, such as people's interaction with the sea, and changes in the use of crops such as the introduction of millet, which appears to have grown more commonly elsewhere in Europe in the medieval period (Bonsall et al., 2004; Reitsema et al., 2010).

The study will set Mesembrian diet within its wider geographical context of Mediterranean, coastal, Black Sea and Greek colonial diets with comparative studies from around the Graeco-Roman world of antiquity and Medieval Europe. The primary aim is to identify the content of the Mesembrian diet. This will involve assessing the importance of marine and terrestrial components in the diet which will be particularly interesting due to the site's immediate proximity to the sea and the mixed attitudes towards seafood in antiquity (Purcell, 1995). It will also identify the proportions of plant foods and animal products being consumed. The study aims to observe any changes in diet over time between the Classical (5^{th}-4^{th} century B.C.), Hellenistic (4^{th}-2^{nd} century B.C.), Early Byzantine (5^{th}-7^{th} century A.D.), Medieval (8^{th}-14^{th} century A.D.) and Antiquity periods, assigned to the burials by the excavation team based on associated artefacts, as well as by time and space with the comparison of the Kraibrezna burials. Intra-population variation will also be observed by age, sex and associated burial goods as a possible indicator of social status. A holistic approach to the study of past diet is essential; therefore, to compliment the stable isotopic findings, comparisons will be made with ancient literary texts, archaeological evidence and the dental analysis from the site.

After the overview and aims of the project have been laid out in this introductory Chapter 1, Chapter 2 will consist of a literary review, taking into consideration the background and past findings of stable isotope analysis, similar projects from which comparisons to the Mesembrian population could be drawn and an overview of diet in the Mediterranean World as known from the ancient literary texts and archaeological evidence. Chapter 3 will focus on a study of the dentition from the two cemeteries under analysis as another useful indicator of diet, which will provide a useful comparison for the stable isotope results from within the same population. Chapter 4 will lay out the materials and methods used for collagen extraction and stable isotope analysis, as well as general skeletal analysis. The results of this process will be presented in Chapter 5, then Chapter 6 will discuss these results in terms of their significance within the wider study and draw conclusions on the diet and its variation at Mesembria.

Chapter 2: Literature Review

Literary and Archaeological Evidence for Diet in the Mediterranean World

A great deal of current knowledge of diet in antiquity through to Medieval times from the region that was once the Greek world and the Roman and Byzantine Empires, or what could be referred to as the wider Mediterranean world, has come from ancient literary texts. Information can be taken from literature on the appreciation of food, such as Athenaeus' *Deipnosophistae* and Apicius' *The Art of Cooking*, on the medical benefits of foods from physicians, such as Hippocrates and in Galen's *On the Properties of Foodstuffs*, and in agricultural accounts from Roman writers, including Cato, Varro and Collumella (Prowse et al., 2004; Keenleyside et al., 2009). Many of the surviving accounts were written in Hellenistic and Roman times but most likely drew some of their material from earlier accounts from Classical Greece (Garnsey, 1999). The sources collectively agree upon a 'Mediterranean triad' of grain, olive oil and wine which formed the basis of most diets and which were supplemented in varying proportions, depending on location, social class, sex and site type, by legumes, fruit, vegetables, meat, dairy, eggs, seafood, nuts and honey (Faas, 1994; King, 1999; MacKinnon, 2004). Meat and fish have sometimes been identified as highly valued and definitive of a rich man's table, although this was not always the case and many people simply lived off what was available and therefore variation in meat consumption is more likely to have been seasonal (Wilkins and Hill, 2006). The Greeks on the Black Sea coast created *gáros* or *garum* (fish sauce) which was the product of fermentation of fish thus preserving a marine product and making it more widely available (Dalby, 1996). Sex differences in diet also seemed to revolve largely around meat with males being given preferential access to luxurious and nourishing foods (Garnsey, 1999).

In the Byzantine and Medieval periods the sources were similar, from physicians' comments and travellers' tales to inscriptions on the taxation of food records of dietary regimes in monasteries (Bourbou and Richards, 2007; Bourbou, 2010). The written sources are increasingly focused on church calendars and monastic directions imposing fasting (Salamon et al. 2008); however, some histories and travellers' accounts have survived, such as Niketas Choniates' *Histories*, Evliya Çelebi's *Travels* and Liudprand's *Mission to Constantinople*. Some authors even included lists of specific foods that took their interest, such as the available wild and cultivated plant types or breeds of fish (Garvie-Lok, 2001). The diet appears to have been consistent with the earlier periods, with the staples being oil, wine and grain, the latter being consumed as bread and forming the bulk of the diet, as had also been attested to in the earlier periods (Dalby, 1996; Bourbou and Richards, 2007). The more privileged grain remained wheat, which was known to be taxed at higher rate from inscriptions in both Roman and Medieval times, while barley, oats and millet were considered suitable for army rations, animal fodder and the poor, with the latter reportedly grown in case of the failure of the preferred crops (Garnsey, 1988; Gallant, 1991). The literary accounts on millet are somewhat varied, seeming to indicate that its use varied by region; as it is isotopically distinct as a C_4 plant, its economic position and usage in the Mediterranean world could be better revealed by stable isotope analysis (Garvie-Lok, 2001). Wine and olive oil remained staples in the Byzantine and Medieval diets and were even included in the basic rations given to monks, although they were avoided during periods of fasting and an excess of wine was observed as a sign of moral weakness (Dembinska, 1985; Garvie-Lok, 2001). They featured in both rich and poor diets, with a basic meal of bread and wine seen as diet of poverty, although different qualities of wine for the wealthy and powerful and for the poor and humble are reported in the *Prodromic Poems* (Jeanselme and Oeconomos, 1923; Luidprand, 1993; Garvie-Lok, 2001). One of the greatest social differences in diet was meat, which was considered to be a luxury supplement. However, one of the weaknesses of literary accounts for determining diet is the use of food as a rhetorical device and it is unclear how much such references allude to what people actually ate. While meat in the Classical period was associated with ritual sacrifice and therefore civilisation, it was often used as a social metaphor for sinfulness and a lack of restraint in Christian symbolism (Shaw, 1998; Garvie-Lok, 2001). Although the accounts indicate that the staples remained the same from Classical to Medieval times, there are appearances of new foodstuffs too. The brief mention of the medical use of cane sugar in the *Prodromic Poems* attests to its presence in the diet but suggests that it was still fairly uncommon in the Byzantine Era (Garvie-Lok, 2001).

The archaeological record supports the collection of food types set out in the literary texts with evidence from plant remains, animal bones, food preparation utensils, storage vessels, food production and fishing equipment and residues of funerary grave offerings (Keenleyside, 2008). This enables some variation to be distinguished between specific sites as well as generally over time. The evidence from middens of animal remains indicates that sheep and goats were the main meat products in the Classical Mediterranean, whereas in the Roman and Byzantine periods pigs had bypassed the caprines as the main meat source (King, 1999; MacKinnon, 2004; Keenleyside et al., 2006). Regional variation was also apparent, illustrating that availability of resources was an important factor, with fish bones and fishing equipment being restricted to coastal and riverside sites and camel bones appearing in midden piles at the Roman site of Leptiminus in Tunisia (Keenleyside et al., 2009; Vika and Theodoropoulou, 2012). Although these aspects of archaeology are beginning to receive more attention, traditionally Classical, Hellenistic, Roman and Byzantine archaeology have been dominated by a focus on art and architecture, biasing excavation and publication efforts away from middens and habitation sites (Garvie-Lok, 2001). Additionally, excavation techniques have often not been favourable for the recovery of bones, particularly fish bones as there is a rarity of wet and dry sieving in traditional practices, and therefore the archaeological record to date, without the use of stable isotope analysis, is uninformative as an indicator of fish consumption (Gallant, 1985; Payne, 1985; Snodgrass, 1987; Powell, 1996).

Skeletal and Dental Evidence for Diet: possibilities and limitations

Skeletal indicators of diet are generally reflective of nutritional deficiencies; however, such indicators are rarely exclusively caused by dietary factors. For example, lines of arrested growth (Harris lines) at bone diaphyses, in a similar role to dental linear enamel hypoplasias, may be caused by periods of starvation or malnutrition but the stress may also be caused by pathological stress (Brothwell, 1981; Piontek et al., 2001). Some metabolic diseases, such as rickets, osteomalacia, iron deficiency anaemia – as manifested by porotic hyperostosis and cribra orbitalia – and scurvy, can be indicative of deficiencies in the diet, but they can also be caused by pathological factors, including inadequate absorption of various vitamins and minerals (Mays, 1998). While porotic hyperostosis and cribra orbitalia have been traditionally assigned as indicators of iron deficiency anaemia (El-Najjar et al., 1976), more recent research has put forward alternative causes, including vitamin B12 deficiency or endemic malaria (Brickley, 2000). Robusticity and stature have also been considered as factors reflecting on the adequacy of the diet (Mays, 1998); however, none of these indicators can be taken exclusively as dietary and it is often difficult to identify the actual cause. Additionally, as the present study focuses on what people were eating, rather than the adequacy of the diet and general health of the population, these skeletal factors are not focused on here.

Many studies have used dental pathologies as indicators of diet; for some they are the central focus of research, for others they are used in conjunction with stable isotope analysis as this study has done. Details of the nature of dental pathologies used in this study and how these reflect diet can be found in Chapter 3, but this is a review of how studies have used such information to interpret diet and the possibilities and limitations of such studies. Dental pathologies can be used to identify variation within the population, such as between the sexes. In populations from both Bronze Age Lerna and the Classical colony at Apollonia, where dental studies were done to support stable isotope analysis, a C_3 terrestrial diet predominated, but with higher caries in females and higher calculus in males at both sites. Conclusions were drawn, based on the dental evidence, that the women had a rich carbohydrate diet while the men consumed more protein, a difference which was not detected isotopically (Keenleyside et al., 2006; Keenleyside, 2008; Triantaphyllou et al., 2008). At the Greek colony of Metaponto in Italy the dental evidence was used to identify different lifestyles between the urban and rural environments with the rural population suffering less from caries, hypoplasia and periodontal disease (Henneberg, 1998). However, the dental evidence alone cannot identify the cause of this difference and the stable isotope analysis identified a very similar balanced, variable diet at both sites, even with fairly similar amounts of seafood, with the coastal, urban site having less than 10% more on average (Henneberg et al., 1999). However, upon closer inspection of the isotopic results, it is evident that there was a more varied socioeconomic range in the city, with wider ranging values of the marine contribution in the diet and with males having generally higher marine proportions, suggesting some division of foodstuffs dependent perhaps on different social roles or status. It is possible that the slightly higher urban fish consumption helped to prevent caries due to the micro-elements, such as fluoride and strontium present in high quantities in seafood, that can prevent caries (Henneberg and Henneberg, 2003). However, this does not seem to adequately explain the high caries frequencies of both populations and demonstrates the limitations of the interpretation of dental data.

It has been a popular feature of dental studies to observe a change in diet over time as indicative of cultural change. This was observed in the transition from the Mesolithic to Neolithic which has traditionally been characterised by a change in subsistence patterns from hunter-gatherer to agriculture. Generally hunter-gatherer populations have negligible levels of caries, as demonstrated by pre-European contact Greenland Eskimos who subsisted almost entirely off fish and meat (Pedersen, 1947). The transition is visible in a worldwide study of average caries rates which indicated 1.72% in hunter-gatherers to 4.37% at the advent of agriculture in hunter-gatherer populations with some plant cultivation (Turner, 1979). However, dental evidence also demonstrates that this dietary change was not wholesale, as Lillie and Richards' (2000) study of the Mesolithic to Neolithic shift in the Ukraine showed an absence of caries and prevalence of calculus in both periods, demonstrative of fisher-hunter-gatherer diets throughout. In populations from both Italy and Croatia, a change in alimentary habits was observed between the Late Antique and Early Medieval periods in terms of greater wear in the later period, suggesting more vigorous mastication due to the consumption of hard, fibrous foods or perhaps different food preparation techniques (Belcastro et al., 2007; Šlaus et al., 2011). For the Italian populations there were few other differences and it was therefore concluded that there was substantial continuity in diet but with increased meat consumption in the Early Medieval period. The Croatian population experienced general dental deterioration with higher caries rates – alongside abscesses, antemortem tooth loss and alveolar resorption – suggesting higher quantities of carbohydrates in the later diet and therefore the ‘hard, fibrous’ foods cannot in this case be interpreted as meat. This demonstrates some inconsistencies in the interpretation of dental pathologies. It is possible that the increased wear came from non-dietary activity, such as making fishing nets, as males had significantly higher levels of anterior wear than females and the general dental deterioration due to dietary change as a result of political, social, economic and religious change (Šlaus et al., 2011). The Italian population’s largely constant diet is perhaps due to its rural situation in an area characterised even in pre-Roman times by an agricultural economy and therefore may illustrate ecological factors taking precedence over cultural, social and economic ones (Belcastro et al., 2007). Interpretation of dental pathologies can be difficult as similar manifestations can result from different causes and the evidence can often be conflicting; however, when used with other forms of evidence it can strengthen the evidence for diet and even identify patterns not distinguishable from the other forms of evidence.

Basic Principles of Stable Isotope Analysis for Dietary Reconstruction

Stable isotope analysis of bone collagen can be used in dietary studies of human populations to observe changes in subsistence (Bonsall et al., 1997), population migrations and coastal-inland mobility (Fischer et al., 2007; Hakenbeck et al., 2010; Lightfoot et al., 2012), within-population variation in diet over time or by age, sex, burial type (Keenleyside et al., 2006; Reitsema and Vercellotti, 2012) and urban versus rural (Henneberg et al., 1999), and weaning ages of infants (Mays et al. 2002). This is done by analysing the ratios of carbon and nitrogen isotopes, $^{13}C/^{12}C$ and $^{15}N/^{14}N$, expressed as $\delta^{13}C$ and $\delta^{15}N$ in the collagen. Variation of isotopic signatures occurs due to fractionation, which is the change in isotopic ratios caused by chemical processes such as photosynthesis and metabolism (Van der Merwe, 1982; Tykot, 2006). Therefore, foods have different isotopic characteristics due to the slightly different masses of the isotopes of the same element, which leads to different rates of reaction (DeNiro, 1987). Stable isotopes, unlike radioactive ^{14}C used in carbon dating, do not decay but remain fixed and are able to survive in bone tissue (Van der Merwe, 1982). As bone has a slow turnover rate in adults, it is able to reflect the average diet of an individual over much of their lifetime (Chisholm et al., 1983). $\delta^{13}C$ and $\delta^{15}N$ are calculated in any sample by comparing the sample values against internationally recognised fixed standards, a Cretaceous marine fossil, Peedee Belamnite (PDB), for carbon and AIR (atmospheric N_2) for nitrogen, and measured in parts per thousand or per mil (‰) (Tykot, 2006). Different dietary elements are therefore identified by different photosynthetic pathways in C_3 and C_4 plants which deplete the carbon isotopes to different extents (Fig.2); C_3 plants (-33 to -22‰) deplete the $\delta^{13}C$ from the atmosphere (~ -7‰) during photosynthesis by more than C_4 plants (-16 to -9‰). Most food plants are C_3, including wheat, barley, rice, legumes, tubers and nuts, while C_4 plants, such as maize, sugarcane, sorghum and millet, are less common, particularly in Europe (Van der Merwe, 1982; DeNiro, 1987). With the consumption of these plants, and each stage of further metabolism as the animals that eat the plants are in turn eaten, the $\delta^{13}C$ values are enriched (DeNiro, 1987). The different values for marine and terrestrial organisms are due to the varied carbon content of the atmosphere and the sea, with marine animals additionally usually having elevated $\delta^{15}N$ values

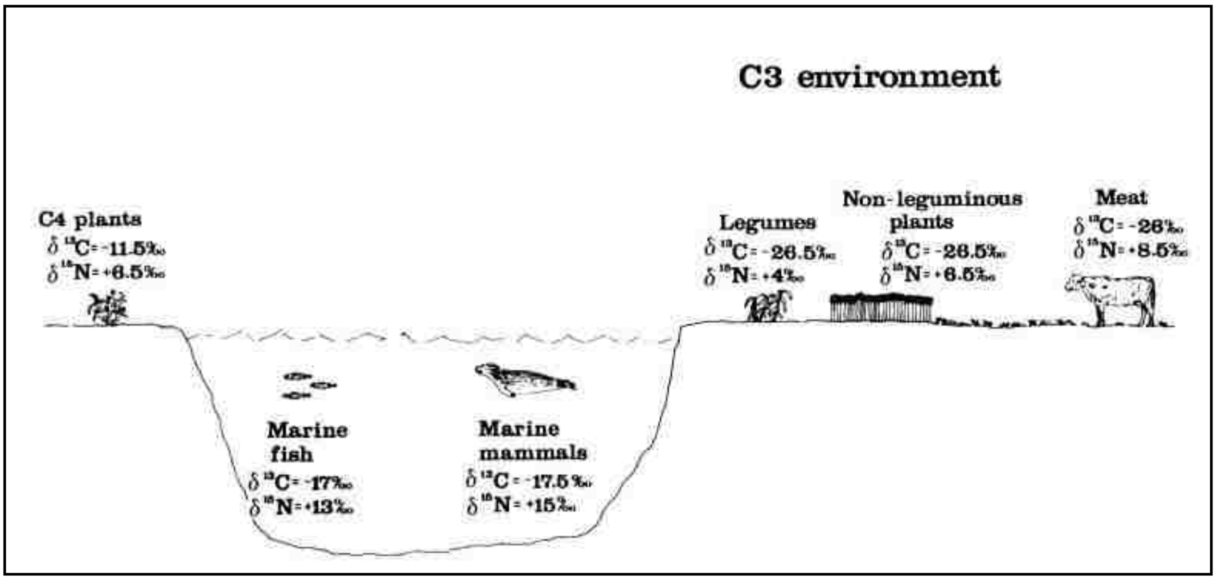

Figure 2: Representation of typical isotopic values of marine and terrestrial, plant and animal and C3 and C4 foods (Figure 9.1 in Mays, 1998).

compared to terrestrial ones. The varying trophic levels throughout the food chain, indicated by a uniform increase in $\delta^{15}N$ of about 3‰ at each level, enable herbivores, omnivores and carnivores to be distinguished (Tykot, 2006; Hedges and Reynard, 2007).

Past Studies of Stable Isotope Analysis for Dietary Reconstruction

The use of stable isotope analysis for the reconstruction of the diets of past peoples has revolutionised the way in which dietary, food and subsistence studies are examined. Traditionally, stable carbon and nitrogen isotope analysis has been used to great effect in prehistoric studies investigating the major shift in subsistence patterns at the Mesolithic-Neolithic transition from hunter-gather nomadic groups to agricultural sedentary populations (Lubell et al., 1994; Bonsall et al., 1997; Lillie and Richards, 2000; Milner et al., 2004; Eriksson et al., 2008). Its growing popularity for scrutinising the diet of historic populations has enabled new depths of detail to be brought to light on what is already known of diet from literary accounts and archaeology. While the value of these disciplines' contribution to dietary studies cannot be overlooked, it is often the case that literary accounts and artistic representations will only depict the foodstuffs being consumed by the elite classes and at rich banquets, or alternatively, in the case of fasting rituals, foods that were avoided, while neglecting the daily diet of the majority of the population (Keenleyside et al., 2006; Bourbou, 2010). Additionally, there are many branches of archaeology, such as palaeobotanical, archaeozoological, osteological and basic artefactual studies, as mentioned above, which can analyse such features as food deposits and plant remains, midden heaps and animal burials, human palaeopathology and demographics, and food or drink vessels and artistic depictions respectively, which enable a broader view of diet throughout the entire population and identify the range of specific foodstuffs available to compliment the stable isotopic results (Garnsey, 1999; Keenleyside, 2008; Triantaphyllou et al., 2008).

Stable isotope analysis of human bone tissue, however, enables the actual diets of individuals and populations to be identified, including the quantities of different food types consumed, as the isotopic ratios of food types are preserved in the consumer's tissue (Prowse et al., 2004; Petroutsa and Manolis, 2010; Reitsema et al., 2010). Therefore, individuals whose diets consisted of large proportions of prestigious foodstuffs, such as meat or seafood, can be differentiated from those eating only plant foods (Purcell, 1995; MacKinnon, 2004; Tykot, 2006). Stable isotope analysis cannot, however, indicate specific species of plants or animals being consumed from the human bone collagen, if samples of flora and fauna are not available from the specific site, and some differences in diets, for example between men and women, may be subtle and not isotopically detectable if the different foodstuffs have similar isotopic signatures, as would be the case with different cuts of meat (Bourbou and Richards, 2007; Keenleyside, 2008). Similarly, factors such as freshwater fish can go undetected in the diet due to their middling values between marine and terrestrial signatures (Hedges and Reynard, 2007); values can also become confusing when terrestrial mammals are consuming marine plants, as was found to be the case with sheep eating seaweed on North Ronaldsay Island, Orkney (Balasse et al., 2005); or C_4 plant and fish $\delta^{13}C$ signatures can be confused, although the only C_4 plant found in Europe was millet and it was uncommon until the Medieval period (Reitsema et al., 2010; Vika and Theodoropoulou, 2012). Inter- and intra-population comparisons can be made, taking into consideration changes over time or space or differences by age, sex or burial type (Richards et al., 1998; Henneberg et al., 1999; Prowse et al. 2005; Keenleyside et al., 2009). Some studies have even expanded their focus beyond just diet to consider migrations of individuals or populations, which can be identified in the different isotopic signatures of plants being consumed from different climatic regions, as was the case with three individuals from the Poundbury Camp Cemetery on the south coast of England (Richards et al., 1998), or with the use of strontium and oxygen isotopes (Budd et al., 2004; Tafuri et al., 2006; Chenery et al., 2010; Keenleyside et al., 2011).

Stable Isotopic Studies of Greek Colony Populations

Apollonia was a remarkably similar site to Mesembria as it was also a Greek colony located along the same stretch of coastline on the Black Sea, with a busy harbour and flourishing trade centre. Keenleyside's work on the skeletal material at Apollonia, particularly that on stable isotope analysis and dentition for dietary reconstruction, will therefore provide a useful comparison to the Mesembrian material (Keenleyside and Panayotova, 2005; Keenleyside et al., 2006; Keenleyside, 2008; Keenleyside et al., 2011). The stable isotope analysis varied somewhat from this study in that it analysed bone apatite as well as collagen but the conclusions were largely based on the collagen as there was some indication of diagenesis in the apatite (Keenleyside et al., 2006). Keenleyside concluded that the population of Apollonia consumed a mixed diet of marine and terrestrial foods, with no significant variation by age, sex or burial type, although in revisiting the topic in her study of dental pathology she suggests that there may have been subtle dietary differences between the sexes (Keenleyside et al., 2006; Keenleyside, 2008). These results were observed to have been remarkably similar to the 1st century AD Roman site of Isola Sacra on the Mediterranean which was interpreted as indicating that geography and availability of resources were more important factors for diet than history or local culture and also confirms what the literary texts illustrate of little change over time across the Mediterranean world (Prowse et al., 2004; Keenleyside et al., 2006). Keenleyside's recent study of oxygen isotopes identified 'non-locals' in the population, which is not surprising considering Apollonia's position as a thriving centre of trade (Keenleyside et al., 2011).

Although this study of Mesembria does not look at oxygen isotopes, it is important to consider that individuals with remarkably different diets could be immigrants from outside the region.

The only other Greek colony site to have undergone stable isotope analysis is Metaponto in Italy, with the material taken from two 7th to 2nd century BC cemetery sites, coastal urban Crucina and rural inland (by 3.5km) Pantanello (Henneberg et al., 1999). As another coastal site surrounded by rich agricultural land, the diet of both cemeteries indicated a mixed marine-terrestrial diet with high proportions of C_3 plants, terrestrial animals and seafood (Henneberg and Henneberg, 2003). The likelihood of the majority of C_3 plants in the diet being starchy grains is supported by the high caries frequencies. The difference in seafood intake between the two cemeteries was only about 10%, but rather than being an indication of motivations beyond the availability of resources, this illustrates the close connections, communications and exchanges within the city-state, between the city and its hinterland (Henneberg et al., 1999). Variation between the sexes was indentified with the lowest values of marine protein intake among females (Henneberg and Henneberg, 2003).

Stable Isotopic Reconstruction of Byzantine and Medieval Diets

Salamon's study of change in the Mediterranean diet between the early and late medieval periods is somewhat limited in that it only uses data from two inland sites in western Italy (Salamon et al., 2008). Additionally, the significant change observed between these diets is based upon the new fishing industry in the Atlantic and advances in the preservation of fish, allowing inland sites access to fish which had not been widely available before. This is not as relevant for coastal sites which had always had easier access to fresh fish and it is unclear whether this new fish trade expanded further east across the Mediterranean as the majority of stable isotopic studies from the period were focused on Northern Europe (Fuller et al., 2003; Polet and Katzenberg, 2003; Müldner and Richards, 2005; Barrett et al., 2011). What is interesting, however, is the concept that this increase in fishing may not have solely been a product of supply and new technologies but rather a product of demand due to Christian fasting practices which covered a third of all days in a year and permitted the replacement of meat with fish (Barrett et al., 2011). This is supported by the isotopic studies of monasteries in England and Belgium where the monks appear to have consumed higher levels of marine foods than the lay people (Polet and Katzenberg, 2003; Müldner and Richards, 2007). This factor would undoubtedly have been relevant for the religious centre that Mesembria became during the Byzantine period; however, it may not have constituted a change from earlier times if fish consumption was already high.

Bourbou and Richards' (2007) examination of the 11th century AD site of Kastella on Crete did not show high levels of fish consumption other than in three male individuals out of a total sample size of 26. Generally, a C_3-based diet was identified with a surprisingly high contribution of animal protein from meat, dairy or eggs and with the goat data suggesting that the fodder being consumed had a C_4 or marine plant element from either millet or seaweed respectively. Further study of Greek Byzantine populations have shown a similar diet of C_3 plants with significant amounts of animal protein but also, notably, evidence of marine protein consumption at both coastal and inland sites (Bourbou et al., 2011). Garvie-Lok's (2001) thesis on diet from ten medieval and early-modern Greek cemeteries also found a predominantly C_3-based diet with varied but small contributions of C_4 elements. She proposed the possibility of bread being made from a 2:1 C_3/C_4 grain mixture;

however, with unknown amounts of olive oil and cane sugar acting as distortion factors, it is difficult to calculate proportions of C_4 plants in the diet (Garvie-Lok, 2001). The ten cemeteries used were a mixture of coastal, inland and island sites, none of which showed a significant contribution of marine resources, although the two island populations appeared to have consumed some marine elements. Even with trade links importing dried or salted fish inland, it is unlikely they could have consumed the same amounts as the coastal populations. The high $\delta^{15}N$ values were therefore ascribed to chicken eggs, which would have had the same $\delta^{13}C$ values as terrestrial fauna but elevated $\delta^{15}N$ values (Garvie-Lok, 2001). Rather than assuming that these sites did not observe Christian fasting, it is possible that they replaced meat with dairy products and eggs rather than fish.

While variations in diet between sites of the same period can be accredited to any number of factors from location and available resources to cultural and religious reasons, it remains difficult to be certain of current speculations as there are still relatively few studies based around stable isotope analysis for dietary reconstruction. Those that do exist are often geographically sporadic and their sample sizes are frequently small. This study takes a step in the right direction in adding another population to the growing database of dietary knowledge but for a better understanding of widespread dietary patterns more and larger studies must be conducted.

Chapter 3: Dentition and Diet

Dental Pathologies as Indicators of Diet

Although stable isotope analysis can paint a very accurate picture of food types actually being eaten by individuals, dental pathologies are another primary source of information for diet as everything being eaten comes into direct contact with the dentition (Hillson, 2005). The relationship between diet and oral health of past populations remains the subject of debate due to other factors, such as genetic variability and non-dietary environmental and social influences, also contributing to conditions within the mouth (Larsen, 1997; Triantaphyllou et al., 2008). However, it is generally accepted that diet is a contributing, and often the main, factor (Hillson, 2005) and can therefore be used to support the stable isotope analysis results in interpreting the diet of the population of Mesembria.

Calculus and caries are the most useful indicators of diet as they are believed to be indicative of proportions of protein and carbohydrate intake. Caries is manifested by the loss of mineral in the form of cavities which occurs in an acidic environment caused by starches and sugars. Calculus, on the other hand, is a build-up of mineralised plaque caused by alkaline conditions, often due to a high protein diet (Hillson, 1979). While the two are often thought to be mutually exclusive (Hillson, 1979), as makes sense due to their affiliations with such opposing pH conditions, the slight inverse relationship is not strong and in an individual jaw it is not uncommon to see both caries and calculus (Hillson, 2000). Abscesses are caused by inflammation of the pulp cavity which is exposed to microorganisms in the mouth either by cavities, wear or fractures and leads to a build-up of pus at the root apex which is released through the alveolar process by the formation of a granuloma or cyst (Hillson, 2000).

It is, however, important to point out that these are greatly simplified explanations for the development of these diseases. Lieverse's (1999) study, for example, focuses on the aetiology of calculus formation, which she accuses of so often being oversimplified in concentrating on the direct contact of food rather than the diet's effect on the mineral content of saliva or the chewing effect on salivary rates, in addition to non-dietary factors such as using the teeth as tools and habitual chewing. Such complications mean that high calculus and low caries rates can prevail in predominantly carbohydrate or predominantly protein diets (Keenleyside, 2008), which makes an interpretation of diet difficult without supporting evidence.

Dental pathologies are age progressive by nature as enamel cannot remodel, as is the case with the progressive demineralisation of caries. Similarly, calculus is a progressive accumulation of mineralised plaque (Hillson, 2000). It is therefore to be expected that this will also prove to be the case in the Mesembrian population. Although less inherently linked to the nature of the pathologies, sex differences are also often observed, most commonly with women being found to have higher rates of caries. This is interpreted as being due to men having had greater access to protein sources such as meat and fish, while the female diet consisted of more cariogenic carbohydrates (Larsen, 1983). This is often found to be the case in prehistoric early agricultural societies (Temple and Larsen, 2007; Gamza and Irish, 2010); meanwhile, despite the ancient literature for various cultures suggesting differential diets by sex, it has often not proved to be the case for historic populations that have undergone a dental examination for the purposes of reconstructing diet (Keenleyside, 2008; Esclassan et al., 2009).

Materials

174 individuals (3030 teeth) were used from the cemeteries of Mesembria; however, there is an extremely uneven distribution over time, with 104 of those individuals being from Medieval contexts, 30 of Hellenistic date, 16 from the Early Byzantine period and only 8 each from the Classical period, Antiquity group and Kraibrezna Street cemetery. The sample size was limited by preservation and poor excavation, with many dentitions missing entirely and any with fewer than 10 teeth were excluded as being unrepresentative. As the study is focusing on adult diet and juveniles are not included in the stable isotope analysis sample, they have also been excluded from the dental study.

Methods

These individuals have been examined for caries, calculus and periapical abscesses on a simple present or absent basis and are recorded by time period, age and sex. Caries is recorded by both individual (Table 1) and tooth (Table 2). Calculus is only recorded by individual (Table 3) as the original skeletal examination did not record its occurrence by tooth. Similarly, abscesses are only noted by individual (Table 4) as the skeletal inventories did not mention numbers of sockets present. Although antemortem tooth loss would also provide useful data, without the complete dentition, maxilla and mandible, it was often not possible to distinguish from postmortem loss. Tooth wear can also be a useful indicator of how hard or soft a diet is and can contribute to caries and abscess development, but as it was also used for age estimation this produces a circular argument and is not included in this study (Hillson, 2000). All statistical analyses were performed using GraphPad Software or by hand, using a manual calculator.

Problems of Preservation and Sample Size

Problems always lie in the preservation, excavation, storage and cleaning of teeth. Often, if in poor condition, they will not be recognised as teeth, and if the soil around the jaw is not sieved, loose teeth can easily be missed, particularly anterior, single-rooted teeth which can become dislodged most easily. Teeth can easily be cracked or chipped if top and bottom jaws are stored in occlusion and calculus deposits can be dislodged easily either in the ground or during excavation, cleaning and storage (Hillson, 2000). As is commonly an issue with archaeological populations, this study suffers from a small sample size and particularly its skewed spread across the different groups. This is presumably a result of a mixture of poor preservation and incomplete excavation, as well as inconsistent recording methods which meant the exclusion of more individuals and pathologies from being studied.

	Age	Males	%	Females	%	Indeterm.	%	Total	%
Classical									
	<30	0/2	0	0/2	0	0/1	0	0/5	0
	30-45	1/2	50	0/0	0	0/0	0	1/2	50
	45<	1/1	100	0/0	0	0/0	0	1/1	100
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		2/5	40	0/2	0	0/1	0	2/8	25
Hellenistic									
	<30	5/8	62.5	2/4	50	0/3	0	7/15	46.67
	30-45	0/3	0	0/1	0	0/0	0	0/4	0
	45<	0/1	0	2/3	66.67	0/2	0	2/6	33.33
	Unknown	0/0	0	0/0	0	2/5	40	2/5	40
Total		5/12	41.67	4/8	50	2/10	20	11/30	36.67
Early Byzantine									
	<30	3/4	75	0/3	0	1/2	50	4/9	44.44
	30-45	1/3	33.33	0/0	0	1/1	100	2/4	50
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	1/3	33.33	0/0	0	0/0	0	1/3	33.33
Total		5/10	50	0/3	0	2/3	66.67	7/16	43.75
Medieval									
	<30	8/13	61.15	4/17	23.53	4/12	33.33	16/42	38.1
	30-45	7/14	50	5/9	55.56	1/1	100	13/24	54.17
	45<	7/10	70	1/3	33.33	1/1	100	9/14	64.29
	Unknown	3/7	42.86	2/3	66.67	7/14	50	12/24	50
Total		25/44	56.82	12/32	37.5	13/28	46.42	50/104	48.08
Antiquity									
	<30	0/0	0	1/2	50	0/0	0	1/2	50
	30-45	1/1	100	0/0	0	0/0	0	1/1	100
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/1	0	0/1	0	0/3	0	0/5	0
Total		1/2	50	1/3	33.33	0/3	0	2/8	25
Kraibrezna									
	<30	0/0	0	0/1	0	1/1	100	1/2	50
	30-45	0/2	0	2/2	100	1/2	50	3/6	50
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		0/2	0	2/3	66.67	2/3	66.67	4/8	50

Table 1: Caries rates by individual, recorded by time period, age and sex.

	Age	Males	%	Females	%	Indeterm.	%	Total	%
Classical									
	<30	0/27	0	0/34	0	0/16	0	0/77	0
	30-45	1/16	6.25	0/0	0	0/0	0	1/16	6.25
	45<	1/20	5	0/0	0	0/0	0	1/20	5
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		2/63	3.17	0/34	0	0/16	0	2/113	1.77
Hellenistic									
	<30	11/141	7.8	16/75	21.33	0/36	0	27/252	10.71
	30-45	0/71	0	0/14	0	0/0	0	0/85	0
	45<	0/4	0	5/32	15.63	0/15	0	5/51	9.8
	Unknown	0/0	0	0/0	0	7/51	13.73	7/51	13.73
Total		11/216	5.09	21/121	17.36	7/102	6.86	39/439	8.89
Early Byzantine									
	<30	8/70	11.43	0/91	0	3/52	5.77	11/213	5.16
	30-45	5/42	11.9	0/0	0	2/26	7.69	7/68	10.29
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	1/17	5.88	0/0	0	0/0	0	1/17	5.88
Total		14/129	10.85	0/91	0	5/78	6.41	19/298	6.38
Medieval									
	<30	23/262	8.78	8/297	2.69	15/244	6.15	46/803	5.73
	30-45	9/216	4.17	9/159	5.66	3/24	12.5	21/399	5.26
	45<	20/180	11.11	2/52	3.85	1/13	7.69	23/245	9.39
	Unknown	7/130	5.38	3/31	9.68	28/248	11.29	38/409	9.29
Total		59/788	7.49	22/539	4.08	47/529	8.88	128/1856	6.9
Antiquity									
	<30	0/0	0	1/18	5.56	0/0	0	1/18	5.56
	30-45	4/24	16.67	0/0	0	0/0	0	4/24	16.67
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/12	0	0/22	0	0/22	0	0/56	0
Total		4/36	11.11	1/40	2.5	0/22	0	5/98	5.1
Kraibrezna									
	<30	0/0	0	0/29	0	6/28	21.43	6/57	10.53
	30-45	0/60	0	15/47	31.91	4/62	6.45	19/169	11.24
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		0/60	0	15/76	19.74	10/90	11.11	25/226	11.06

Table 2: Caries rates by tooth, recorded by time period, age and sex.

	Age	Males	%	Females	%	Indeterm.	%	Total	%
Classical									
	<30	0/2	0	0/2	0	0/1	0	0/5	0
	30-45	1/2	50	0/0	0	0/0	0	1/2	50
	45<	0/1	0	0/0	0	0/0	0	0/1	0
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		1/5	20	0/2	0	0/1	0	1/8	12.5
Hellenistic									
	<30	3/8	37.5	1/4	25	1/3	33.33	5/15	33.33
	30-45	1/3	33.33	0/1	0	0/0	0	1/4	25
	45<	0/1	0	1/3	33.33	0/2	0	1/6	16.67
	Unknown	0/0	0	0/0	0	1/5	20	1/5	20
Total		4/12	33.33	2/8	25	2/10	20	8/30	26.67
Early Byzantine									
	<30	3/4	75	1/3	33.33	1/2	50	5/9	55.56
	30-45	3/3	100	0/0	0	1/1	100	4/4	100
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	1/3	33.33	0/0	0	0/0	0	1/3	33.33
Total		7/10	70	1/3	33.33	2/3	66.67	10/16	62.5
Medieval									
	<30	5/13	38.46	7/17	41.18	4/12	33.33	16/42	38.09
	30-45	5/14	35.71	4/9	44.44	1/1	100	10/24	41.67
	45<	4/10	40	2/3	66.67	0/1	0	6/14	42.86
	Unknown	4/7	57.14	1/3	33.33	10/14	71.43	15/24	62.5
Total		18/44	40.91	14/32	43.75	15/28	53.57	47/104	45.19
Antiquity									
	<30	0/0	0	1/2	50	0/0	0	1/2	50
	30-45	1/1	100	0/0	0	0/0	0	1/1	100
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	1/1	100	0/1	0	1/3	33.33	2/5	40
Total		2/2	100	1/3	33.33	1/3	33.33	4/8	50
Kraibrezna									
	<30	0/0	0	0/1	0	1/1	100	1/2	50
	30-45	2/2	100	2/2	100	1/2	50	5/6	83.33
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		2/2	100	2/3	66.67	2/3	66.67	6/8	75

Table 3: Calculus rates by individual, recorded by time period, age and sex.

	Age	Males	%	Females	%	Indeterm.	%	Total	%
Classical									
	<30	0/2	0	0/2	0	0/1	0	0/5	0
	30-45	0/2	0	0/0	0	0/0	0	0/2	0
	45<	0/1	0	0/0	0	0/0	0	0/1	0
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		0/5	0	0/2	0	0/1	0	0/8	0
Hellenistic									
	<30	3/8	37.5	0/4	0	0/3	0	3/15	20
	30-45	0/3	0	0/1	0	0/0	0	0/4	0
	45<	0/1	0	1/3	33.33	0/2	0	1/6	16.67
	Unknown	0/0	0	0/0	0	0/5	0	0/5	0
Total		3/12	25	1/8	12.5	0/10	0	4/30	13.33
Early Byzantine									
	<30	0/4	0	0/3	0	0/2	0	0/9	0
	30-45	1/3	33.33	0/0	0	0/1	0	1/4	25
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/3	0	0/0	0	0/0	0	0/3	0
Total		1/10	10	0/3	0	0/3	0	1/16	6.25
Medieval									
	<30	3/13	23.08	1/17	5.88	0/12	0	4/42	9.52
	30-45	1/14	7.14	3/9	33.33	0/1	0	4/24	16.67
	45<	3/10	30	0/3	0	0/1	0	3/14	21.43
	Unknown	3/7	42.86	0/3	0	4/14	28.57	7/24	29.67
Total		10/44	22.72	4/32	12.5	4/28	14.29	18/104	17.31
Antiquity									
	<30	0/0	0	1/2	50	0/0	0	1/2	50
	30-45	1/1	100	0/0	0	0/0	0	1/1	100
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/1	0	0/1	0	1/3	33.33	1/5	20
Total		1/2	50	1/3	33.33	1/3	33.33	3/8	37.5
Kraibrezna									
	<30	0/0	0	0/1	0	0/1	0	0/2	0
	30-45	0/2	0	0/2	0	0/2	0	0/6	0
	45<	0/0	0	0/0	0	0/0	0	0/0	0
	Unknown	0/0	0	0/0	0	0/0	0	0/0	0
Total		0/2	0	0/3	0	0/3	0	0/8	0

Table 4: Abscess rates by individual, recorded by time period, age and sex.

Results

For the total population across all time periods, caries and calculus occurred in exactly the same high frequencies of 43.68% of the population. In contrast, when caries was recorded by tooth it occurred in only 7.19%, which illustrates the value of recording both by individual and by tooth. Calculating dental pathologies by tooth effectively increases the sample size and enables differentiation between individuals with one diseased tooth and those with 32. Numbers of abscesses are relatively small, appearing in only 14.94% of the total population.

Caries rates are higher in men than women by 13.42% when observed by individual, but the difference of 0.42% when measured by tooth is negligible and neither difference was statistically significant using Pearson's Chi-square test (By individual: X^2=2.2, p=0.14. By tooth: X^2=0.15, p=0.7). There also appears to be an increase in the frequency of caries from Classical to Medieval when observed by individual (Fig.3). However, when observed by tooth the Classical is particularly low and the Hellenistic shows a dramatic increase (Fig.4). For statistical testing the Classical was grouped with the Hellenistic and the Early Byzantine with the Medieval, due to their cultural and temporal similarities and overlap, to create a larger sample size. There was no statistically significant difference between time periods in caries either by individual (X^2=2.07, p=0.15) or tooth (X^2=0.25, p=0.62) which may still be due to the small sample size despite the grouping of time periods. In comparing the Kraibrezna Street burials to the burials from the main cemetery of contemporary date, the Kraibrezna Street group had higher rates of caries by both tooth and individual; however, the difference was not found to be statistically significant by either tooth (X^2=3.67, p=0.06) or individual (Fisher, p=1.0), although the former was narrowly outside the 5% significance boundary.

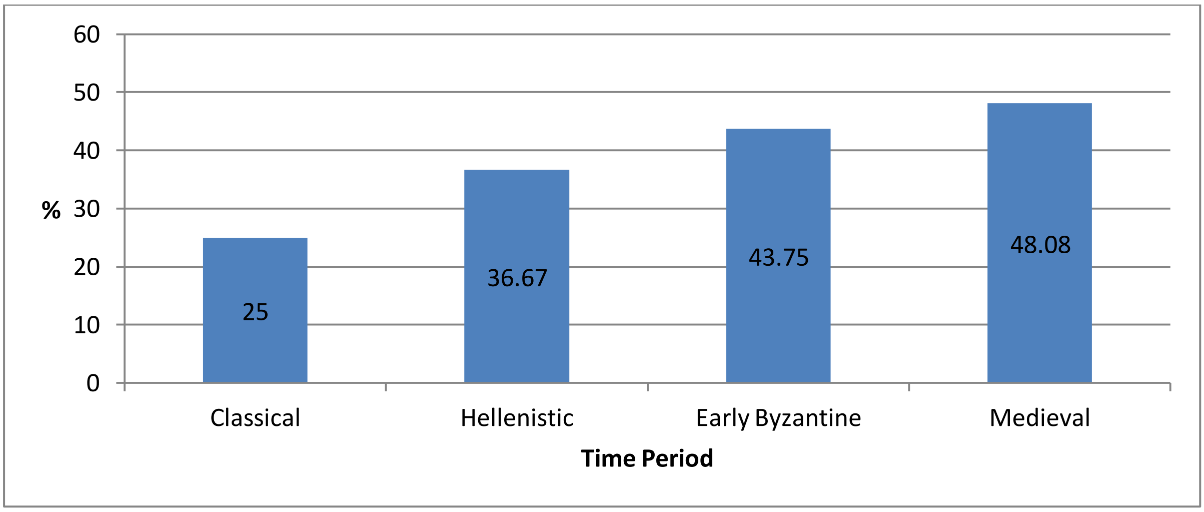

Figure 3: Bar chart for caries frequencies observed by individual over time.

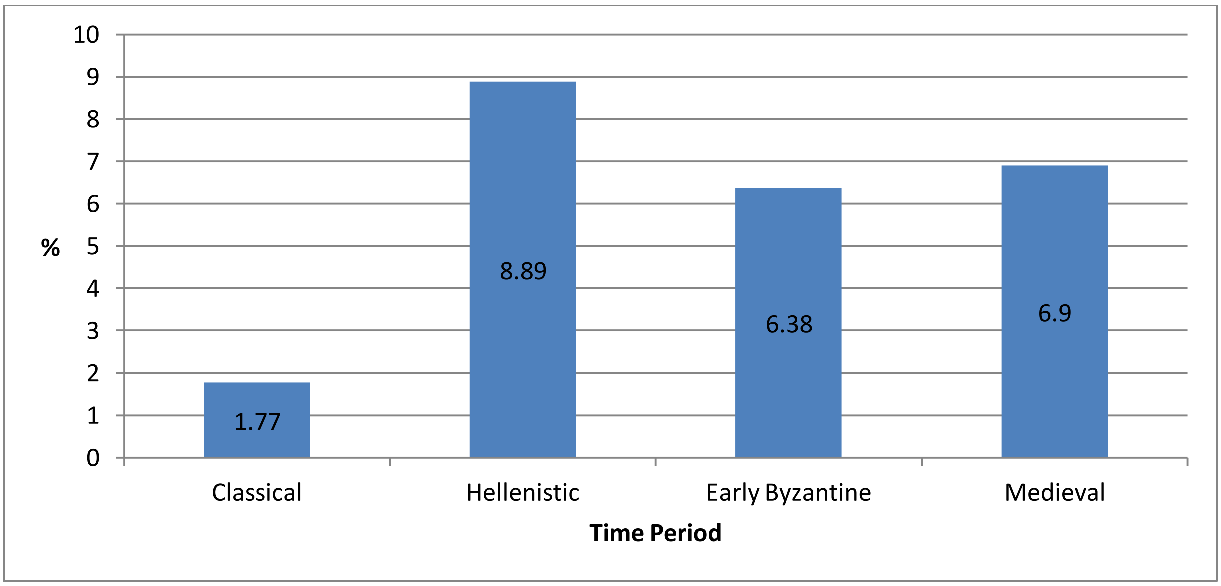

Figure 4: Bar chart for caries frequencies observed by tooth over time.

Calculus, like caries, was found to be higher in men than women in the overall population but although there appears to be a 6.11% difference, this was not statistically significant (X^2=0.46, *p*=0.5). It is at its lowest in the Classical period and peaks in the Early Byzantine (Fig.5). Again, the time periods were combined to create a larger sample size for each group and the difference between Classical-Hellenistic and Early Byzantine-Medieval was found to be statistically significant (X^2=6.73, p <0.01). The Kraibrezna Street population have the highest prevalence of the disease, with 12.5% increase in calculus rates compared to the Early Byzantine group. However, due to the small sample size it cannot be said to be statistically significant (Fisher, *p*=0.67).

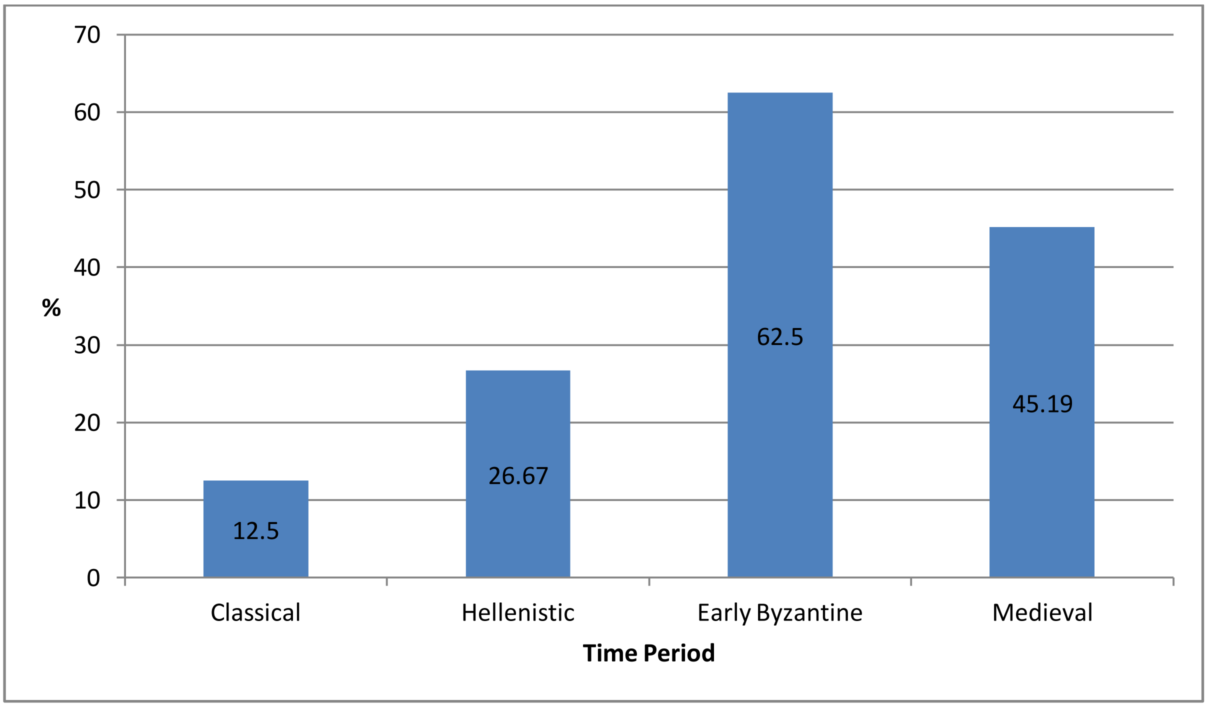

Figure 5: Bar chart for calculus frequencies observed by individual over time.

Similarly, there was no statistically significant difference between males and females in terms of the occurrence of abscesses (X^2=1.45, *p*=0.23), with only an 8.24% difference – albeit with men having greater rates of the disease as was the case with the other pathologies – and a small sample size of 174 individuals, many of which had incomplete dentitions and often only loose teeth. In general the occurrence of abscesses was low, which could be a result of the poor survival and preservation of the maxillary and mandibular bones hindering its observation, or simply that it was an uncommon pathology. Abscess rates appear to fluctuate and do not show any pattern over time (Fig.6) and this is supported by Fisher's exact probability test which showed that the difference between the time periods was not statistically significant (*p*=0.6). Unlike with caries and calculus, which had their highest occurrence in the Kraibrezna Street population, there were no abscesses discovered, which cannot be attributed to problems of preservation as, although there were only eight individuals, they were all in a good state of preservation and had largely complete dentitions.

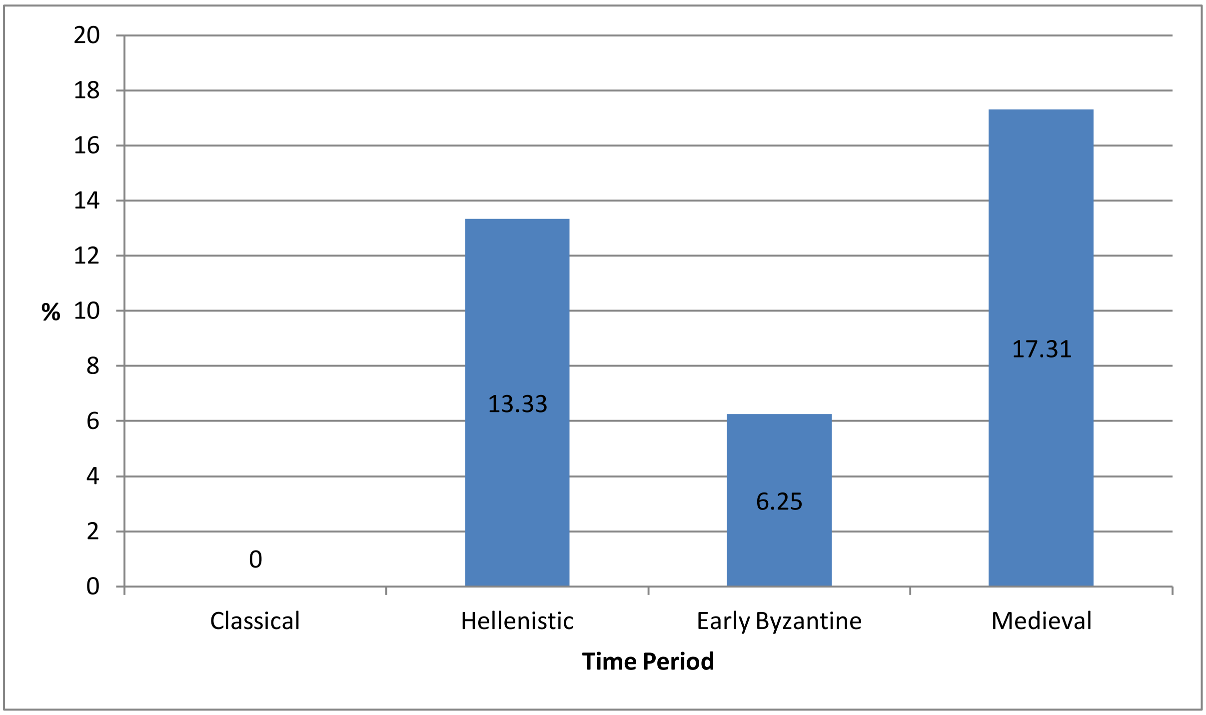

Figure 6: Bar chart for calculus frequencies observed by individual over time.

Dental pathologies are generally age progressive and while the <30 age group always shows the lowest frequency for all the pathologies, in some cases the 30-45 group had higher frequencies of pathological teeth than the 45< group. This distortion of the figures is probably due to relatively few individuals living to this age, and therefore there is a good chance that a smaller sample will be less representative, as well as higher rates of antemortem tooth loss depleting the number of teeth.

Discussion

While there is a slight indication that males had poorer oral health than females and that there was a degree of deterioration of teeth from Classical to Medieval times, the only statistically significant difference by either sex or period was that calculus frequencies increased from the earlier period to the later one. However, some of the trends and patterns which are suggested by the numbers may fail to meet the significance requirements as a result of small sample sizes, therefore, the study of the dentition could produce more dependable results after future study seasons when the entire population of the Mesembrian cemetery has received a full skeletal examination. Calculus is particularly difficult to interpret as it can be indicative of either a high protein or high carbohydrate diet (Roberts and Manchester, 2005). Its coincidence with high caries rates, particularly in the later period, may suggest that the diet was high in carbohydrates. This could be attributed to the introduction of cane sugar in the Medieval period which would be identifiable isotopically, or it could be an increase in the consumption of bread with little variation in the diet due to rules of abstinence connected with Christianity. This would also fit with the suggestion that the Kraibrezna Street population had the highest rates of both caries and calculus as this was a small, and perhaps exclusive, cemetery intimately associated with the Basilica of the Holy Mother Eleusa. However, this raises the question of what was being consumed during the Classical period, as previous studies and literary texts suggested that bread and cereals would have made up the predominant proportion of most diets, but perhaps in reality they had a more varied diet than the literary sources suggest. This could also be simply the weakness of the sample which is small and may be unrepresentative.

It is unusual for males to have worse dental health than females, especially with caries, therefore it may be the case that the higher rates for men are not representative as is shown by the statistical testing. It is possible that men and women were consuming a similar diet or that any differences were in the preparation of food or in terms of different cuts of meat or types of grain. It could also be the case that antemortem tooth loss was higher in females, misrepresenting the numbers of carious teeth. However, when observed by tooth, caries rates for males and females were almost identical in support of both eating the same foodstuffs.

The dental evidence gives a limited amount of information here; however, when combined with the stable isotopic evidence, it is possible that some of the patterns suggested by the dental pathologies will be supported or disproved to give a clearer picture of what was being consumed by the Mesembrian people.

Chapter 4: Materials and Methods

Materials

The Mesembrian cemetery was excavated during three seasons (2008-2010) by the National Institute of Archaeology and Museum, Sofia, and the Museum of Ancient Nessebar, with further excavations of a smaller cemetery site on the island in 2011, and the analysis of the skeletal material is ongoing by the team from the University of Edinburgh. Burial goods from each grave are known from an electronic artefact book compiled by the excavation team from the Museum of Ancient Nessebar (undated) and from excavation photos taken of each grave. 23 bone samples of the Mesembrian population from across the time span of the larger cemetery on the mainland and from the smaller Kraibrezna Street Byzantine cemetery on the island were selected for stable isotope analysis. Although an even number from each group would have been preferable, only a small number of individuals from some of the less well represented groups were analysed during the 2012 Study Season. There were two Antiquity samples, three from the Early Byzantine period, four each from the Classical and Hellenistic periods and the Kraibrezna Street cemetery and six from the best represented era, the Medieval period. The general preservation of the skeletal material was quite poor, although the Kraibrezna Street remains were in relatively good preservation. The poor preservation of the material in the main cemetery was exaggerated by poor excavation as can be seen from the many bones left behind on the surface of the cemetery site. As the analysis of the skeletal collection is ongoing, the record of human remains is still incomplete.

The samples were selected according to time period, as mentioned above, ensuring as even a spread as was possible across the occupation of the site. Additionally, juveniles were excluded to avoid complicating the study with too many variables. For the Classical, Early Byzantine and Antiquity groups the samples represented the entire adult population of individuals from those periods studied during the 2012 season, while the Hellenistic, Medieval and Kraibrezna Street samples were taken at random from the population but keeping the numbers of samples similar to those that were selected based on availability. Although the study aims to draw comparisons on diet by age, sex and burial goods, these were not factors when selecting the individual samples as they would have created a biased sample. The preferred sample type was long bone due to its thick cortical bone. The selection was based on availability of pieces already fragmented, to cause the minimum amount of disturbance or destruction to the human remains and sometimes the bone was specifically identified but with some samples this was not possible. Although animal bones from the same site as the human remains can provide a useful baseline for the local food chain, none were selected for stable isotope analysis as too few were available and could therefore have provided unrepresentative information.

Methods

The skeletal material was analysed for age and sex following well established methods on the skeletal elements available. For ageing the individuals the dentition was used when available, applying Lovejoy (1985), Miles (1963) and Brothwell's (1981) standards. Despite preservation inhibiting the identification of the fourth rib, where a sternal rib end was available, Isçan et al.'s

(1984, 1985) method was applied. The morphology of the auricular surface (Lovejoy et al., 1985) and pubic symphysis (Todd, 1920; Brooks and Suchey, 1990) were assessed if the pelvis was well enough preserved and on the rare occasions that the skull was intact Meindl and Lovejoy's (1985) cranial suture closure technique was used. Sex was determined using established standards of cranial and pelvic morphology set out in Buikstra and Ubelaker's (1994) standards book (Phenice, 1969; Acsadi and Nemeskeri, 1970; Walker, 1994).

Grave No.	No. Days in 100ml 1N HCl (No. HCl changes)
AHM 363	8 (1)
AHM 540	6 (1)
AHM 668-1	1 (0)
AHM 668-2	1 (0)
AHM 694	9 (1)
AHM 798	5 (0)
AHM 1049	13 (2)
AHM 1181	5 (0)
AHM 1053	5 (0)
AHM 1152	10 (2)
AHM 1178	5 (1)
AHM 605	8 (2)
AHM 636	13 (2)
AHM 637	1 (0)
AHM 641	8 (2)
AHM 643	20 (3)
AHM 784	1 (0)
AHM 412	1 (0)
AHM 691	15 (3)
OT 24	5 (0)
OT 32	1 (0)
OT 33	3 (0)
OT 35	14 (3)

Table 5: Days in acid and acid changes for each sample.

The samples were cleaned and prepared in the Bone Chemistry Laboratory at the University of Edinburgh. The samples were cleaned using disposable scalpels to remove a layer from the external surface of the bone and then weighed. The collagen extraction process was carried out following the method of Longin (1971) as adapted by Brown et al. (1988). This process involved immersing the cleaned bone sample in 100ml 1N HCl until the inorganic component of the bone was demineralised. This step of the process varied greatly between samples in how long it took for the formation of bubbles to cease and the sample to become soft and translucent; Table 5 illustrates how many days each sample spent in acid and how many acid changes were made. A chunk of bone was used in preference to powdered bone as studies have shown that in poorly preserved bone this method produces more dependable results with acceptable C/N ratios (Schurr, 1992; Garvie-Lok, 2001). This stage is often followed by a NaOH treatment to remove humic contaminants; however, it is omitted here and is a common methodological variation (e.g. Mays, 1997; Richards and Hedges, 1999; Lillie and Richards, 2000), as it can result in a degree of sample loss due to the vulnerability of collagen to the chemical (Stafford et al., 1988; Mueller 1989; Katzenberg, 1989; Bocherens et al., 1999). The demineralised bone sample was then filtered through GF/A glass microfibre filters and rinsed three times with purified water. The sample was then returned to a beaker with purified water and set on a sand-bath over an 80°C hot plate for approximately 16 hours. A further ultrafiltration step was carried to eliminate as many contaminants as possible and the cartilaginous filtrate was retained. This solution was set back directly on the 80°C hot plate to evaporate to a volume of ~10ml, then transferred to a vial and put into a -80°C freezer. The sample was then lyophilised until the solution was gone, leaving collagen in the form of a white/cream coloured crystalline powder. The final dry collagen weight was recorded in order to calculate the yield, as an indicator of diagenesis. The prepared samples were transferred to the Scottish Universities Environmental Research Centre (SUERC) Accelerator Mass Spectrometer Laboratory where the samples were weighed into tin capsules and measured using a CF-IRMS system, consisting of a Costech ECS 4010 combustion elemental analyzer coupled to a Thermofisher

Delta V Advantage gas source isotope ratio mass spectrometer. The isotopic results were analysed statistically using VassarStats or by hand, using a manual calculator.

Indicators of Diagenesis

For results to be dependable, it is important to ensure that the collagen has not undergone any diagenetic degradation, which can commonly occur in archaeological bone samples and therefore studies have been carried out to develop means of assessing this diagenesis (DeNiro, 1985; Schoenenger et al., 1989; Van Klinken, 1999). The indicators of diagenesis used for this study are collagen yield by weight, atomic C/N ratio, and carbon (%C) and nitrogen (%N) content. Collagen yield is useful as the smaller the amount recovered, the greater the chance that it has been degraded or contains other materials that can produce anomalous $\delta^{13}C$ and $\delta^{15}N$ values. Although opinion varies on selecting an appropriate cut-off point, below which the sample should be rejected, it is somewhat arbitrary as the degradation process is a gradual one (Garvie-Lok, 2001). However, this study uses a 1-2% collagen yield cut-off, as is commonly recommended by other studies (DeNiro and Weiner, 1988; Ambrose, 1990; Mays, 1997). Atomic C/N ratio, measured by the elemental analyser, can indicate diagenesis on two levels. When collagen is broken down and lost, carbon and nitrogen can be differentially lost (Ambrose, 1990). Additionally, the inclusion of carbon-rich contaminants, such as lipids, can alter the C/N ratio (Garvie-Lok, 2001). For this study a range of 2.9 to 3.6 for C/N ratios was used, as recommended by DeNiro (1985). The carbon (%C) and nitrogen (%N) content, also measured in the elemental analyser, demonstrate the concentration of these atoms in the sample. The accepted values fall within the ranges of 13%-47% for %C and 5%-17% for %N, as advocated by Ambrose (1990). When used together these assessments of diagenesis should enable any degraded samples to be identified and rejected.

Chapter 5: Results

Collagen Preservation

All samples fall within the acceptable values according to the diagenesis indicators, as outlined in the previous chapter, suggesting that collagen was sufficiently preserved in all the bone samples for their use in dietary reconstruction. Some results did fall into a borderline zone between 1% and 2% for collagen yield and although ideally 2% would be the preferred cut-off point, values in this region over 1% have been deemed satisfactory in cases where the other indicator values were acceptable (Stafford et al., 1991; Ambrose, 1993; Van Klinken, 1999). The results of the stable carbon and nitrogen isotope analysis, alongside their diagenesis indicators and demographic, burial and sample details, are presented in Table 6.

Grave No.	Sex	Age Group	Grave Goods	Bone Type	$\delta^{13}C$	$\delta^{15}N$	C/N	%N	%C	% Yield
Classical										
AHM 363	Unknown	<30	Y	Long bone	-19.3	9.6	3.2	15.6	42.6	2.4
AHM 540	Male	30-45	Y	Radius	-18.8	9.9	3.2	15.8	43.1	1.9
AHM 668-1	Male	45<	Y	Radius	-19.0	9.4	3.2	13.0	35.8	1.4
AHM 668-2	Indeterminate	Unknown	Y	Long bone	-18.9	9.4	3.2	10.0	27.8	2.2
Hellenistic										
AHM 694	Female	45<	Y	Radius	-19.2	10.3	3.2	15.4	42.2	2.0
AHM 798	Unknown	Unknown	Y	Humerus	-18.7	10.0	3.2	14.7	40.7	8.0
AHM 1049	Female	Unknown	Y	Long bone	-18.6	10.4	3.2	15.2	41.6	4.9
AHM 1181	Male	30-45	Y	Long bone	-18.8	10.1	3.2	14.1	39.0	9.5
Early Byzantine										
AHM 1053	unknown	<30	N	Humerus	-19.4	10.0	3.2	14.8	40.4	7.5
AHM 1152	Male	<30	N	Rib	-16.8	10.3	3.2	15.1	41.6	2.0
AHM 1178	Male	Unknown	N	Long bone	-19.1	11.1	3.2	15.3	42.1	7.1
Medieval										
AHM 605	Male	<30	N	Fibula	-19.5	7.6	3.2	15.0	40.9	1.1
AHM 636	Male	30-45	Y	Long bone	-18.8	10.7	3.2	15.6	42.8	4.3
AHM 637	Female	<30	N	Long bone	-18.4	8.8	3.2	11.0	30.0	2.2
AHM 641	Male	<30	Y	Ulna	-18.5	10.7	3.2	15.4	41.8	5.3
AHM 643	Male	30-45	N	Long bone	-19.1	10.8	3.2	15.0	41.5	4.8
AHM 784	Unknown	<30	N	Ulna	-19.0	11.2	3.2	12.2	33.7	1.0
Antiquity										
AHM 412	Female	Unknown	Y	Long bone	-19.3	10.4	3.4	5.0	14.6	2.5
AHM 691	Female	45<	N	Radius	-19.1	10.4	3.2	15.2	41.9	7.0
Kraibrezna Street										
OT 24	Female	30-45	N	Radius	-17.9	10.5	3.2	14.9	41.1	29.3
OT 32	Male	30-45	N	Radius	-18.3	11.9	3.2	13.2	36.4	1.5
OT 33	Female	<30	N	Radius	-18.7	10.5	3.2	11.3	31.0	2.2
OT 35	Female	30-45	N	Long bone	-18.3	10.6	3.2	15.2	41.8	7.0

Table 6: Results of stable carbon and nitrogen isotope analysis, with diagenesis indicators and demographic, burial and sample data.

Isotopic Results for Dietary Reconstruction from Human Remains

The $\delta^{13}C$ values had a range of 2.7‰ from -19.5‰ to -16.8‰ and an average of -18.8‰, while the $\delta^{15}N$ values had a larger range of 4.3‰ from 7.6‰ to 11.9‰ with an average of 10.2‰. These values are slightly elevated compared to an entirely C_3 terrestrial diet which would typically produce $\delta^{13}C$ values of around -22‰ to -20% (Chisholm et al., 1982; Van der Merwe, 1982; DeNiro, 1987) and $\delta^{15}N$ tissue values of around 6‰ for those consuming predominantly nonleguminous C_3 plants and closer to 9‰ for those getting most of their protein from C_3-feeding animals or animal products. It is unfortunate, however, that no site-specific floral or faunal isotopic values exist for Mesembria to provide a more accurate baseline from which to compare the human values. It is likely that there is a marine contribution to the predominantly C_3 terrestrial diet, as was expected due to the site's close proximity to the sea and which would explain the elevated values. Although few marine remains survive from archaeological sites previous studies have looked at modern marine values which can vary greatly from garum ($\delta^{13}C$ -14.7‰, $\delta^{15}N$ 6.5‰, Prowse et al., 2004) or anchovies ($\delta^{13}C$ -17.5‰, $\delta^{15}N$ 6.3‰, Garvie-Lok, 2001) which may barely be discernible from a mixed C_3/C_4 terrestrial diet to marine carnivores, such as blue whiting ($\delta^{13}C$ -14.8‰, $\delta^{15}N$ 17.9‰, Garvie-Lok, 2001[1]). These values illustrate the difficulty in interpreting marine elements in the diet but as both $\delta^{13}C$ and $\delta^{15}N$ were elevated compared to a C_3 diet it cannot be explained by C_4 plants which would only elevate the $\delta^{13}C$ signal (tissue value c.7-8‰, Van der Merwe, 1982; DeNiro, 1987). The small ranges in the isotopic ratios indicate a fairly homogeneous diet across the population and there appears to be a slight positive linear correlation between $\delta^{13}C$ and $\delta^{15}N$, although the relationship was not strong enough to prove significant using Spearmann's rank correlation coefficient (r_s=0.26, p=0.23).

Isotopic Variation by Time Period and Cemetery

The average values for each period (Table 7) do not follow any clear trend and fluctuate only slightly indicating little change in diet over time, although the Classical $\delta^{15}N$ values are noticeably lower (Fig.7), but the Kruskal-Wallis test was used to compare all the groups of values and indicated that the difference between them was not statistically significant ($\delta^{13}C$ H=7.92, p=0.16, $\delta^{15}N$ H=8.59, p=0.13). However, in pooling the groups as was done for the dental analysis to increase the sample size and determine trends, the early diet (Classical and Hellenistic) is more clustered than the later one (Early Byzantine, Medieval and Kraibrezna Street), suggesting a more varied diet in the later period. Although the Early Byzantine values are particularly erratic, the later period generally appears to have slightly more elevated values.[2] While this difference was not statistically significant for the $\delta^{13}C$ values (Mann-Whitney, U=38, p=0.33), the difference between the early and later $\delta^{15}N$ values was significant (U= 21, p<0.05). The Kraibrezna Street group notably have the most elevated $\delta^{13}C$ and $\delta^{15}N$ averages; however, in order to carry out statistical analysis to compare this cemetery to the larger one, even using the non-

	$\delta^{13}C$	**$\delta^{15}N$**
Classical	-19.0	9.6
Hellenistic	-18.8	10.2
Early Byzantine	-18.5	10.5
Medieval	-18.9	10.0
Antiquity	-19.2	10.4
Kraibrezna Street	-18.3	10.9

Table 7: Average isotopic values for each group.

[1] These are fish tissue values and therefore prior to the enrichment that would occur when metabolised into human tissue.

[2] This can be most clearly seen from the graph for distribution by burial goods (Fig.10) which turned out to be indicative of time period rather than social or economic status.

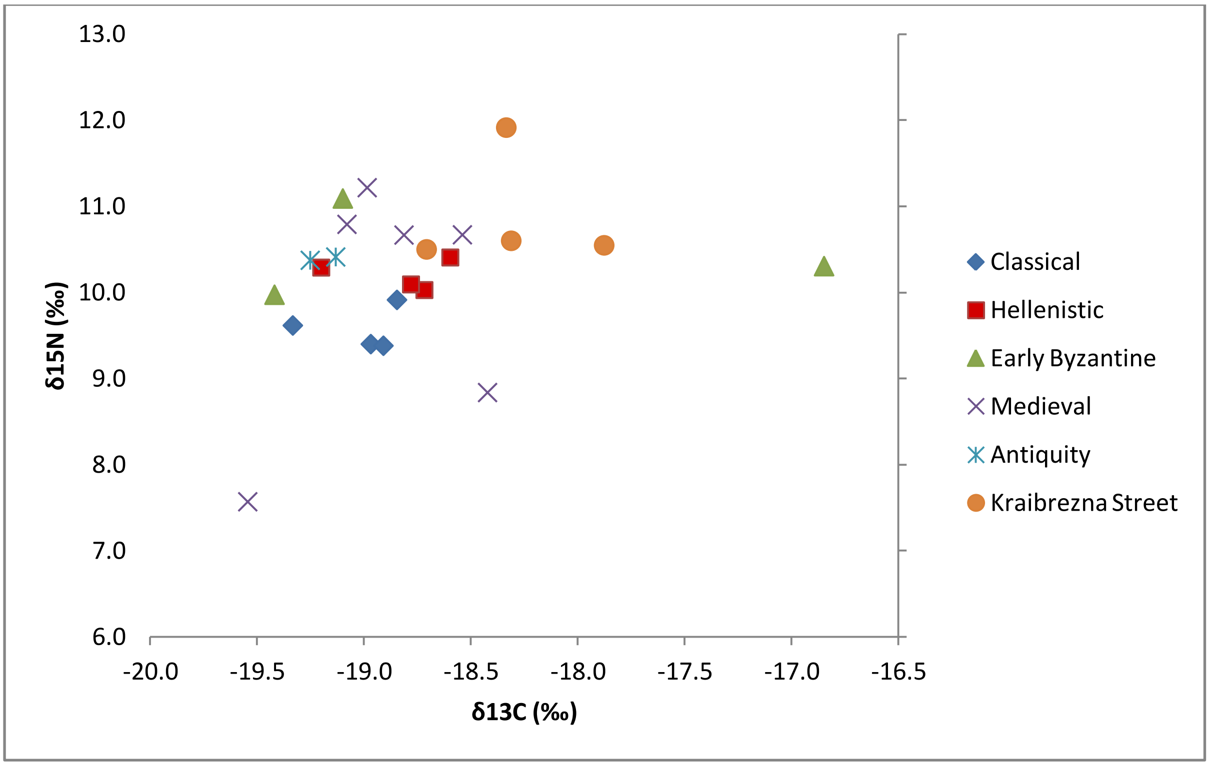

Figure 7: Scattergraph demonstrating isotopic signatures by time period and cemetery.

parametric Mann-Whitney test, each group must have at least five samples. An extra virtual value was therefore created taking an average of the four samples ($\delta^{13}C$ -18.3‰, $\delta^{15}N$ 10.9‰) in order to test this theory that the individuals in the Kraibrezna Street cemetery had a slightly different diet to those in the main cemetery, which proved to be highly significant ($\delta^{13}C$ U=86.5, $p<0.01$, $\delta^{15}N$ U=78, $p<0.05$). With significantly elevated $\delta^{13}C$ and $\delta^{15}N$ values in the Kraibrezna Street cemetery it is likely that these individuals had a greater marine component to their diet; however, the test was carried out using a constructed value and would therefore need to be confirmed using a larger sample size.

Isotopic Variation by Sex, Age and Burial Goods

While the distribution of values appears somewhat different for the sexes (Fig.8), with the males generally following a positive linear pattern and the females varying by $\delta^{13}C$ but with little $\delta^{15}N$ variation, their average values were exactly the same ($\delta^{13}C$ -18.7‰, $\delta^{15}N$ 10.2‰) and the Mann-Whitney test confirmed no statistically significant difference ($\delta^{13}C$ U=43.5, p=0.79, $\delta^{15}N$ U=35.5, p=0.72). Unfortunately some samples had to be omitted from the comparison as the individuals were of indeterminate or unknown sex, the former referring to those with intermediate morphological features, the latter to those too fragmentary for any sexing technique to be applied. For comparing the distribution of the different age groups, this was again the case, with a small number of individuals being omitted due to fragmentary remains inhibiting ageing techniques. Although the age groups appear to be vaguely clustered (Fig.9) there was no statistically significant difference between them ($\delta^{13}C$ H=3.13, p=0.21, $\delta^{15}N$ H=2.87, p=0.24). It is clear from Table 6 that the distribution of burial goods (Fig.10) is most strongly determined by time period rather than being an

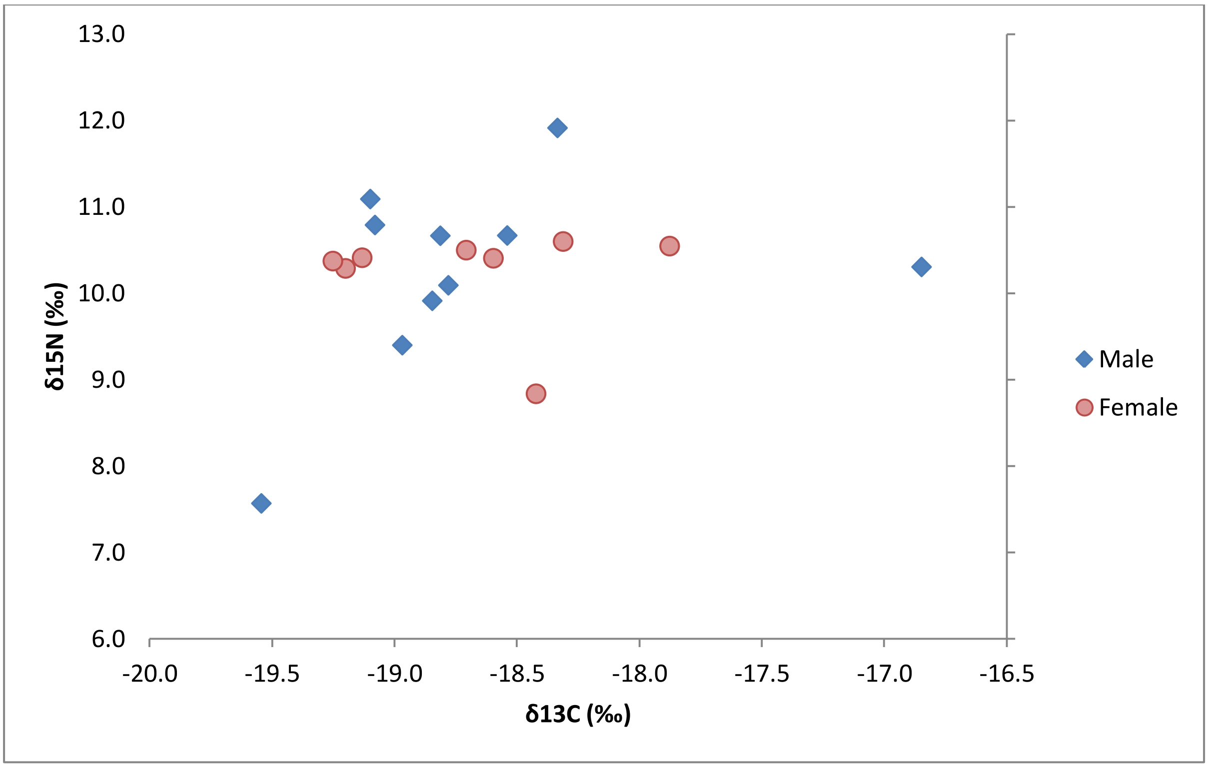

Figure 8: Scattergraph demonstrating isotopic signatures by sex.

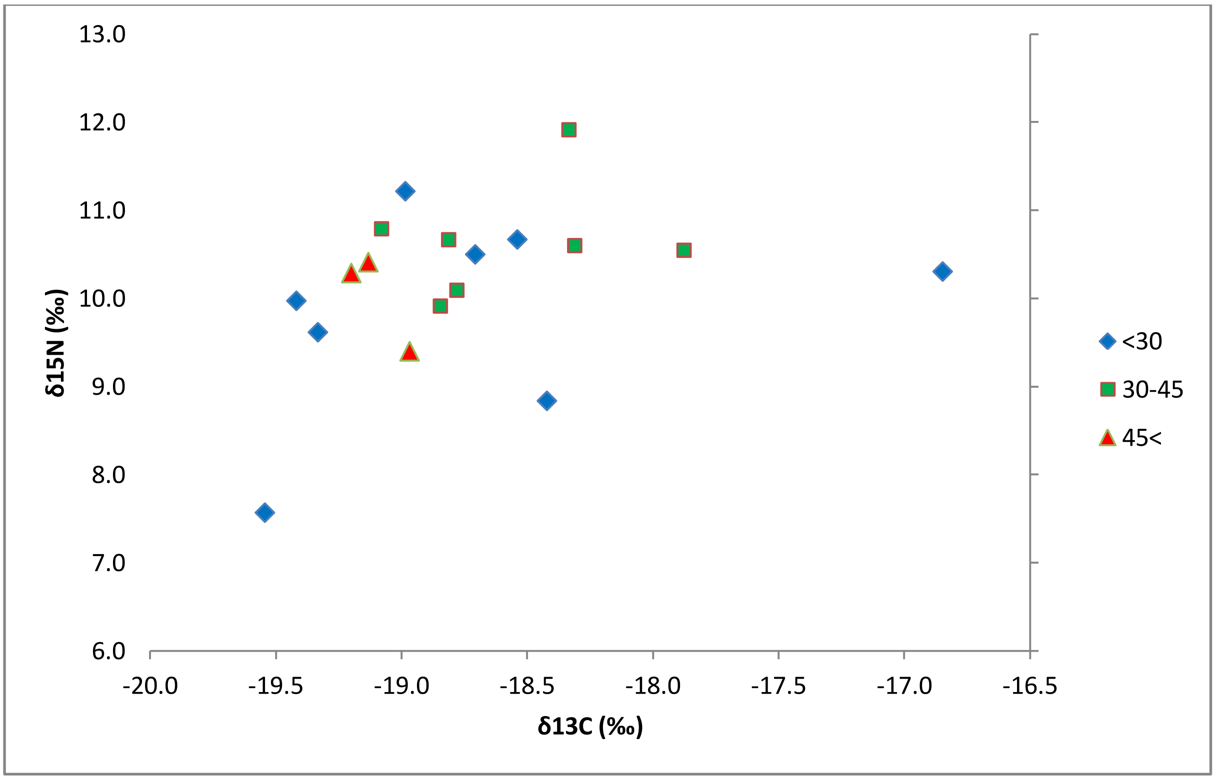

Figure 9: Scattergraph demonstrating isotopic signatures by age group.

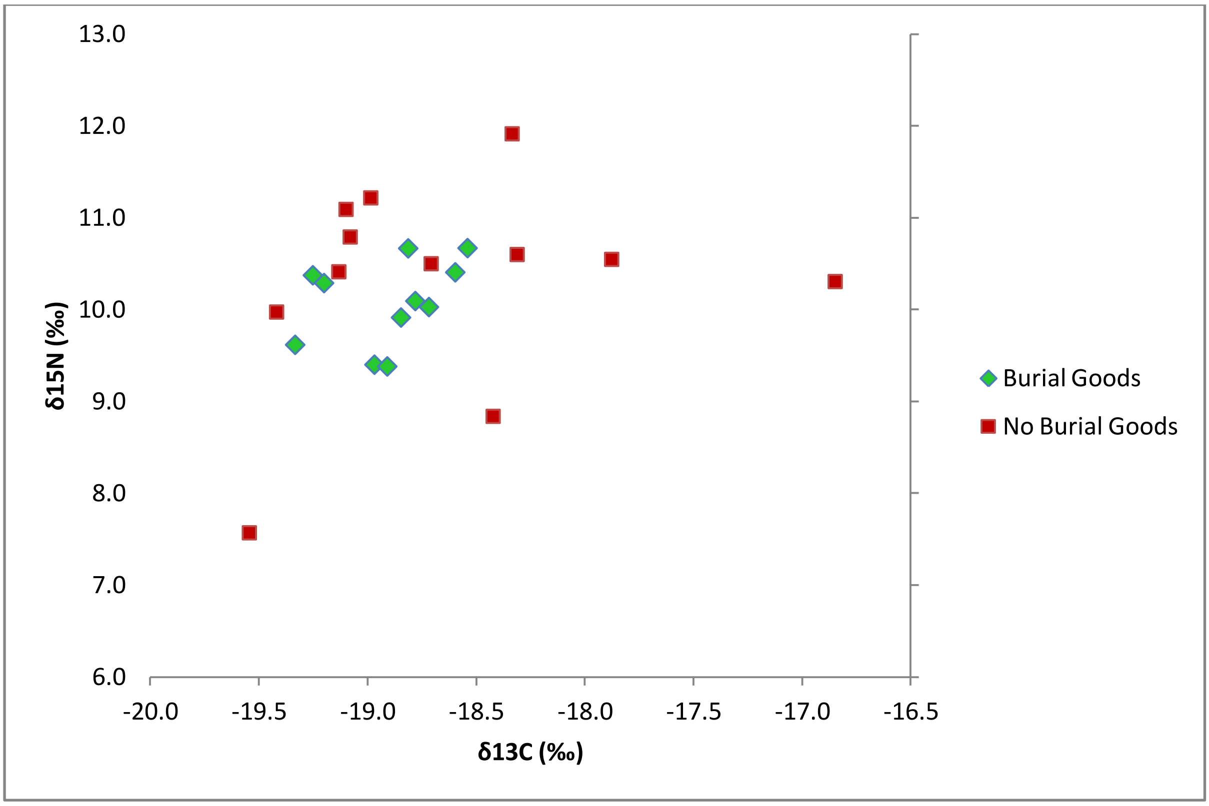

Figure 10: Scattergraph demonstrating isotopic signatures by associated burial goods.

indicator of social standing or economic status and is therefore most illustrative of the difference mentioned above between the early and late periods with the tighter clustering representing a more homogeneous diet in the Classical and Hellenistic periods when burial goods were a funerary custom.

These results fall within the expectations provided by similar studies from around the Mediterranean world and contribute to current knowledge of past diet on the Black Sea, in Greek colonies, in Christian Europe and over time in the Mediterranean, as discussed in the following chapter.

Chapter 6: Discussion and Conclusion

Reconstruction of Diet at Mesembria

As expected from a review of the ancient literature, archaeological evidence and stable isotopic studies of similar sites, the people of Mesembria were eating a predominantly C_3 terrestrial diet including a significant terrestrial animal product component, elevating the $\delta^{13}C$ and $\delta^{15}N$ values to an extent, and a contribution from marine proteins too, accounting for the level of elevation in the isotopic signatures. While generally in keeping with the literary sources, with wheat making up the bulk of the diet, most often in the form of bread, which explains the high caries frequencies, alongside other C_3 plants such as olives for oil and grapes for wine, the isotopic results enable a more detailed picture to be painted of this population's diet. The literature does not generally focus on a common daily diet and is therefore unclear on the everyday consumption of meat and fish. It appears, from the isotopic evidence, that this population was getting adequate protein from meat, or its by-products, and fish and demonstrates that these commodities were not just for the rich banquets featured in the literature (Wilkins and Hill, 2006). These were not making up the bulk of the diet but did provide enough protein that little had to be drawn from plant foods, which would have been richer in carbohydrates and lipids and would therefore have contributed little to bone collagen; this is known as the 'routing' hypothesis (Ambrose and Norr, 1993; Prowse et al., 2004). Legumes are often attested to in ancient recipes and commentaries but with a $\delta^{15}N$ signal close to 0‰ there is no evidence for their presence in the Mesembrian diet, as has been the case at similar sites (Keenleyside et al., 2006; Bourbou et al., 2011). However, taking into consideration the highly variable marine isotopic signals, it could be possible that a relatively small amount of legumes could be cancelled out by high trophic level marine-life.

The results of this study are remarkably similar to those from Apollonia (av. $\delta^{13}C$ -18.5‰, $\delta^{15}N$ 10.1‰, Keenleyside et al., 2006), unsurprisingly, as it was also a Greek colony on the western Black Sea coast, although it only featured Classical and Hellenistic period burials, which further demonstrates the similarity of Mesembrian diet over time. Although more distant geographically, the only other Greek colony site which has undergone stable isotope analysis, Metaponto, also showed comparable results suggestive of a similar diet (rural cemetery av. $\delta^{13}C$ -19.5‰, $\delta^{15}N$ 10.5‰, urban cemetery av. $\delta^{13}C$ -19.0‰, $\delta^{15}N$ 11.2‰, Henneberg et al., 1999), indicating how Greek colonialism was a key factor in the strong cultural ties and thriving trade links around the Mediterranean world which resulted in similar dietary habits. The results from both Apollonia and the Roman period site of Isola Sacra, which also had very similar results (av. $\delta^{13}C$ -18.8‰, $\delta^{15}N$ 10.8‰, Prowse et al., 2004), were plotted on a terrestrial-marine gradient based on the transition from a predominantly marine to predominantly terrestrial diet from the Mesolithic to Neolithic in Portugal (Fig.11, Lubell et al., 1994) following the routing hypothesis of a 2:1 gradient of $\delta^{15}N$:$\delta^{13}C$. Both had a much steeper gradient (closer to 4:1) due to a considerably larger range in the $\delta^{15}N$ values compared to the $\delta^{13}C$ ones. This divergence from the trend seen in other studies of marine consumers (Lubell et al., 1994; Richards and Hedges, 1999) may be due the nitrogen, essential for the synthesis of amino acids, and the carbon, used in the construction of non-essential proteins, being derived from different sources, the former from protein-rich food such as fish and the latter from plant-derived foods with a narrower range of $\delta^{13}C$ values (Prowse et al., 2004). However, it is also possible that the variation lies in the wide range of values from possible fish sources of different

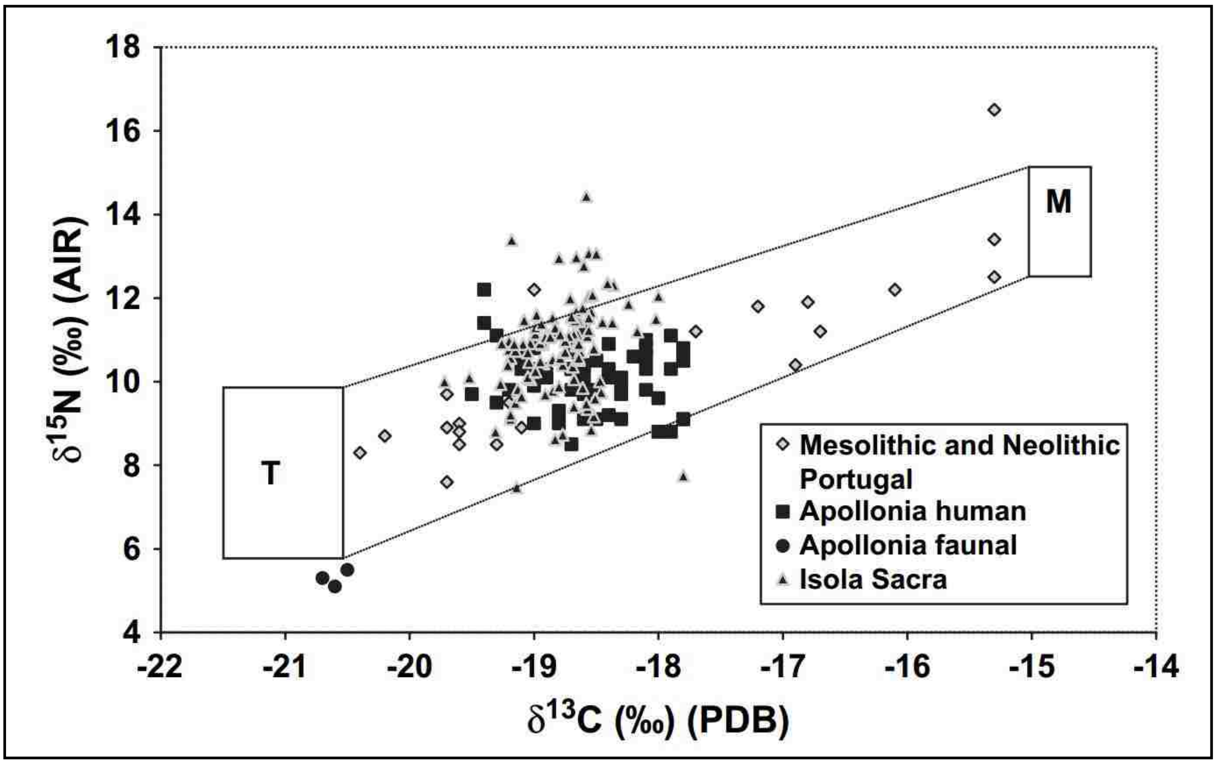

Figure 11: Plot of δ^{13}C and δ^{15}N values for Apollonia, Isola Sacra and Portugal. The boxes labelled 'M' and 'T' represent the collagen values of individuals consuming a range of purely marine or terrestrial foods. (Fig.6 in Keenleyside et al. 2006)

trophic levels, suggesting that the Mesembrian population consumed a variety of marine foods from garum and shellfish to small and medium sized fish. Another factor that can elevate δ^{15}N values, greater than and disproportionately to the δ^{13}C ones, is the use of fertilisers, such as manure, in the soil (Bogaard et al., 2007); however, the pattern of the variation, with a degree of elevation in the δ^{13}C values, makes either varying levels and different sorts of marine food or the carbon and nitrogen isotopes being derived from different sources more likely explanations. The study of eight Greek Byzantine sites, with δ^{13}C and δ^{15}N average ranges from -18.2‰ to -19.2‰ and 8.2‰ to 9.5‰, represent a fairly similar diet to the Mesembrian one (Bourbou et al., 2011); however, the lower δ^{15}N values at these sites, which at some of the sites are still interpreted as having a marine component in the diet, suggest that the Mesembrian people may have been consuming fish of a slightly higher trophic level. Just as these sites, which were wide ranging both geographically and chronologically (6th-13th centuries), demonstrated a general 'Byzantine diet' (Bourbou et al., 2011), this study and its comparison to similar sites demonstrate a general 'Mediterranean diet' of even wider ranging proportions over time and space.

Variation in Diet by Time Period and Cemetery

Across the different time periods there was little variation in diet. However, the slightly more varied diet in the later period and elevation of values, in particular the significant rise in δ^{15}N signals from the early to later period, suggest that a marginal increase in fish consumption could be caused by a number of factors, such as availability of resources due to improvements in fishing technologies and food preservation techniques or mixed attitudes or different levels of adherence to Christian fasting regimes (Salamon et al., 2008; Rutgers et al., 2009; Bourbou, 2010; Bourbou et al., 2011). The only difference in dental pathologies that proved to be statistically significant was the increase in the occurrence of calculus from the earlier to later period which is compatible with this suggested increase in protein intake. An increase in fish consumption is attested to throughout Europe in the Byzantine period due to these factors including its appearance more often at inland sites (Salamon et al. 2008; Reitsema et al., 2010; Bourbou et al., 2011). The increase at inland sites produces a much more remarkable change in the diet of the population which does not occur at Mesembria as there was already a significant marine element in their diet, acting as a reminder that although fish consumption can be interpreted as a result of Christian abstinence or new preservation techniques, it must be considered within its wider environmental and economic context (Bourbou et al., 2011). At Sagalassos in Turkey, the observation of human diet having more clustered isotopic values in the Classical-Hellenistic than Roman-Byzantine was attributed to husbandry practices with livestock being kept in the same area and being fed similar fodder in the early period and diversifying later on (Fuller et al., 2012). The results do not go any way towards placing the Antiquity burials temporally, as their isotopic values are fairly centrally located compared to the rest of the samples, demonstrating a similar diet to the other periods. There were two particularly erroneous samples in the Mesembrian cemetery, AHM 605, which had the most depleted isotopic values for both carbon and nitrogen indicating a diet based largely on C_3 plants perhaps with a small contribution from animal protein, and AHM 1049, which had a particularly enriched $\delta^{13}C$ signal which indicates a significant dietary contribution from either C_4 plants or low trophic level fish. Just as 'non-locals' were identified at Apollonia (Keenleyside et al., 2011), these different diets could indicate migrants or visitors, which could have taken the form of merchants or travellers to the port and trade centre, or in the Christian periods, pilgrims coming to visit the religious centre at Mesembria. If this was the case, an influx of people from neighbouring or even more distant communities could also contribute to a more varied diet. Although diet remained fairly similar over time and space, with this concept of a 'Mediterranean diet' due to strong trade links, shared technologies and cultural communications, these values indicate that there were still variations in diet. Additionally, upon broadening the temporal spectrum, it is evident that diet had not always been so homogeneous in this area, as the isotopic results from the Copper Age sites of Varna and Durankulak indicated an almost entirely terrestrial diet, despite their proximity to the Black Sea (Honch et al., 2006).

Although the test was carried out using a constructed value and should be repeated using a larger sample size, the difference between the main cemetery on the mainland and the Old Town island cemetery on Kraibrezna Street was statistically significant. The Kraibrezna Street group had the most elevated isotopic values, which is particularly interesting when considered alongside the dental data which showed the highest levels of both calculus and caries. The isotopic values suggest that this group were consuming larger amounts of marine foods and considering these burials' close association with the Basilica of the Holy Mother Eleusa, the idea that the increased fish consumption was due to individuals who adhered strictly to fasting regimes is fitting. This is conflicting with the caries data, in that the minerals in fish can assist the prevention of caries formation, but although the levels of fish may be higher, the diet would still have been predominantly cariogenic carbohydrates. The caries rates could also be a result of somewhat luxurious foodstuffs, such as dates or honey, if the church diet was a slightly wealthier one, which has proved to be the case in other studies where the staunch ecclesiastical ascetics had a more varied diet than they would have wished to portray (Rutgers et al., 2009). At any rate, the Kraibrezna Street diet appears to have been a slightly special one. It is difficult to explain who these individuals buried in this exclusive cemetery

– rather than the traditional one – might have been; they cannot be priests as both males and females were present. Although there were both male and female groups who followed monastic, ascetic lifestyles, it would have been usual for them to be buried together in association with the same church. There are also other factors to consider in the differences between the two cemeteries, such as the fact that the ancient settlement was on the island (long before the causeway was constructed), and it would therefore have been a laborious task to transport the dead to the mainland for burial, and the questions of where were the Roman period burials and also why they reverted back to the traditional cemetery in the Early Byzantine period for some of their burials. The discovery of other burial grounds from Mesembria could go some way towards enlightening some of these unknown factors.

Variation in Diet by Sex, Age and Burial Type

Despite ancient literary sources referring to differences in diet between the sexes, isotopically there was no statistically significant difference. There was, however, a difference in their distributions, which is difficult to interpret, because while the linear variation in male diet can be attributed to slightly varying contributions of marine food in the diet, neither marine nor terrestrial animal products explain the lack of variation in the female $\delta^{15}N$ signatures, unless women were consuming varying amounts of low trophic level fish or garum. Another possible explanation would be small contributions of C_4 plants in the women's diet but the overall picture does not indicate any notable C_4 contribution to Mesembrian diet, although it is known to have featured in small quantities elsewhere in Europe and the Mediterranean world, particularly in the Medieval period (Garvie-Lok, 2001; Reitsema and Vercellotti, 2012). It is still possible that there were variations that cannot be detected isotopically, such as the more choice cuts of meat or finer breads being reserved for the men, or even the difference between meat and other animal produce, such as milk and eggs. The dental results suggested generally worse dental health in males, but as this was, again, not statistically significant it would appear that, on the whole, men and women in every period were consuming essentially the same diet.

As this study focused solely on adult diet there was no expectation that there would be any difference between the age groups, as proved to be the case. In studies that have included children, differences in diet have sometimes been identified, particularly for breastfeeding infants (Prowse et al., 2005; Triantaphyllou et al., 2008). Some studies have used grave type or burial goods as indicators of social or economic status within the population in order to determine whether or not diet varied within a social hierarchy (Keenleyside et al., 2006; Reitsema and Vercellotti, 2012), which is a dubious practice anyway in archaeological interpretation as 'the dead do not bury themselves' (Leach, 1979). However, as all of the graves excavated at Mesembria were basic pit or cist graves and the presence of burial goods was determined by time period, with the early graves generally having a modest array of artefacts and the later graves with none,[3] this analysis was not appropriate for this study. If the cemetery was representative of the entire population, this would indicate that there was little variation by any sort of social hierarchy; however it is difficult to discover whether or not this was the case.

[3] The 'burial goods' in the two Medieval burials were probably unintentional , as a part of clothing with the bronze buttons in Grave 641, or an incidental placing of the bronze coin of John II (1118-1143) in Grave 636.

Limitations and Further Study

The greatest obstacle to interpreting the isotopic – and to a lesser extent dental – results and reconstructing the diet of the Mesembrian population was the small sample size. The trends that have been identified may be false, as in most cases they were statistically insignificant, and this can cause confusion where there appears to be contradictory evidence, for example, with the higher caries levels in the later period when the statistically significant calculus and isotopic data suggests an increase in marine protein consumption. Although this could be explained by an increase in sweet, sticky foods in the diet, as the caries increase was not statistically significant, it may be a false trend. The following study seasons will see continued analysis of the skeletal remains at Mesembria which will increase the sample size for such complete-population studies as for the dentition; however, stable isotope analysis is a more time-consuming and costly procedure which hinders an analysis of the entire population. Nevertheless, even a slightly larger sample would enable the trends that have been cautiously identified here to be confirmed and improve the chances of results being statistically significant. Going forward with this study, the analysis and interpretation of the human collagen stable isotopes would greatly benefit from a comparison with site-specific archaeobotanical and faunal baseline values. Although archaeological fish bones rarely survive, the values of the terrestrial plant and animal life would provide a good guideline to determine how much the human values were being elevated above these values to determine the proportion of marine food in the diet, and by cross-referencing the values with the isotopic values of modern fish, some suggestion could even be made of what types of fish featured in the diet. Just as the sites that had similar isotopic values to the Mesembrian population proved to be invaluable to the interpretation of the results, further study of diet at similar sites will only strengthen and clarify the picture that is being painted of diet in the wider Mediterranean world over time and space.

Conclusion

This study demonstrates how valuable stable isotope analysis can be for knowledge of diet in past populations and in particular how it can be used optimally alongside literary and archaeological evidence, including osteological, zooarchaeological and palaeoethnobotanical aspects. Even where some of these factors could not be included, the study recognises that taking a holistic approach is important for the clearest and most detailed picture of a population's diet. Isotopic study is particularly valuable in that it is unselective and enables the entire population's diet to be investigated, including underrepresented groups, such as women and the poor, unlike the literature which often focuses on the feasting elite or fasting monks.

There was little intrapopulation variation in the diet at Mesembria by sex, age or burial type and only a small, gradual increase in marine food consumption over time. The most noteworthy variation was by cemetery, with the small, and evidently exclusive, Kraibrezna Street cemetery individuals' diet consisting of larger proportions of marine foods, as well as possibly cariogenic sweeteners, than those in the mainland cemetery. The location of these burials may be some sort of indicator of religious status within the community, giving these individuals greater access to certain foodstuffs either due to religious edict or privilege and wealth. This diet, however, was still made up of largely the same components as the rest of the population, particularly the roughly contemporary later diet with an increased and possibly more varied marine component than in the earlier period. The diet, which was largely similar over time, was a predominantly C_3 terrestrial diet with a significant marine contribution. The bulk of the diet would have been made up of grain, most likely wheat, in the form of bread and would have been supplemented by other isotopically indistinguishable plants such as olives, grapes and other fruits and vegetables; however, there is no evidence for the inclusion of legumes. The majority of the dietary protein would have come from both terrestrial and marine animal products. The former could have been in the form of dairy foods, eggs, meat or a combination as these foods are isotopically similar. The marine element would have varied slightly throughout the population from garum – which is known from the literary sources to have been produced on the Black Sea (Dalby, 1996) – and shellfish to small and medium fish. The dental evidence supports the isotopic interpretation of diet, with the high levels of both carbohydrates and protein in the diet resulting in high rates of both caries and calculus. As there is fish being consumed in all periods it is clear that ready availability of resources is the most important factor in the population's consumption of animal proteins; however, the increase in the later period indicates that religious fasting was a secondary factor. This reconstruction of diet is in accordance with that of Mesembria's neighbour, Apollonia, and other coastal sites around the Mediterranean world, including Roman, Byzantine and Medieval sites from the coasts of modern Croatia, Italy and Greece (Prowse et al., 2004; Keenleyside et al., 2006; Salamon et al., 2008; Bourbou et al., 2011; Lightfoot et al., 2012). As a diachronic study it unites these temporally different studies in demonstrating a similar diet over time, creating a concept of a general 'Mediterranean diet', at least for the coastal sites. Two samples with erroneous isotopic values, which may indicate that the individuals were immigrants or visitors to the site, demonstrate that some inland sites would still have had limited access to marine resources and during times of fasting would have resorted to a vegetarian or vegan diet, and that at some sites throughout Europe the C_4 plant, millet, was being consumed as a 'fallback' grain or as a supplement in animal fodder (Bourbou et al., 2011; Fuller et al., 2012).

The reconstruction of diet at Mesembria was made possible through the interpretation of the stable isotopic results and their comparison with a study of the dentition of the population, similar studies and ancient literary sources, all of which corresponded to depict a clearer picture of diet than any single source of evidence could have done alone. This study highlights the importance and value of stable isotope analysis and contributes to current knowledge of past diets on the Black Sea, in Greek colonies, in coastal populations and in the Mediterranean world.

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