ROMAN DIET AND NUTRITION IN THE VESUVIAN REGION: A STUDY OF THE BIOARCHAEOLOGICAL REMAINS FROM THE CARDO V SEWER AT HERCULANEUM

By

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Abstract

The Roman town of Herculaneum, due to its burial by the eruption of Vesuvius in AD79, provides the rare opportunity to study the diet of middle and lower class Romans living in an urban context in mid-1st century AD Italy. Knowledge concerning Roman diet, prior to the growth of bioarchaeology in the 1960s and 1970s, was derived from the ancient texts and focused primarily on the elite diet. The diets of the poorer classes have often been considered monotonous and unhealthy and consequently, malnutrition is believed to have been widespread in urban centres. Collaboration between the numerous sub-disciplines of bioarchaeology, including archaeobotany and zooarchaeology, has begun to take place amongst scholars working on the Vesuvian sites and diet is currently being studied using a more holistic approach. The ancient sources act as a secondary resource and it is now the physical food remains that play a crucial role in examining Roman diet and associated topics such as trade, health and nutrition.

This thesis investigated the bioarchaeological remains from the Cardo V sewer that ran beneath the shop/apartment complex of *Insula Orientalis* II in Herculaneum. It is the first large scale study to combine both new and existing bioarchaeological material from Herculaneum in an effort to provide the site with its own bioarchaeological data set, particularly with regards to food and diet. In total, 220L of soil was examined for carbonized and mineralized seeds, seashells, eggshells and fish bones. 194 taxa were identified, included including 94 botanical, 45 fish, 53 shellfish and two bird taxa. 114 of the 194 taxa can be considered edible foodstuffs. The statements of the ancient authors concerning dietary diversity have been examined in light of these findings and found to be comparable. The material displayed little taphonomic bias when compared to Pompeian bioarchaeological assemblages. The excellent preservation of the material, combined with data from modern food sciences, has allowed for much needed interpretation to take place in the areas of health and nutrition. The variety of cereals, fruits and seafood indicate close connections with the nearby land and sea and consequently, the economic implications of such extensive resource exploitation have been considered. A nutritional analysis of the finds have shown that diets were nutrient dense and healthy, enabling the people of Herculaneum to achieve modern day stature as well as survive and recover from illness. Thus it can no longer be assumed that those of moderate means ate an unhealthy and monotonous diet, that malnutrition was widespread in urban centres, and finally, that descriptions of foodstuffs in the ancient sources apply only to the wealthy.

CONTENTS
VOLUME I: THE TEXT

List of in-text figures

List of in-text tables

VOLUME II: FIGURES AND APPENDICES

List of Figures

APPENDICES

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"Indeed, food and nutrition in antiquity represents one of the most promising fields of investigation available to scholars at the present time." (White 1976: 182)

Chapter 1: Introduction

1.1 Introduction and research aims

When the term bioarchaeology was first coined in 1972 it referred to the study of animal bones (Clark 1972: 2). In response to advances in archaeological science and the growing recognition of the value of integrating data from different biological resources, the definition was altered. Bioarchaeology, in the UK, is now the overarching term used to define the study of any biological material from an archaeological site as it relates to past human lives and environments (Knüsel 2010: 62-67). Archaeobotany, zooarchaeology, paleoichthyology and stable isotope analysis, to name a few, are considered to be sub-disciplines of bioarchaeology. Although site preservation conditions, quantities of funding and the availability of resources vary from excavation to excavation, ideally a site should be studied using a bioarchaeological approach whereby all archaeologically important biological material is retained, processed and analysed. This approach leads to a more holistic understanding of the past while also enabling the results from the various sub-disciplines to be cross referenced with one another; thereby reducing sampling and processing biases.

The Roman sites buried by the eruption of Mount Vesuvius in AD79, including Pompeii and Herculaneum, are beginning to be studied from a bioarchaeological perspective (Fig. 1.1). Botanical, faunal and insect remains are now collected as part of standard sampling procedures and the publication of the results has led to the creation of region wide datasets and finds lists (Jashemski and Meyer 2002; Borgongino 2006). Newer scientific techniques have also created the need for a re-examination of some of the earlier finds. The most pertinent example involves the human skeletons, where the dietary data collected using trace mineral analysis are now considered inferior to results obtained by stable isotope analysis (Lazer 2009: 214). Claims, however, of extremely low fish consumption based on the initial isotope results did not correspond with the recovery of thousands of fish bones, subsequently leading to a re-examination of the stable isotope results and the creation of better baseline carbon and nitrogen isotope values (Andrew Jones March 23, 2011, pers. comm.; Nitsch 2012: 225-243; Craig *et al.* 2013).

The majority of the bioarchaeological data from the region comes from Pompeii as it has been subject to more extensive sampling than the nearby villas. Herculaneum, prior to the large scale cleaning of the site by the Herculaneum Conservation Project (HCP) in 2006, lagged significantly behind with regards to bioarchaeological research (Wallace-Hadrill 2006). The site had never been properly sampled for bioarchaeological material and the only biological finds were those intermittently recorded during the early excavations. Moreover, the entire region is notably lacking in broad interpretations of the data. Beyond Robinson and Ciaraldi's work on the shift from intramural to extramural crop processing in Pompeii in the mid-2nd century BC, most of the publications of the bioarchaeological material have focused on individual excavations or sites (Robinson, M. 1999: 101; Ciaraldi 2007: 148-150; Matterne and Derreumaux 2008; Murphy *et al.* 2013).

This thesis, focusing primarily on the bioarchaeological material from the Cardo V sewer, is the first large scale study to combine both new and existing bioarchaeological material from Herculaneum in an effort to provide the site with its own bioarchaeological data set, particularly with regards to food and diet. As a large urban domestic deposit situated beneath small shops and apartments, the new material from the sewer sheds light on the diets of those of lower to middle socioeconomic standing living in the Bay of Naples in the mid-1st century AD. The level of preservation in Herculaneum is extremely good, thus creating the opportunity to gain a better understanding of life in this ancient town and the Vesuvian region, often with a degree of clarity and detail that cannot be achieved at Pompeii. In addition, this new material allows for much needed interpretation to take place in the areas of health, nutrition and resource utilization. The results question our understanding of the cost and availability of foodstuffs as well as the dietary diversity of the lower classes. The importance of bioarchaeology cannot be underestimated and this thesis is one of the first to show that the results can be used to analyse more than just the foods and foodways of ancient peoples.

1.1.1 Research goals and objectives

This study examines the botanical and faunal material from the Cardo V sewer. The mammal bones recovered from the sewer have not yet been analysed and thus, in this study, they are only briefly mentioned. The ceramic finds have been used to date the material to the final decade before the AD79 eruption (Paul Roberts May 23, 2011, pers. comm.). In other words, the bioarchaeological material represents 10 years of accumulated human, domestic and kitchen waste produced by those living and working above the sewer in the multi-storey shop and apartment complex of *Insula Orientalis* II (Fig. 1.2). The material consists of carbonized and mineralized plant assemblages as well as fish bones, otoliths, shellfish and eggshells. Following the identification and quantification of the material, the thesis has two main goals: to gain an understanding of the taphonomic and depositional history of the Cardo V bioarchaeological material, and to determine the relationships between the inhabitants of *Ins. Or.* II and the assemblage with regards to diet, nutrition, consumption and food acquisition practices. A study of this scale and degree of detail has not been conducted for Herculaneum and it is hoped that in addition to providing a very nuanced picture of life in this ancient town, it will also highlight the importance of using modern ecological and nutritional data hitherto underutilized or unexplored by archaeologists.

The specific research aims of the project are:

- To identify the botanical, fish otolith and shell material from the Cardo V sewer and establish a methodological approach for quantifying and analysing a large dataset composed primarily of mineralized material
- To determine the quality of preservation and establish any taphonomic biases through a comparison with bioarchaeological material from Pompeii
- To determine the diets as well as the food processing and consumption activities of those living in *Ins. Or.* II
- To compare the statements of the ancient sources as they related to food consumption practices, particularly in the Bay of Naples, with the finds from the sewer
- To use modern food science to analyse the nutritional value of the fresh, preserved and processed foods consumed in *Ins. Or.* II and to subsequently assess the nutritional status and health of those living in this *insula* according to the bioarchaeological and skeletal remains
- To utilize the remains to go beyond diet and highlight other lifestyle and economic aspects of the ancient world that can be studied using bioarchaeological material

1.2 Nomenclature

While the conventional nomenclature for plant, fish and shellfish species are straightforward (*genus species*), their presentation within scholarly texts can vary significantly. Taxa can be listed in taxonomic or alphabetical order while common names can vary based on the author’s native language and geographical location. When scientific names are presented in this thesis they are listed in alphabetical order so that the reader can quickly locate the desired species or genus. Plant names follow Stace (2010), *Flora d'Italia* (Pignatti 1982) and *Flora Europaea* (Tutin 1964-1980) and the most updated family, genus and species names are used. A list of older, but common family or species names are provided in Appendix A. Fish and shellfish names are based on the most up to date entries in the World Register of Marine Species (WoRMS) and SeaLifeBase.[1] Following the species tables in chapter 5, common names are generally used. The most contemporary and well-known English name is used for the common names, which may differ from the specific British term for the species.[2] When appropriate, the raw data tables in the appendix list the proper anatomical name for the portion of the plant recovered, such as caryopses or endocarp. However, within the text the term 'seed' is often used for simplicity reasons, particularly when referring to multiple taxa.

1.3 Historical background

Reading scholarly publications concerning Roman food and diet is much like walking through a maze. At the centre lie the ancient sources, the archaeological remains and the physical food remains. Depending on the research question, there are multiple routes out of the maze with the paths often intersecting one another in the form of interdisciplinary work. However, by walking only one route, the reader will miss much of the important information that lies along the other paths. The aim of this chapter is to provide an aerial view of this maze both chronologically and topically. The first section will involve a brief discussion of Roman attitudes towards food and the ancient sources used most often in this

[1] Both WORMS and SeaLifeBase are available online at: http://www.marinespecies.org/ and http://www.sealifebase.org/

[2] In this study, broad bean is given as the common name for *Vicia faba* var. *minuta* as that is the term most frequently used in both academic and non-academic publications. However, in the strictest sense *Vicia faba* var. *minuta* refers to the small horse bean grown today for animal fodder and not the widely consumed larger flatter bean. This large variety did not exist in antiquity.

thesis. The following section will review the study of Roman food and diet prior to the advent of archaeobotany. There will then be a brief introduction to archaeobotany as botanical finds make up the bulk of the Cardo V material. The final section reviews the incorporation of archaeology and archaeobotany into the primarily literary based study of Roman food ways.

1.3.1 The ancient sources

The study of Roman food and diet begins with the Romans themselves. The surviving literature is filled with references, descriptions and allusions to food, demonstrating that the Romans did not consider it merely subsistence. Food played a critical role in defining Roman culture, establishing and reinforcing social values and in creating a boundary between Romans and "others." Moreover, food helped define an individual's membership within Roman culture, their social status, wealth and moral values (Corbier 1999: 130; Dupont 1999: 114). Recognizing this complicated relationship with food, and its frequent expression within the ancient literature, is crucial if we wish to use the ancient texts as a viable resource (Gowers 1993: 7). Within the context of this thesis, the ancient authors act as a secondary resource, used to support the bioarchaeological remains and modern scientific data.[3] They also provide invaluable insight into food preparation and preservation techniques. Each of the following chapters examines the food finds from a different perspective, and thus a range of ancient texts have been used throughout this study.

The most pertinent authors are those who either geographically and/or chronologically lived in close proximity to AD79 Herculaneum and the Bay of Naples. Pliny the Elder (AD 23-79) is by far the most important resource. As *praefectus* of the

[3] A full analysis of Roman food and identity is beyond the scope of this work. For good analyses of Roman attitudes towards food and identity see Hudson (1989), Gowers (1993), Dupont (1999), Purcell (2003) and Feldman (2005).

navy at Misenum, he was familiar with the region and often provides a firsthand account of the foodstuffs found in Campania (Duncan-Jones 1982: 23- 24). His *Historia Naturalis* was written as an encyclopaedia and thus all types of foods are discussed including both the mundane and the extravagant. It is often easy to differentiate between the two. Mundane items are described simply as foodstuffs while extravagant or luxurious items, especially those of which he disapproves, are accompanied by an anecdote demonstrating their decadence. For example, when discussing apples he simply states that there are several new varieties whereas in his description of red mullet he claims that Asinius Celer paid 8000 *sesterces* for a single fish (*HN* 15.47-52, 9.67). The major challenge in using Pliny lies in his descriptions of past and present consumption practices. He often states that a food or dish used to be popular but that that is no longer the case. The highest honour of the legumes once belonged to the broad bean and the Romans used to be a porridge eating people but now they mostly eat bread (*HN* 18.83, 18.117). These statements may be true as far as the elite are concerned, but how applicable are they to people of middle or lower socioeconomic status? Thus we must be careful when using Pliny and keep in mind that he, like most of the other ancient authors, were not necessarily writing for or about the average person.

Cato (234BC-149BC), Columella (AD4-70) and to a lesser extent, Varro (116BC-27BC) are the other authors that provide detailed accounts of food in the Campanian region. All three owned land in Italy, Cato owning a farm in northern Campania while Columella and Varro owned land closer to Rome (Dillon and Garland 2013: 66). Although their treatises are in the form of agricultural handbooks they provide important information on foods commonly grown and available in ancient Italy. Similar to Pliny, they often focus on the mundane, including food preservation techniques and simple rustic recipes. The chronological spread of their works enables us to see changes over time, including the introduction of new foods, varieties and cultivars.

Unlike Pliny and the agronomists, who use more factual information, the satirists and poets almost always use food as a metaphor or symbol. For Horace (65BC-8BC), Martial (AD40-102/104), Juvenal (late 1st century AD - 2nd century AD) and Athenaeus (late 2nd-early 3rd century AD), food is a method of establishing the wealth, status and moral values of a character as well as providing social commentary (Hudson 1989; Gowers 1993: 246-247). Consequently, it is almost impossible to determine the frequency of an item in the diet or its availability to people of lower status. In this thesis these authors are used primarily to establish the cost or value of foodstuffs in relation to one another.

There are also the more specialized texts where food is described for a particular purpose or where only a narrow range of items are discussed. Galen (AD129-217) is concerned with food from a nutritional and medical perspective, highlighting the importance of particular goods rather than their ease of availability or volume of consumption (*Alim. Fac. passim*). Oppian of Corycus's *Halieutica* (2nd century AD) only describes fish and fishing methods while Diocletian's Edict on Maximum Prices (AD301) focuses solely on cost. Despite their chronological and spatial distance from Herculaneum, these resources are important as they supply information concerning food preparation techniques and details about food items not necessarily mentioned by the other authors.

Finally, there is *De re coquinaria*, a collection of recipes compiled sometime during the late 4th century AD.[4] Although attributed to Apicius, this collection of recipes cannot be attributed to a single person or date (Grocock and Grainger 2006: 13-15). The earliest recipes probably date from the 1st century AD since silphium is listed as an ingredient and, according to Pliny, it was extinct by the mid-1st century AD (*HN* 19.39).

[4] There are other ancient sources mentioned briefly in this thesis, but it is only the ones described above that feature predominately in the analyses, particularly in chapter 7.

Despite its murky history, this text is useful as a description of edible foodstuffs and preparation techniques.

1.3.2 The study of Roman food and diet 1850-1970

The survival of this large body of ancient material has led to a significant amount of modern research into Roman food and diet. However, the study of Roman food and the study of Roman diet are not always identical and overlapping. The Oxford English Dictionary (1989) defines diet as, "Food; the provisions or victuals in daily use, viewed as a collective whole, especially in relation to their quality and effects." In modern scholarship the quality and effects of diet focus upon the caloric and nutrient needs required to sustain the human body. Roman food, while required in the study of Roman diet, can also be studied in the context of its symbolic, cultural, and religious implications; as a separate entity from diet (Dupont 1999; Feldman 2005). Therefore, from this point forward Roman diet will refer to works that study Roman food from a nutritional perspective. The majority of the scholarly literature focuses on Roman food. This is especially true for books and articles published before the advent of archaeobotany, when authors had to rely almost exclusively upon the ancient sources for their information.

Alexis Soyer's *Pantropheon,* published in 1853, is one of the first large scale studies of Roman food, although he groups Roman food with that of the ancient Greeks, Jews, Assyrians and Egyptians. His book consists of a comprehensive list of foodstuffs, gathered from numerous ancient sources, and covers goods such as grains, pulses, vegetables, seasonings and meat. Despite its early date it is quite a complete list and while several inventories of Roman foodstuffs have been created since Soyer's publication, few have provided any new information (André 1961; Brothwell and Brothwell 1998).

In the first half of the 20th century scholars began to focus on specific foodstuffs and incorporate archaeological material into their works. Day's (1932) study of agriculture in the Vesuvian area used information both from excavations and the ancient sources to create a vivid, although inaccurate picture of food production. Beginning with Day, the three foods of the Mediterranean triad (grain, wine and olive oil) became the focus, and sometimes the sole focus, of research for several scholars. During the late 1940s Jasney (1941-42, 1944, 1950) published multiple articles on Greek and Roman grain and bread, while in the early 1950s Moritz (1958) published his book on grain mills.

The 1960s saw little change in the study of Roman food. André’s *L’Alimentation et la cuisine à Rome* (1961) is the major publication of the decade and, similar to Soyer, consists of a catalogue of Roman foods gathered from the ancient sources. There was an increased interest in the study of spices reflected in Miller’s 1969 book on the Roman spice trade and Gemmill’s 1966 article about silphium. However, the major focus remained on the foods of the Mediterranean triad with White publishing several articles on Roman grain and farming (1963, 1967, 1970a, 1970b).

1.3.3 Brief history of archaeobotany

Archaeobotany is the collection, identification and interpretation of plant remains from archaeological contexts (Miksicek 1987: 211). The discipline has a long history, but did not become a standard component of archaeological excavations until the 1970s. The term paleoethnobotany, more commonly used in North America, was coined in 1959 and the first conference devoted to this topic was held in 1978 (Pearsall 2000: 2-3).

The first formal study of plant remains took place in 1826 when Kunth examined desiccated plant material from Egyptian tombs. Heer continued the practice in 1865 when he discovered waterlogged deposits from lakeside villages in Switzerland. For the remainder of the 19th century and for the first half of the 20th century, plant remains were studied in Europe and North America, but primarily in places with exceptionally well preserved waterlogged or desiccated material (Gilmore 1931; Jones 1936; Gremillion 1997: 1; Pearsall 2000: 4-5). Led by Helbaek in the 1950s, archaeobotany was incorporated into several excavations in the Near East and archaeological teams were now beginning to include a botanist (Helbaek 1960, 1963, 1969; Renfrew 1973: 2-3; Watson 1997: 14-16; Pearsall 2000: 4).

The introduction of machine assisted flotation in the early 1970s drastically changed the study of archaeobotany. Struever is credited with popularizing flotation in 1968 and since then it has developed into its own sub-discipline with books and articles focused entirely upon its uses and challenges (Williams 1973; Keepax 1977; Miksicek 1987: 211; Wright 2005). The creation of mechanized flotation devices, such as the Ankara type flotation machine, allowed for the large scale collection and sorting of environmental samples (Renfrew 1973: 21; Pearsall 2000: 6) (Figs. 1.3-1.4). On-site flotation, by separating heavy soil from the relatively light macrobotanical remains, increases the amount of macrobotanical material that can be brought back to a laboratory. As a result of this new technology, the number of environmental finds from sites has increased dramatically in the last 40 years. The field of archaeobotany now includes research into new methods and technologies for plant recovery and identification such as the use of scanning electron microscopy (SEM), carbonization experiments, and starch and phytolith analysis (Boardman and Jones 1990; Butler 1991; Wright 2003; Braadbaart *et al.* 2005; Braadbaart 2008; Braadbaart and van Bergen 2005; Fritz 2005: 800-801 Piperno 2006; Torrence and Barton 2006; Church 2013).[5] Although a considerable amount of archaeobotanical research has focused on prehistoric sites (Brothwell and Brothwell 1998: 194), the popularization and expansion of the field has had a significant impact on the

[5] For complete overviews of the history of archaeobotany see Renfrew (1973), Hastorf and Popper (1988), Watson (1997), Jacomet and Kreuz (1999: 11-21) and Pearsall (2000).

study of Roman food and diet with Classical archaeologists now regularly taking environmental samples during excavation.

1.3.4 The study of Roman food and diet 1970-2013

The influence of archaeobotany on the study of Roman food and diet began in the 1970s. While the focus remained on the Mediterranean triad and the ancient texts remained the primary sources of information, some authors began to acknowledge the presence of environmental finds (Frayn 1975, 1979). At the end of his article on the olive in the Mediterranean, Boardman (1976: 193) states that macrobotanical remains, when combined with other archaeological evidence, could increase our knowledge of the relationship between man and the olive tree in the classical world.

It was also in the 1970s that scholars began studying Roman diet. White's (1976) article on food requirements and supplies in Classical times was the first to attempt a study of the nutritional content of Roman food and its impact on health by integrating faunal, botanical and archaeological evidence. Before beginning his analysis, White gives a brief overview of the study of Roman food. He points out that, "...the standard reference books are, for the most part, unsatisfactory both in content and approach. The compilers still usually leave the reader with the impression that all Romans enjoyed a twelve course dinner..." (White 1976: 146). Although the article is still quite dependent on the ancient sources and focuses heavily upon bread production and quality, it does contain two crucial sections. The first is the study of Roman food across all the social classes and the move away from the focus upon banquets and *cena.* Secondly, Appendix E contains a published chart of the calorific, protein, fat and carbohydrate values of common Roman foods (White 1976: 190).

Research on the Vesuvian sites also benefited from the increased interest in archaeobotany and Roman diet. During the early excavations of the 1800 and 1900s archaeobotanical and faunal finds were recorded only sporadically in the excavation reports and find spots were often omitted. The late 19th and early 20th centuries did see some improvement. The botanical finds from an excavated shaft at the Temple of Isis in Pompeii were published by Overbeck and Mau in 1884. In 1897, Pasqui recorded the food finds from the *villa rustica* La Pisanella while in his 1902 book on Pompeii and Herculaneum, Mau listed the types and find spots of seeds and grains found in *dolia* throughout the two towns. In 1904 Wittmack published a list of 24 carbonized food plants found at Pompeii, although most of the items have now disappeared from the Naples Museum. During the middle of the 20th century botanical research focused on the identification and description of plants in wallpaintings and mosaics (Casella 1950; Ciaraldi 2007: 35-37).

In the 1960s and 70s Wilhemina Jashemski brought the study of plant remains at Pompeii to the forefront. She focused upon gardens and the use of open space, while applying Vittorio Spinazzola's previously established technique of making plaster casts to tree root cavities (Spinazzola 1953: 757-758). Although her identifications were not always correct, Jashemski (1963, 1973, 1974, 1979) provided scholars with a significant amount of new data on the types of plants grown within the town as well as evidence for food production within the city walls.

The identification and publication of plant remains discovered at Vesuvian sites continued into the 1980s. In 1975 a large cache of carbonized hay was found at the *villa rustica* at Oplontis in Torre Annunziata and the publication of the finds revealed 88 items identified to species (Ricciardi and Aprile 1988). Meyer (1980, 1988) published the first detailed lists, with photographs, of carbonized material from Pompeii, Herculaneum and numerous villas. This work, combined with the subsequent discovery and analysis by Bisel (1987) of 139 skeletons from Herculaneum, considerably advanced the study of the Roman food and diet in the Vesuvian area.[6] However, except for the excavations carried out by Jashemski and those at Oplontis, studies of botantical finds were generally limited to pre-existing collections, such as those in the Naples Museum.

Despite the publication of these new archaeobotanical datasets, throughout the 1980s the ancient authors remained the principal resource in the study of Roman diet (Fidanza 1979). At the same time as Meyer published his list of carbonized plant remains, Evans (1980) published a detailed model of the diet of the classical Italian peasantry. Evans conceded that the ancient sources can only provide a limited amount of information and he did include modern research on the flowering times of edible plants and standard nutritional requirements as stated by the UN’s Food and Agricultural Organization (FAO). Foxhall and Forbes’ 1982 seminal article on grain as a staple food conducted an in-depth study of ancient wheat and barley processing and the amount of grain required to support an individual based on sex and age. Their study used grain figures from the ancient sources as well as experimental archaeology and modern ethnographic comparisons. It was the first article to apply detailed modern nutritional information to ancient consumption patterns. A few years later, Sippel (1987) continued the study of Roman diet by publishing an article on dietary deficiency amongst the poor in ancient Rome. His views on ancient nutrition were extremely negative. However, he did not use the available archaeobotanical material and his nutritional information was outdated. These problems emphasize the need for a correct and detailed knowledge of basic human nutrition since it is one of the few parameters in the study of diet that does not change over time. A short article by Waterlow (1989) suggested that most people in ancient Greece and Rome did receive an adequate

[6] Bisel’s work on the Herculaneum skeletons will be discussed in detail in chapter 7.

amount of energy and nutrients but his claims are also based primarily on the ancient source and very little bioarchaeological evidence.

The study of Roman food in the 1980s, while not undergoing any drastic changes, did expand the range of food topics studied. There was still an intense focus upon grain, wine and olive oil, although now from a more archaeological perspective (Rossiter 1981; Mattingly 1988; Peacock 1989). Spurr's 1983 paper on millet in Roman Italy expanded the study of food types and continued the long standing debate about Roman grain preferences (Rickman 1980a: 4-6).[7] Publications on food processing appeared at this time, as did an increased interest in food-related topics such as health, cooking and satire (Scobie 1986; Brothwell 1988; Stahl 1989; Hudson 1989).

Publications about Roman food increased significantly in the 1990s. The study of food from a social perspective remained a popular topic, especially the relationship between food and status (Wilkins 1993; Purcell 1995; Dupont 1999). Aside from Brothwell and Brothwell's (1998) comprehensive study of ancient foodstuffs, research began to focus on specific food types such as meat and fish (Frayn 1995; Ørsted 1998). Work by Flint-Hamilton (1999) and Corbier (1999) on legumes highlights the importance of rereading the ancient sources. Authors such as Pliny placed a high value upon legumes for both their nutritional benefits and ease of cultivation (Pliny *HN* 18.98; Columella *RR* 2.7.1). However, modern scholars have tended to categorize legumes either as food for the lower classes or famine foods and have generally neglected them in favour of work on the Mediterranean triad (Braun 1995; White 1995).

Peter Garnsey became the primary scholar on Roman diet in the 1990s. His 1991 article was the first comprehensive reconstruction of Roman diet. In addition to the calorific, protein and fat requirements listed by previous authors, he also included an

[7] There has been, and still is, the belief that the Romans preferred bread wheat over all other types of grain including emmer wheat and barley. However, a re-examination of the ancient sources and recent archaeobotanical discoveries have begun to challenge this belief (see section 7.2.1).

analysis of essential amino acids and vitamins. While he focused predominantly on the nutritional impact of a heavily grain-based diet, he did acknowledge the importance of other foodstuffs such as legumes, meat and vegetables and included them in his reconstruction. His later books cover a range of food-related topics including dietary variety, famine foods, malnutrition and taboos (Garnsey 1998; 1999). King's (1999) research on faunal remains from Italian sites acted as a complement to Garnsey's work by adding a more archaeological basis to the study of Roman diet. Although Garnsey's work is nutritionally accurate, the majority of his information about Roman food was derived from the ancient authors.

In the 1990s, several Pompeii excavations utilized the now well-developed techniques of bulk flotation and sieving. This vastly increased the number of botanical species identified within the town as well as information on foreign foods, dietary diversity and preservation methods. The Anglo-American Pompeii Project (AAPP) excavated the entirety of Region VI, Insula I between 1994-2005 and the botanical material has been published in several books and articles (Ciaraldi 1996, 2007; Jones and Robinson 2004; Murphy *et al.* 2013) (see fig. 1.5 for region and *insulae* locations). It was the first large scale excavation to take soil samples from each context including areas that had no association with food preparation or consumption. Since samples are usually only taken from areas such as kitchens and gardens, the AAPP samples provide important data on the quantity and types of food finds from a wide variety of contexts (Ciaraldi 2007: 54-56). The House of the Wedding of Hercules (VII.IX.47) was excavated by an Italian team led by Andrea Carandini from 1994-1995 (Carafa 1997) while the British School at Rome and the University of Reading's excavation of the House of Amarantus (I.IX.11-12) took place between 1995-1998 (Fulford and Wallace-Hadrill 1999). Both houses produced significant quantities of botanical material (Carafa 1997; Robinson, M. 1999). Excavations by the

German Archaeological Institute at Rome of the House of the Postumii (VIII.IV.4) produced fewer finds although only a single room was fully sampled for macrobotanical remains (Dickmann and Pirson 1998).

Sampling at Pompeii continued throughout the 2000s. The garden of the House of the Greek Epigrams (I.IX.18) was sampled by Mark Robinson in 2007 (Robinson 2007c). In addition, the Porta Nocera necropolis was sampled for food and ritual remains while samples were taken from several bakeries during the cleaning work done by the Pompeii Pistrina Project (Matterne and Derreumaux 2008; Monteix *et al.* 2011). A small quantity of material was recovered from drains in the Pompeian forum, excavated during the University of Augsburg's Forum Pompeii project in 2008 (Kockel and Flecker 2008).[8] Extensive excavations at Insula VIII.VII.1-15, as part of the Pompeii Archaeological Research Project: Porta Stabia (PARP:PS), were undertaken between 2005-2013, and the botanical material is now in the process of being identified and analysed (Ellis and Devore 2009, 2010).

Macrobotanical remains have also been found at Roman period sites throughout Europe, and only a brief summary is provided here. In Italy, material was recovered from the Roman harbour in Pisa (Bertachhi, *et al.* 2008) while the modern town of Modena has been extensively sampled for waterlogged remains (Rinaldi *et al.* 2013). Plant remains from over 100 sites in Northern Italy have also been collected, providing important geographical and chronological data (Rottoli & Castiglioni 2011; Bosi *et al.* 2013). Excavations in Belgium (Cooremans 2008) and Croatia (Šoštarić and Küster 2001) have produced detailed finds lists of carbonized and waterlogged remains respectively. Additionally, there has been a great deal of work done at Berenike, Mons Claudianus and Myos Hormos in Egypt, and at several sites in the UK, France and Germany (Kroll 2001;

[8] These botanical samples have been identified by the author and sample descriptions and find lists can be found in Appendix E.

Egypt: Cappers 1999a, 1999b; Van der Veen 1999, 2001, 2011; Van der Veen and Hamilton-Dyer 1998; UK: Van der Veen 2008; Marshall *et al.* 2008; Van der Veen *et al.* 2007; Germany: Knörzer *et al.* 1999; France: Vandorpe 2010). The increased number of Roman period sites with botanical finds has also allowed scholars to undertake large scale analyses of changes in food and plant composition across space and time (Bakels *et al.* 1997; Bakels and Jacomet 2003; Livarda and Van der Veen 2008; Van der Veen *et al.* 2008; Livarda 2011). These analyses are helpful for inter-site comparison in terms of both assemblage composition and preservation conditions.

There have been a limited number of publications examining ancient food practices based on the integration of the archaoebotanical and archaeological material. These studies have focused on the social aspects of food such as status differentiation, feasting, trade, and spatial organization (Kreuz 2000; Palmer and Van der Veen 2002; Van der Veen 2003; Fuller 2005; Livarda 2013). Published works focusing on the relationship between ancient diet, nutrition and health, using archaeobotanical data, remain extremely rare (Wing and Brown 1979; Gilbert and Mielke 1985; Sutton *et al.* 2010). Instead, work on health and diet in the ancient world has mainly been done through an examination of animal and human bones or isotopic analysis (Henneberg *et al.* 1999; Bisel and Bisel 2002; MacKinnon 2004; Prowse *et al.* 2005; Laurence 2005; Lazer 2009; Craig *et al.* 2009; Keenleyside *et al.* 2009; Crowe *et al.* 2010; Nitsch 2012).

The study of Roman food in the 2000s, while continuing the research of the last century, has produced some new trends. There is still an interest in the Mediterranean triad and in the analysis of Roman food from a literary and social context (Purcell, 2003; Danaher 2005; Erdkamp 2005). However, the acknowledgement of a diet based on more than grains, wine and olive oil has led to the study of ancient food processing techniques (Curtis 2001). In 2006 Thurmond published a book dedicated to food preservation and processing in classical Rome. It combines the information supplied by the ancient authors with modern data on food processing and preservation. While covering typical foodstuffs such as grains and wine the book also goes into detail about vegetables, fruit and spices.

Finally, the increasing scholarly interest in Roman food over the past two decades has been mirrored by a growing mainstream interest, especially in the form of cookbooks. It is perhaps due to the increased number of botanical finds, which are often highlighted in newspapers, but it is equally possible that it is due to the increased interest in experimental and exotic cooking that has taken place around the world. Beginning in 1992 at least five cookbooks of Roman recipes, all based on the recipes of Apicius, have been created (Giacosa, 1992; Dalby and Grainger, 1996; Grant 1999; Faas 2003; Grainger 2006). Some, such as Grainger's, are quite well researched and do provide useful information about food preparation methods and taste.[9]

1.4 Thesis structure

The two volumes of this thesis should be used in conjunction so that images can be seen at the same time as the associated text. The first volume contains the text as well as full species lists. The appendix or second volume, contains all the images (except for some figures in chapter 5) and supplementary information such as nutrient data tables and the raw data for the plant, fish and shell finds. It also contains all the data on the Pompeii material that was both examined by the author and used for comparative purposes. This first chapter has provided a historical background to Roman food, archaeobotany and the involvement of archaeobotany at the Vesuvian sites.

The following chapter provides background information for the town of Herculaneum and its excavation history, the excavation of the Cardo V sewer, as well as a

[9] Mrs. Grainger has reconstructed a Roman kitchen in her garden and used recreations of Roman tools to test her recipes (April 24, 2010, pers. comm.).

detailed description of *Ins. Or.* II. Chapter three is intended for those not familiar with archaeobotany or bioarchaeology, providing descriptions of preservation methods and formation processes, including a lengthy description of the mineralization process. Chapter 4 discusses the methodological approach used in this study, highlighting the application of species accumulation curves (SACs). Chapter 5 presents the results of the identification and quantification of the material including density, abundance and ubiquity scores for all material and preservation types. The remainder of the thesis is dedicated to an analysis and discussion of the results. Chapter 6 is structured in a similar manner to chapter 3, but examines specifically the preservation and formation of the Cardo V assemblage. The material is compared to the finds from Pompeii, particularly with regards to taphonomy and ritual burnt offerings. Chapter 7 is divided into four sections. The first compares the food finds and the statements of the ancient authors while the second assesses the nutritional quality of the diet based on the food finds from the sewer. The third section builds on the other two and examines the nutritional value of the diet in relation to food processing and preservation techniques, soil quality and phytonutrients. The final section compares the nutritional quality of the dietary evidence with the results of the analyses done on the Pompeii and Herculaneum skeletons. Chapter 8 features three case studies designed to highlight food acquisition practices and the food economy of Herculaneum. Carbonized olive stones are discussed in the context of fuel use while the weed seeds are used to assess evidence for cereal importation. The fish and shellfish remains are utilized to reconstruct the fishing practices in the Bay of Naples. The final chapter summarizes the major findings of this thesis, as well as the interactions that were taking place between people and their foodstuffs in AD79 Herculaneum, Campania and the wider Roman Empire.

"Strabo's gentle Libyan winds meet Dionysius' safe haven, and conjure up an image of a spot that was truly blessed, between the fertile green slopes of Vesuvius and the glittering crescent of the bay." (Wallace-Hadrill 2011a: 89)

Chapter 2: The site of Herculaneum, *Insula Orientalis* II and the Cardo V sewer

Archaeological material cannot be fully understood or discussed without first understanding the archaeological and historical context of the remains. *Ins. Or.* II and the Cardo V sewer are not simply a building and its associated septic tank; they are structures that were created, altered and incorporated into the fabric of Herculaneum, subjected to the same excavation methods that uncovered and exposed the town to the elements as well as the public. The aim of this chapter is to place *Ins. Or.* II and the Cardo V sewer into their proper contexts geographically, historically and archaeologically. The chapter begins with a brief description of the geographical and geological position of Herculaneum on the Bay of Naples and the layout of the town as it is visible today. This section is followed by an overview of Herculaneum's systems of water supply and removal. The middle of the chapter is dedicated to *Ins. Or.* II, providing a structural history of the building and detailed descriptions of the units situated above the sewer, namely II.6-14. The Cardo V sewer is then described in detail, highlighting the layout of the main tunnels and later additions. The final section of the chapter focuses on the AD79 eruption of Vesuvius and a brief history of the excavations of the town from the 1700s until the present day. The chapter concludes with a detailed description of the excavation of *Ins. Or.* II and the Cardo V sewer.

2.1 Overview of the Roman town of Herculaneum

When Herculaneum was founded in the 4th century BC, the site was almost certainly chosen for its geographical location. The town is situated on a terrace that slopes gently towards the sea. It is flanked by two small rivers, one to the east and the other to the west (Fig. 2.1). According to the ancient sources, Herculaneum's south westerly exposure made it a particularly healthy place to live as the gentle winds limited the number of malaria-carrying mosquitoes (Strabo *Geog.* 5.4.8; Laurence 2005:88). Its location as an excellent point of anchorage is attested to by Dionysius of Halicarnassus (*Ant. Rom.* 1.44.1) who says that Herculaneum was named after Hercules when he anchored his fleet on its shores. Herculaneum was situated only 10 km from the center of Neapolis, 16 km from Pompeii and 20.5 km from the port at Puteoli and thus had easy access to trade routes (Fig. 2.2). It was this ideal location that enabled Herculaneum to develop into a wealthy urban center.

Very little is known of Herculaneum's early history and none of the town's original architecture survives.[10] The grid plan suggests that it may originally have been a Greek settlement, but the evidence is extremely scant (Fig. 2.3). Strabo states that, like Pompeii, Herculaneum was originally controlled by the Oscans and then subsequently by the Etruscans, the Samnites and finally the Romans (*Geog.* 5.4.8). The varying control and influence of the Etruscans and Greeks over the Bay of Naples, prior to the Roman domination, has led Wallace-Hadrill (2011a: 89-106) to suggest that Herculaneum was probably an Etruscan settlement where the inhabitants spoke Oscan. However, only one Oscan inscription from Herculaneum has survived and it was not until the 1st century BC that the town would have become recognizable both culturally and physically to those who lived there at the time of the eruption.

During the Social War of 91-89BC, Herculaneum, along with Pompeii, sided against Rome. The town was besieged and eventually captured by Sulla's legate Titus Didius (Velleius *Hist. Rom.* 2.16.2). Herculaneum was granted the status of *municipium* in 89BC and Latin became the official language (DeKind 1998: 21). The end of the Social

[10] The first masonry structures appear in the 2nd century BC (Andrews 2006, 1: 165).

War brought peace and prosperity to the Bay of Naples and during the 1st century BC the wealthy elite from Rome began building their enormous and lavishly decorated villas along the coastline. The sudden influx of wealth to the region is visible in Herculaneum in the form of well decorated public buildings including the central baths, the Basilica Noniana and the theatre (Monteix 2010a: 349). Herculaneum's coastal city wall was no longer needed as a defensive structure and some of the largest houses, such as the House of the Stag, incorporated the wall into their architecture (Fig. 2.4). The town continued to grow slowly with the construction of the *palaestra* complex and *Ins. Or.* II during the Tiberian and Claudian periods (Monteix 2010a: 260; Wallace-Hadrill 2011a: 275). The earthquake of AD62 significantly damaged the town but it appears to have been fully repaired by the time a second major earthquake, or series of earthquakes, occurred during the 70s AD (Fröhlich and Jacobelli 1995; De Carolis and Patricelli 2003: 76; Monteix 2010a: 234-235). Again, the city repaired itself and the increase in the number shops and upper floor apartments during this time suggests that the city was in a period of economic growth when the eruption occurred in AD79 (Monteix 2010a: 353).

2.1.1 City layout

The oldest feature of the city is probably its street grid, and thus Herculaneum was always set up as a series of rectangular *insula* blocks enclosed by *cardines* (north-south streets) and *decumani* (east-west streets) (Fig. 2.5).[11] Only the southern half of the town has been excavated, approximately 4.5 hectares, although probably to its eastern and western limits.[12] The presence of the theatre to the north reveals there is much more yet to be uncovered and it is estimated that the entire town is between 15-20 hectares (Guidobaldi

[11] All directions refer to site north, not true north.

[12] The town is limited by a steep slope and the river to the east (Cinque and Irollo 2008: 427-428). Villa of the Papyri, as a suburban villa (despite its proximity to the town) suggests that the excavations have reached the western edge of the city proper.

2008: 22; Wallace-Hadrill 2011a: 105). The excavated portion of Herculaneum consists of eight *insulae* bordered to the east by the *palaestra*, *Ins. Or.* I and II (Fig. 2.5). There are five excavated *cardines* and two *decumani*, including the *decumanus maximus* located at the very northern edge of the excavations. The southern end of the town, facing the Bay of Naples, comprises the suburban baths, a large terraced space with two small temples, and beneath the terrace, a series of barrel vaults that supported the terrace (Fig. 2.6).

The western and northern edges of the site are less well defined. To the west, *Insulae* I and VIII and *Insula Occidentalis* remain chiefly unexcavated, but just slightly farther west an extremely well preserved bath building has been fully excavated (Guildobaldi 2008: 20-21)(Fig. 2.3). The extreme western edge of the town is bordered by the Villa of the Papyri, which was explored extensively during the Bourbon period (1711-1780) but only a small portion of the front facade and rooms have been exposed. To the north, a series of large buildings beyond the *decumanus maximus,* including the so-called basilica and a multi-storey *insula*, were explored by Bourbon tunnels. However, due to the presence of the modern town above, these structures have also remained unexcavated (Maiuri 1958: 29; Guidobaldi 2008: 20).

Despite its relatively small size and population, estimated to be between 4000-5000 inhabitants, Herculaneum was supplied with a large number of public buildings (Camodeca 2008: 87). The theatre, no longer accessible through the Bourbon tunnels, could hold 1350 people (Wallace-Hadrill 2011a: 151). The political heart of the town was located in the north west corner and includes the College of the *Augustales*, now believed to be the *Curia,* the Basilica Noniana and the so-called 'basilica', probably an open porticoed space (Wallace-Hadrill 2011b: 131-133) (Fig. 2.3). Notably absent is a well defined forum with its open spaces. The debate surrounding the location and nature of the Herculaneum forum is still ongoing.[13]

In addition to political buildings, Herculaneum also had three baths: the suburban baths, the central baths in *Insula* VI and the baths near the Villa of the Papyri. The *palaestra* complex was probably used as a religious space but may also have had a bath complex at its northern end (Monteix 2010a: 265-267). Other religious spaces included the two temples situated on the seaside terrace. Again, the small number of temples and especially the absence of a Capitolium are striking and it is probable that additional temples are present in the unexcavated sections of the site. Also missing from the excavated area is a *macellum* and the harbour. The harbour was probably located beyond *Ins. Or.* I and the *palaestra* where the eastern branch of the river met the sea (Cinque and Irollo 2008: 427-428; Wallace-Hadrill 2011a: 103).

The domestic spaces of Herculaneum include large houses of over 1000m^2 with dozens of rooms and large open peristyles. These houses are comparable in size to Pompeian homes such as the House of the Faun and the House of Cryptoporticus. In Herculaneum these homes tend to be located along the city wall and include the House of the Stag, the House of the Telephus relief and the House of the Mosaic Atrium (Fig. 2.5). There are also many more moderate sized homes, between 700-600m^2 particularly along the *Decumanus maximus* such as the House of the Bicentenary and the House of the Black Salon. Again in terms of size, these are comparable to the House of Ephebus and the House of Paquius Proculus at Pompeii (Wallace-Hadrill 1994: 189-212, Wallace-Hadrill 2011a: 226).

Herculaneum has more surviving upper floors and more multi-storey apartment blocks than Pompeii (Andrews 2006, 1: 220). This is probably due to the physical

[13] For recent scholarship on the debate please see Adamo Muscettola (1982), Allroggen-Bedel (1983), Pagano (1996), Wallace-Hadrill (2011a, b) and Monteix (2012: 685).

constraints created by the slope of the eastern terrace, forcing people to build up instead of out. *Ins. Or. II* will be described in detail in the following section, but it is sufficient to say here that this three storey shop and apartment block, in addition to the multi-storey *insula* to the north of the *palaestra*, created the appearance of a densely inhabited town, more in the manner of Ostia than Pompeii. Constructed nearly a century earlier than the *insulae* at Ostia, *Ins. Or.* II may have acted as a prototype (Wallace-Hadrill 1994: 110; Andrews 2006 1:185-190).

The shops and workshops in Herculaneum were restricted to a relatively limited number of spaces, especially in comparison to Pompeii where they line almost every street. Large houses, without attached shops, dominated the town south of the *decumanus inferior* and commercial spaces were limited to the northern half of the *cardines* (Fig. 2.5). The largest concentration of shops can be found along both sides of the Cardo V with the units on the ground floor of *Ins. Or.* II comprising almost a quarter of all the shops in the town (Monteix 2010a: 255). All of the 52 excavated shops seem to have been producing and selling goods for a local market and not for surplus or export (Monteix 2010a: 87).

2.2 Water management

Supply

Herculaneum's systems of water supply and removal took advantage of the town's geographical and geological position. Herculaneum is situated on a tuff terrace with the top 8-10 m of the terrace composed of solidified volcanic ash from the Avellino eruption (3.4Ka BP) and the underlying 15 m composed of tuff from the Ottaviano eruption (8Ka BP) (Cinque and Irollo 2008: 426). Ground water ran between these two layers and wells were easy to carve into the rock (Camardo 2007: 168). The area's average rainfall of 900mm per year, falling primarily between October and March, also enabled the use of cisterns (Jansen 1991: 146). The cisterns were filled by channelling and collecting rain water from the roof. The distribution of these wells and cisterns demonstrates that most houses had a private supply of water (Jansen 2002: 99) (Fig. 2.7).

By the mid-1st century AD the town was connected to an aqueduct whose water probably came from a spring on the slopes of Vesuvius (Jansen 2002: 107; Camardo 2007: 172-173).[14] Two water towers reduced the water pressure before it was channelled through lead pipes to private houses, three large public fountains, the *palaestra* pool and the *tepidarium* of the central baths (Camardo *et al.* 2006: 185) (Figs. 2.7-2.8).[15] The small number of public fountains and the relatively small number of houses connected to the aqueduct highlights an important difference between the water supplies to Pompeii and Herculaneum. The presence of so many domestic cisterns and wells, still in use at the time of the eruption, suggests that in Herculaneum piped water was not considered an essential household amenity (Jansen 1991: 161). Finally, as will be shown in section 2.4, the nature of the Cardo V sewer eliminated the possibility of *Ins. Or.* II having its own water supply and it is probably for this reason that two of the three public fountains are situated at either end of the building (Fig. 2.7).

Removal

The tuff terrace that allowed easy access to groundwater was the major driving force in the creation of Herculaneum's water and waste drainage system. The 8% slope of the terrace towards the sea meant that the streets could be used to channel rainwater towards the beach (Camardo *et al.* 2006: 190 n.24) (Fig. 2.9). Similar to Pompeii, Herculaneum had raised

[14] Although originally believed to be a branch of the Serino aqueduct (that fed the Imperial fleet at Misenum), the pipes in Herculaneum do not show the build up of calcium carbonate that is found in the Serino aqueduct (Camardo 2007: 172-173).
[15] The other baths were fed by well water (Jansen 1991: 160).

sidewalks so pedestrians could avoid the water. The removal of waste and waste water presented significantly greater challenges.

The hard and compact tuff terrace did not absorb water and thus cesspits could not be used as easily as they were at Pompeii where the porous volcanic subsoil readily absorbed liquid (Jansen 2002: 110). Cess pits were used but they had to be cleaned out on a frequent basis, as indicated by an inscription from a column in the peristyle of the House of the Black Saloon (CIL. IV suppl. 3.4.10606). Consequently, large sewers were built beneath the *cardines* that drained waste water towards the beach.

The Cardo III sewer was 60 cm wide and 1.05 m high and drained the forum baths (including its eight-person public latrine), the *decumanus inferior* and the houses that ran along the Cardo III. The sewer extended from the *decumanus maximus* to the southern end of the town where it emptied into a tank before continuing straight through a tunnel and emptying onto the beach (Camardo 2011) (Fig. 2.7). There is a sewer beneath the Cardo IV that is approximately the same size as the Cardo III sewer. A sink hole has been identified under temple B on the terrace that was probably similar to the Cardo III tank. The Cardo IV sewer then continued under the fourth arcade of the vaulted terracing before it too emptied onto the beach (Camardo 2007: 180). The Cardo V sewer (described in detail in section 2.4) did not empty onto the beach and instead functioned as a cesspit for the waste generated by those living in *Ins. Or.* II.

2.3 *Insula Orientalis* II

The north eastern section of the town is occupied by the large multi-building complex referred to as the *palaestra* (Fig. 2.10). At the centre is an open space with a cross shaped pool, surrounded by a portico on three (and possibly four) sides. To the north lies the partially excavated multi-storey *insula* block and a cryptoporticus. Very little of the southern end of the palaestra has been excavated, revealing only the first two columns of the portico and part of a potential peristyle. The western side has been fully excavated and is occupied by *Ins. Or.* II with its shops and apartments facing the Cardo V and its back porticoes and *aula* facing into the center of the complex towards the pool.

While *Ins. Or.* II is one of Herculaneum's most unusual buildings, its multi-functionality enables us to view it as a microcosm of the town. This large concrete and brick structure contains domestic, commercial and public spaces. The relationships between these spaces were created and altered during three broad phases: initial construction, AD62 earthquake repairs and AD 70s repairs.

Phase I – Initial construction

Herculaneum could not support large bodies of water until the construction of the aqueduct. The cryptoporticus and the small rectangular pool just to the south were the first parts of the *palaestra* complex to be built during the Augustan period (Monteix 2010a: 263). Construction on *Ins. Or.* II started shortly after and the building was finished sometime between AD25-35 (Monteix 2010a: 260). Pagano (1996: 243) has suggested that the building had to have been completed by AD29, the year of the empress Livia's death, as roof tiles were found stamped with the names of *figlinae* of Livia. However, simply because the tiles were made in AD29 does not mean that they were used in that same year and it is best to use a broader estimation. The *insula* was built entirely in concrete and faced with *opus reticulatum* B with door jambs in either *opus vittatum* or *opus vittatum mixtum*. A careful study of the masonry by Nicholas Monteix (2010a: 261-263) has shown that the *insula* was built starting at the northern end and working towards the south. Cores done in *Ins. Or.* II.4 and II.19 have shown that the earthworks beneath the building contain

Augustan material, but whether or not there was a previously existing structure on the site remains unknown (Monteix 2010a: 259).

The consistency of the construction materials and the upper floors, as well as the close relationship between the building and the Cardo V sewer beneath indicates that it was a fully planned structure, built during a single phase (Camardo 2006-2007). The planning and construction of such a large building, in turn, suggests that it was a municipally funded project with the *insula*'s shops and apartments created to subsidize the construction of the *palaestra* and to later pay rent to the town or other public body (Wallace-Hadrill 1994: 117; Monteix 2010a: 288).

It was Mauiri who first suggested that the interior of this large complex functioned as a *palaestra*, constructed in the Greek style and acting as a place for the *juventus* (young men) of the town to exercise, meet and hold *ludi* (games) (Maiuri 1942: 277-278). However, by comparing the *palaestra* in Herculaneum to that in Pompeii, Monteix (2010a: 264 -267) has convincingly argued that this space was not used as a *palaestra*.[16] Instead, he suggests that it was a religious space where the *aula absidata* and the pool acted as a *templum* to Magna Mater. The association of the space with Magna Mater comes from an inscription found above the principal access to the terrace (Guadagno 1995: 127). A second religious space dedicated to Cybele may have been present in the north-eastern portion of the *insula* (Monteix 2010a: 267). The rooms around the *aula* were excavated rapidly in the 1930s with little documentation and as a result their specific functions remain unknown (Andrews 2006, 1: 28).

In the original phase, 77% of *Ins. Or.* II was used as public space with only 23% reserved for commercial and domestic space (Monteix 2010a: 273). The Cardo V side of

[16] Monteix (2010a: 265) also points out that the cross-shaped pool was decorative and not suitable for swimming.

the building contained 14-15 individual units (Fig. 2.11).[17] There were four independent upper floor apartments (II.1B, 2, 7 and 17) that were reached by staircases close to or opening onto the street (Andrews 2006, 1: 183). The remaining units were *tabernae* with attached living spaces. The original shops were quite small, with ground floor space ranging from only 21-31 m^2 (Monteix 2010a: 273).

The structure of the upper floors was established during the initial construction phase. Except for minor alteration, the upper floors remained the same until the time of the eruption (Fig. 2.11). The building had two storeys running the entirety of its length. Since it was built on a significant incline towards the north, the southern end, from II.10 to II.5, contained three storeys. A small portion of the units south of II.4 also contained a third storey. The average thickness of the load bearing walls was 0.8 m, which is slightly thicker than those found in Ostia (avg. 0.59 m), meaning that there could have been an additional storey although no structural evidence survives (Andrews 2006, 1: 183).

Phase II – AD62-approximately AD70

The earthquake of AD62 caused relatively little damage to *Ins. Or.* II and the changes that took place during this time had more to do with the changing nature of the building than to structural repairs. The majority of the repairs centered around the *aula*, where some of the walls and six of the columns in the colonnade had to be rebuilt. The remaining alterations focused on the creation of new doorways and workshop installations.[18] The creation of a doorway between II.13 and II.14 meant that II.11-14 was now a single unit. Unfortunately, we do not know how this large space was used, although Monteix (2010a: 277) has

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[17] There were 14 units according to Monteix (2010a: 272-2) and 15 according to Andrews (2006). The difference is at II.1b where Andrews (2006, 1: 82) has suggested that a staircase led to an independent upper floor apartment.

[18] At this point, in the interest of time and space, it should be noted that the following section will only discuss the units running from II.6 to II.14 as the HCP excavated portion of the sewer spans this distance. For detailed discussions of the changes that took place in the entire *insula* block see Monteix (2010a: 275-286) and Andrews (2006, 2: 329-371).

suggested that part of it probably served a domestic purpose. At II.8 the installation of an oven and millstones clearly indicates that the space was now used as a bakery. The presence of the oven in room 8.4 meant that the two rooms above, 7.6 and 9.5, had to be closed off due to the heat generated during baking. A mezzanine level was installed above 8.2 in order to provide the bakery with more storage space (Andrews 2006, 2: 210). A little bit farther south, at II.5, a masonry table with a large cauldron for washing wool was installed. Despite the increase in workshop installations, the amount of commercial space increased by only 5% from the previous phase and the building was still dominated by its public spaces (Monteix 2010a: 273).

Phase III AD70-79

It was during this final phase that *Ins. Or.* II underwent the most significant changes in relation to structure and use (Fig. 2.11). The building suffered far more damage during the AD70s earthquake or earthquakes, than in the previous one, necessitating a series of repairs that focused on reinforcing the structural stability of the building. An inscription found in the vestibule of *Ins. Or.* II testifies to repair work that was finished in AD76 and had been funded by Vespasian (CIL X, 1406; Guadagno 1995: 122-126). Imperial money seems to have been used to repair the edifice and fill in gaps in the masonry designed to strengthen the building. It is at this time that the façade between II.9 and II.13 was reconstructed in *opus vittatum mixtum* (Monteix 2010a: 281).

An increase in the commercial focus of the structure can be seen in the division of the large space at II.11-14. Doorways in II.11 and II.14 were closed off, creating three separate shops II.11, 13, 14 and one probable apartment at II.12. A masonry counter was installed in II.13, drastically narrowing the doorway. Finally, the doorway between 8.5 and 9.1 was blocked off and a doorway between 8.4 and 8.5 was created. This increased the size of the bakery by one room and decreased the size of II.9 significantly. The latrine that was originally part of II.7 became part of II.8 with the creation of an additional staircase in II.7. The blocking off of entrance ways into the public spaces and the creation of additional shops through the closing of doorways meant that by the time of the eruption, 41% of the ground floor of the building was dedicated to commercial space (Monteix 2010a: 284-286).

The rise in the number of independent commercial units also necessitated an increase in the amount of living space in the building. Since the height of the building could not be increased the growth of domestic space had to come from within. Mezzanines were added in II.18, 14 and 11 which significantly increased the amount of space in the latter two as they were no longer part of the large II.11-14 complex (Monteix 2010a: 284-286) (Fig. 2.12). These mezzanines were probably reached by portable ladders (Andrews 2006, 1: 70).

The increase in commercial and upper floor domestic space within the *insula* is reflective of the wider changes taking place in the town. Numerous houses in Herculaneum were converting their upper floor spaces into private apartments or were converting their houses to allow for more upper floor rooms (Monteix 2010a: 353). By the time of the eruption upper floors in Herculaneum formed one third of the total living space in the town (Andrews 2006 1: 153). The additional living space allowed for increased population density while the rise in the number of shops created economic growth. Combined, the trend towards a more populated and wealthy town meant that a larger number of people, despite their incomes, had to live in upper floor apartments. Thus the size, fittings, décor and layout of many these upper floor apartments show a level of social activity and hierarchy comparable with that seen in the atrium houses of Herculaneum (Andrews 2006, 1: 158). *Ins. Or.* II is no different and the unique layout of each shop and apartment reflect a range of activities and socioeconomic statuses.

2.3.1 Ground floor shops and upper floor apartments – *Ins. Or.* II.6-14

This section will discuss the ground floor shops and upper floor apartments between II.6 and II.14[19] as they were in AD79 (Table 2.1). The locations of all latrine shafts and drains can been seen in figure 2.13. As stated above, alterations and the installation of new features eliminated all traces of the original use of the shops. However, even with the surviving archaeological features, the rapid excavation of the *insula* and the reconstruction of several sections of the building make it difficult to determine the exact function of many of the shops at the time of the eruption. The same statement can be applied to the uses of many upper floor rooms.

Table 2.1. Total commercial and living spaces in each unit situated above the Cardo V sewer

Unit	Ground floor (m^2)	Upper floor (m^2)	Total space (m^2)	Latrine location
Ins. Or. II.6	48.1	49	97.1	SW corner of room 1
Ins. Or. II.7	0	848	848	Second floor, room 22, access by balcony only
Ins. Or. II.8	110.2	0	110.2	Room 8.3
Ins. Or. II.9	35.8	22.3	58.1	SW corner of room 1
Ins. Or. II.10	56.2	19.5	57.7	SW corner of room 1
Ins. Or. II.11-12	85.3	15.4	100.7	SW corner of room 11.1, possibly one in 12.2
Ins. Or. II.13	77.3	7.9(mez)	85.2	None
Ins. Or. II.14	66.5	2.2 (mez)	78.7	SW corner of room 1

*Floor spaces based on the work done by Andrews (2006)

[19] See n.18.

2.3.1.1 *Insula Orientalis II*.6

The northeast corner of this *taberna* has a U shaped counter with a marble surface, four dolia embedded in the masonry and a water heater/cook top (Fig. 2.14) (see *Ins. Or.* II.13 for a description of the water heater). The counter cannot be dated and may have been part of the original construction. The back area is divided into two rooms. The presence of the counter, combined with the numerous amphorae found stacked in one of the back rooms, suggests that this shop sold food and drinks (Mairui 1948: 60). Whether or not it sold hot or cold food remains unknown, but it is probable that it sold dried foodstuffs or wine. MacMahon (2005:78-82) has shown that dolia were impractical for the production and sale of hot food and were better suited to the sale of dried goods. In the southwest corner of room 1 was a staircase that led to two upper floor rooms. These two rooms, 6.4 and 6.5, extended across the entire length and width of the shop below and had a spacious headroom of 3.4 m, suggesting that these rooms acted as the living space for those who owned or worked in the shop below (Andrews 2006 2: 342). These upper floor rooms contained simple field paintings of a black socle with a red main zone (Maiuri 1958: 456).

2.3.1.2 *Insula Orientalis II*.7

The apartment at II.7 was by far the largest and most elaborately decorated of all the living spaces within the *insula*. Situated entirely on the upper floors, it consisted of five rooms on the first floor (100.1 m^2) and 19 rooms on the second floor (747.6 m^2). If it was a single apartment then the total living space was 848 m^2, making it larger than some of the atrium houses in Herculaneum. It also had a second-floor balcony that extended over II.7 to II.9 (Andrews, 2006 2: 348). There were three staircases leading up to the apartment. The staircase located in room 7.2 led directly to the second floor (Fig. 2.11). The eastern and western facing staircases in 7.3 led to different parts of the first floor. According to

Monteix (2010a: 283), the western staircase would have led to a single large room situated above 7.4 and 7.5. The eastern staircase led to rooms 7.11 and 7.12. Although he does not state it explicitly, it appears that Monteix (2010a: 282) is suggesting that repairs and alternation done in the 70s led to the creation of three separate living spaces (Fig. 2.11). Andrews (2006b: 109), on the other hand, argues that all of this upper floor space belonged to apartment II.7. The poor recording of find spots from the first floor of the apartment during the 1930s excavations has caused the artefacts to be of little help in determining the use of these various spaces. Thus, this apartment may have been a single unit, although it was more likely divided up into multiple living spaces.

The second floor of this apartment space was far more private than the first and it seems that the higher quality domestic and entertaining spaces were reserved for this floor. There is a suite of small rooms (7.21-7.25) that according to the *Giornali dei Nuovi Scavi di Ercolano* (*GdS*) (21st-22nd Feb. 1933) contained a kitchen hearth, kitchen tools, 43 bronze coins and a large quantity of pottery. Only seven upper floor kitchens have been found in Herculaneum and this is the only kitchen hearth that has been identified within *Ins. Or.* II (Andrews 2006, 1: 101). A small bronze votive altar and a bronze statuette of a *Lar* provide evidence for domestic religion in the apartment. Expensive finds include a silver ring (E1048), a white marble herm of Bacchus (E1110), multiple bronze jugs, plates and lamps (*GdS* 1933). Andrews (2006, 1: 120) has suggested that, due to its size and expensive finds, the apartment was occupied by a city official.

2.3.1.3 Insula Orientalis II.8

The space at II.8 was converted into a bakery shortly after the AD62 earthquake and acted entirely as a commercial space with no associated living area. (Monteix 2010a: 278). Room 1 was turned into a milling area with the addition of two millstones while the back room probably served as a preparation and kneading area (Fig. 2.15). The oven was in room 8.4. The latrine in room 8.3 was probably for the benefit of the workers.

Downpipes: The NE and SW corners of 8.4 and the NE corner of 8.5 contain small rectangular brick faced columns that hide three downpipes that drained water from the roof into the Cardo V sewer. These pipes are narrower than the latrine shafts and contain the calcium carbonate deposits typical of drainpipes and not the calcium phosphate deposits found in latrine shafts (Andrews 2006 1: 58-59; Andrews 2012).

2.3.1.4 Insula Orientalis II.9

This small two room shop has been very well preserved. The survival of a hanging wooden amphora rack in room 1 led to suggestions that the shop sold wine and possibly food. (Maiuri 1958: 462-463, Monteix 2010a: 125-126) (Fig. 2.16).There was a wooden table with a cooking surface adjacent to the latrine on the southwest wall of room 1. The excavation diaries state that there was also a wooden counter, although neither wooden piece has survived (*GdS* 31st Dec. 1936; Monteix 2010a: 125). Several amphorae with inscriptions were found in the shop but they were not inventoried after the 1930s excavations.

Despite its small size, at only 58.1 m^2, this unit probably housed the shop's owners or tenants.[20] The shop had an upper floor half the size of the ground floor that was reached via the wooden staircase on the NE wall of room 1 (Andrews, 2006 2: 357). The high ceilings of the upper floor rooms allowed them to function as either domestic or storage space (Monteix 2010a: 126). The northern wall of room 1 had a religious niche for worship of the domestic cult and the high degree of decoration in room 2 (panelled wall painting

[20] The name M. Livius Alcimus was found on several amphora, plates and ceramic objects in II.9 (Monteix 2010a: 126).

situated beneath a band of decorated molding) suggests that the ground floor rooms may also have acted as domestic space (Andrews 2006, 2: 360).[21] A wooden bed frame was found 0.7 m above the floor level in room 2 and may have fallen from the floor above during the eruption (Mols 1999: 165).

2.3.1.5 Insula Orientalis II.10

Structurally, *Ins. Or.* II.10 is almost identical to II.14 with large front and back rooms divided by a narrow corridor and a single small enclosed space (Figs. 2.11, 2.17). Unfortunately, the absence of any surviving masonry or wooden structures has made it difficult to determine the exact use of this shop. The recovery of 20 semi-precious stones led Maiuri (1958: 463-464) to believe that this was the workshop of a *gemmarius*. Upon closer analysis, the recovery of bronze objects and tools related to lathe work suggests that this shop sold turned goods as well as incised gem stones (Monteix 2010a: 74). The front and back rooms probably acted as workshop space. A wooden bed frame made of silver fir (*Abies alba)* was found inside the smaller and more private room 2 and was no doubt used as a bedroom (Mols 2002: 228). The upper floor spaces in this shop were small, with a total of only 19.5 m^2. The room above 10.2 was reached via a portable staircase on the eastern wall of room 1. This was a true room while the space above 10.3 was simply a gallery. Due to the slope of the street and thus the building, the first floor at this point in the *insula* was becoming increasingly low and narrow and the upper floor rooms in II.10 had only 1.96 m of headspace (Andrews 2006 2: 360-361). Compared to the high ceilings in II.6, the upper floor spaces here would have been quite dark and cramped and were probably used for storage. According to the 1936 excavation diaries a marble table was found 0.5 m above the surface of the ground floor and had apparently fallen from the first

[21] For a discussion involving the difficulties in establishing a division between public and private room use in wine and food shops see Monteix (2010a: 127-130).

floor (room 10.4) (*GdS*, 5th August, 1936). Considering the low headroom of the first floor, it would be an unusual space to house such a valuable object and it is probable that the marble table originally came from the second floor which was part of II.7.

2.3.1.6 Insula Orientalis II.11

Despite careful analyses of the masonry, construction and repair works, scholars have not yet come to a consensus on the relationship between II.11 and 12. There is a blocked doorway between II.11 and 12, although very little of the masonry has survived. Subsequently, it is difficult to tell whether or not this doorway is ancient or if it is the restoration of later damage such as a Bourbon tunnel (Andrews 2006 2: 362). However, the prevailing notion, as set out by both Monteix (2010a: 418) and Wallace-Hadrill (2011a: 272-278), is that the door is ancient and that II.11 and 12 were not connected at the time of the eruption.

The surviving architectural features and artifacts from II.11 suggest that it was a workshop space involved in textile production. The two highly degraded boilers found in room 1 led Maiuri (1958: 464) to believe that it was a dye shop. However, the absence of both a masonry table for laying out the fleeces and a tub for rinsing them argues against the shop being used to wash or dye wool. While the tiled floor points to some sort of textile production, a more definitive use cannot be determined (Monteix 2010a: 191).

Similar to the other spaces described above, II.11 contained domestic space and there is clear evidence of a bed niche in room 11.2 (Fig. 2.18). The large back room probably also served a domestic function since the mezzanine above rooms 11.2 and 3 had a headroom of only 1.71 m, making them more useful for storage (Andrews 2006 2: 363).

2.3.1.7 Insula Orientalis II.12

Very little is known about this small three-room space and it is not even certain if it was a shop or exclusively a residential unit. In the absence of any surviving masonry features and with few artifact finds, modern scholars simply skim over it, offering neither descriptions nor suggestions as to its function.

Based on the alterations made after the second large earthquake, I believe that II.12 was being used as a small residential unit in AD79. A partition wall was installed at the back of room 1, separating it from II.13 and limiting II.12 to a quarter of its original size. The doorway in 12.3 was closed off as well, eliminating all access to II.13 and a second partition wall was created between rooms 2 and 3. This partitioning had the effect of creating one medium size and two smaller private rooms. In order to increase the amount of space, a mezzanine level, reached by a portable staircase, was built over room 3. The division of the already limited amount of space into multiple rooms suggests a domestic rather than a commercial function. Room 3 could have acted as a bedroom while the mezzanine level was probably used for storage due to its low headroom. The reconstruction of the *insula*'s facade in the AD70s also decreased the size of the doorway, making it narrower than the entrance to many of the shops farther south (Monteix 2010a: 279).

2.3.1.8 Insula Orientalis II.13

The unit at II.13 was a food shop with living quarters at the back. During the AD70s, a U-shaped masonry counter topped with polychrome marble was installed against the northern wall of room 1 (Andrews 2006 1: 366) (Fig. 2.19). It had two dolia on its northern side that were used for the sale of dried foodstuffs.[22] Maiuri (1958: 464-465) believed that it was a *taberna* and *popina*. According to Monteix (2010a: 97-98), the large masonry blocks at the eastern end of the counter are the remains one of the two water heater/cook top combinations found in Herculaneum (the other is at *Ins. Or.* II.6).[23] These heaters were used to provide hot water for wine and act as a cooking surface for the preparation of hot food.

The back rooms probably acted as living and storage space. There was a mezzanine level above the western half of room 4 that was accessed by a portable ladder.

2.3.1.9 Insula Orientalis II.14

This three roomed space is almost structurally identical to II.10. However, II.14 does not contain any surviving architectural or archaeological features and we do not know how the space was used (Fig. 2.20). In the absence of internal structural features, scholars have agreed that it was probably used as a workshop space instead of a retail outlet (Maiuri 1958: 466; Monteix 2010a: 419). The smallest room, 14.2 was probably used as a bedroom.

2.4 Description of the Cardo V sewer

The Cardo V sewer was designed and built as part of the *palaestra* complex and thus its history is inextricably linked to the developments that took place in *Ins. Or.* II and the adjacent religious spaces. The sewer's two main phases of construction and alteration can be seen as a response to the three phases of construction and alteration that characterized

[22] The grains, beans and chickpeas that are often reported to have been found *in situ* in the dolia were in fact put there by Maiuri when he was preparing the building for display (Wallace-Hadrill 2011a: 279). There is no recording of foodstuffs from II.13 in the original excavation diaries.

[23] At IX.11.2 in Pompeii, there is a large raised block of masonry at the end of the counter. Inside this block was a bronze cauldron with its neck reaching up above the masonry surface. A fire could be lit underneath to heat the water inside. A terracotta flue pipe was built into the corner of the masonry block to allow the smoke to escape from the fire (Monteix 2010a: 97-98).

the structures above. The main N-S and E-W branches, which form an almost perfect L-shape, were part of the initial construction (Fig. 2.10). Subsequent additions, including numerous small side branches, resulted in a complex series of tunnels that served the functions of both waste and water removal (Camardo 2006-2007).

Phase I – Initial construction

The oldest surviving portion of the sewer was a small branch located beneath the sidewalk on the eastern side of the Cardo V and stretched from *Ins. Or.* II.15 to 13.[24] The channel collected waste and water from shops II.16, 18, the original northern entrance to the cryptoporticus and the small rectangular pool (Camardo 2008: 418). Its smaller size and off center location relative to the N-S branch of the Cardo V sewer indicates that this tunnel was built first.[25] It was connected to the main N-S branch of the Cardo V sewer at II.14, but had collapsed by the time of the eruption. The recent HCP excavation of this tunnel was not able to determine whether this branch had collapsed prior to the construction of the N-S branch or if it was used in conjunction with the N-S branch until it collapsed (Camardo 2006-2007).

The perfect alignment of the latrines in the shops and apartments of *Ins. Or.* II with the sewer indicates that the planning and construction of the N-S branch was contemporaneous with that of *Ins. Or.* II. The walls and vaulted ceiling of the sewer were made of tuff with large areas built in the irregular *reticulatum* typical of Herculaenum (Camardo 2006-2007) (Fig. 2.21). The tunnel sloped gently downwards, following the slope of the terrace that was created to level this section of the town (Wallace-Hadrill 2011a: 275). The sewer was 86.3 m long, running from II.14 to II.1 and was 80 cm wide.

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[24] This branch originally stretched farther north.
[25] It was 70 cm wide and 2 m high (Camardo 2006-2007).

At its start at II.14 the tunnel was 2 m high but rose to a height of 3.6 m at its southern end (Camardo 2006-2007, 2011: 90).

It was the largest sewer in Herculaneum and for good reason. Unlike the Cardo III sewer that drained onto the beach, the Cardo V did not have an exit point and a wall closed off the sewer to the south. In the absence of an outflow point the sewer was not designed to clear away rain water as heavy inflows of water would have quickly flooded the sewer (Camardo 2006-2007). Instead, its primary function was to collect the waste generated by the residents of *Ins. Or.* II.[26] The eight latrine shafts and three small rain water drains that fed this tunnel in effect turned the sewer into an enormous cesspit. Three large access shafts, located in room 1 of II.1, II.10 and II.14 allowed slaves to enter the sewer and periodically clean out the accumulated material (Fig. 2.22).

In order to deal with the foreseeable build up of organic (and often inorganic material such as pottery, glass and building debris (HCP 2008)), a large E-W branch was also part of the original construction (Fig. 2.23). This branch extended westwards to the back wall of *Ins. Or.* II and was 20.9 m long, 1.7 m wide, and 3.2 m high. The E-W branch of the sewer met the N-S branch at *Ins. Or.* II.3 and acted as a collection point for the material that was slowly shifting down the N-S branch (Camardo 2006-2007) (Fig. 2.10). The liquid contents presumably drained away through an as yet unlocated channel towards the beach.

Phase 2 – The creation of additional channels

Sometime after the initial construction of the sewer, the E-W branch was extended towards the cross-shaped pool. The new, smaller tunnel (80 cm wide and 2 m high) turned slightly

[26] According to the excavation reports of the HCP, some of the downpipes uncovered during the cleaning of *Ins. Or.* II were very large, suggesting that they were designed to drain rain water from the top of the building. Since they could not have flowed into the Cardo V sewer, the HCP has hypothesized that some of these rain water drains must have emptied into another sewer that was designed to hold the rain water and empty it onto the beach (Camardo 2006-2007).

to the north and then continued westwards for another 22.5 m. Running below the gutter on the southern side of the *palaestra*, it intercepted a third channel that ran N-S and drained the cross-shaped pool (Fig. 2.10). The water from the pool was probably intended to minimize the smell of the sewer, particularly at this southern end where the buildup of material would have been greatest. However, the increased inflow of water would become problematic in a sewer system with little outflow. To deal with the problem a small N-S sewer, connected to the large E-W branch was constructed beneath II.1. This channel probably emptied somewhere to the south near the beach and would have carried liquid, although not solids, from the sewer as well as waste from the bakery at II.1 (Camardo 2006-2007).[27]

2.5 Architectural and artefactual evidence for food storage and preparation in Herculaneum and *Insula Orientalis* II

The open air excavations of Herculaneum, prior to the utilization of soil sampling and flotation in the 1970s, mean that only relatively large food stores have been recovered: a dolium or amphora full of cereal grains, a bowl full of walnuts or a pile of figs (Borgoningo 2006) (Fig 2.24).[28] While this system appears to bias the types of foods recorded, in fact, it is probably an accurate representation of foods that were stored in bulk; mostly dried or preserved goods that would not spoil within a short period of time. Moreover, this information highlights one of the only sources of information about foodstuffs in Herculaneum that cannot be illustrated by the Cardo V sewer material. The food remains from the sewer represent primarily human waste, and thus a diet that probably consisted of food consumed at a variety of locations in the town. The food found

[27] A discharge canal was identified under the first arch of the terrace of Nonius Balbus (Camardo 2011: 91).
[28] It was also only in the 1970s that find spots were consistently recorded.

in storage in *Ins. Or.* II, particularly goods on the upper floors, tells us which items were more likely to be consumed (and probably prepared) at home by the residents (Table 2.2).

There was a clear pattern of commercial and domestic food storage in Herculaneum. People primarily used dolia, dry stores and amphora to hold large quantities of non-perishable foodstuffs. The size and location of dolia, in shop masonry counters, meant that they were designed for commercial purposes. Dry stores and amphora could be used to store food on both a commercial and household level.[29] Nine dry stores have been tentatively identified on upper floors at Herculaneum and one has been found at Pompeii. It is clear that the residents of Herculaneum knew that storing food above ground level, similar to the raised floors used in the large grain *horrea* at Ostia, was the best way to protect their goods from damp and pests.These dry stores are usually enclosed rectangular structures lined with *opus signinum* or plain plaster (Andrews 2006, 1: 87-89). Four of the dry stores at Heculaneum contained carbonized foodstuffs at the time of excavation, including one located in *Ins. Or.* II.15 (*GdS*, 26th Oct. 1936; Borgongino 2006: 81).[30]

In addition to holding liquid goods, amphorae were also used to store dry foods. According to the excavation diaries, in October 1936 the workmen found several amphorae inside the dry store at *Ins. Or.* II.15. One amphora contained 13.8kg of broad beans (*Vicia faba)* and another contained 7.5kg of barley (*Hordeum vulgare)* (Borgongino 2006: 81, 123) . In a few rare instances, foodstuffs simply sitting on wooden shelves or in chests on upper floors were recorded by the excavators. At the Casa dello Scheletro, bread and carbonised fruit were found on shelves (Maiuri 1958: 371; Borgongino 2006: 135).

[29] Approximately 50kg of barley was found on the mezzanine level of the Casa di Apollo (Borgongino, 2006: 124).
[30] The other three with carbonized food were at Casa d'Argo, apartment IV.3 and Casa di Apollo (Andrews 2006 1: 88).

The survival of seven upper floor kitchens at Herculaneum, including the one at *Ins. Or.* II.7 also attests to the practice of preparing and cooking these foods upstairs (Andrews 2006 1: 102).[31]

Table 2.2. List of food related activities taking place in *Ins. Or.* II

Type	Location	Evidence
Production	II.8 - Bakery	Millstones, oven
Sale	II.6 – Shop selling dried food and possible hot and cold prepared food	Masonry counter with dolia and possible water heater/cook top Numerous amphorae at the back of the shop
	II.9 – Wine shop, possibly also sold food	Wooden amphora rack Wine amphorae
	II.13 – Shop selling dried food and hot and cold prepared food	Masonry counter with dolia, water heater/cook top
Storage	II.11	Urceo filled with lentils
	II.11	Urceo filled with a mixture of lentils and bitter vetch
	II.15	Amphora filled with broad beans
	II.15	Amphora filled with barley

2.6 The eruption of AD79

This section will provide a brief overview of the eruption as it relates to *Ins. Or.* II and the Cardo V sewer.[32] We are able to reconstruct with precise detail what happened during those two days in AD79 from two letters by Pliny the Younger and recent advancements in volcanology (Sigurdsson and Carey 2002: 37-38). Calculations based on Pliny's letters provided original dates of August 24-25th although recent archaeobotanical and tephra evidence has been used to suggest an autumn date (Borgongino and Stefani 2001; Stefani and Borgongino 2007; Rolandi *et al.* 2008).

The burial of Herculaneum under many meters of pyroclastic material led Maiuri (1941) to hypothesize that the town had been covered by mud flows coming down from the

[31] The upper floor kitchens in Herculaneum - apartment III.12; apartment III.13; Casa del Mobilio Carbonizzato; Casa di Nettunoe Anfitrite; V.18; Casa del Sacello di Legno; *Ins. Or. II*.7, second floor (Andrews 2006 1: 102).

[32] For a detailed description of the eruption see Sigurdsson *et al.* (1985), Gurioli *et al.* (2002), Sigurdsson and Carey (2002) and Wallace-Hadrill (2011).

slopes of Vesuvius. Although the theory became widespread and repeatedly published, it is in fact incorrect. When Vesuvius erupted it created a column rising approximately 30 km into the atmosphere (Gurioli *et al.* 2002: 932). When the column reached the thinner air of the stratosphere it began to spread out and the chance event that the wind was blowing to the south that day meant that Pompeii and Stabia were covered by a rain of pumice lapilli. After approximately seven hours, the column could no longer support its own weight and began to collapse, causing hot gasses and very fine ash to cascade down the mountain (Gurioli *et al.* 2002: 949). This mixture of gasses and ash reached Herculaneum with temperatures between 400-500°C and at speeds of up to 300 km per hour (Sigurdsson and Carey 2002: 55; De Carolis and Patricelli 2003: 101-106). The heat instantly killed all those who remained in the town while the force of the surge knocked over walls and roofs and moved furniture and objects considerable distances. Large beams and roof tiles were found strewn on the beach when it was excavated in the 1980s and during the Maiuri excavations walls were occasionally found to be suspended in the solidified material (Wallace-Hadrill 2011a: 34). This solidified material is not mud, as Maiuri thought, but the consolidation of the ash into tuff as it collided with sea and rain water and cooled (Wallace Hadrill 2011a: 31). The depth of the material at Herculaneum varies and is deepest at the shore front, up to 23 m, due to the hot surges hitting the cool water of the Bay of Naples (Gurioli *et al.* 2002: 936).

Ins. Or. II was subjected to the same forces that damaged the rest of Herculaneum. The entire roof was destroyed as was most of the second floor (Figs. 1.2 and 2.25). Floor levels collapsed and objects fell onto the floor below. It is fortunate for the study of food in Herculaneum that while the heat of the pyroclastic surges was hot enough to carbonize foodstuffs, there was not enough oxygen to turn the items to ash. Thus all the above ground food remains were instantly carbonized in their various containers (see section 2.5). The

Cardo V sewer was slowly filled with ash entering through the latrine and drain shafts. Once the tunnel was full and the ash had hardened into tuff, the sewer became a fully sealed deposit.

2.7 Excavations at Herculaneum

Bourbon tunnels and open-air excavations 1710-1875

Despite its burial, the town of Herculaneum had never been entirely forgotten. The town was recorded on the 4th century Peutinger Table and some of the earliest tunnels into the site contained pottery dated to the late middle ages (Camardo *et al.* 2010: 320). When Prince d'Elbeuf began building his villa on the port of Granatello, about 1km from Herculaneum, he was interested in the marble that the locals were finding. The prince bought the land and during the nine-month excavation from 1710-11, came upon the theatre with its marble statues and panelling (Parslow 1995: 23) (Fig 2.3).

In 1735 Charles III became King Charles VII of Naples (and Charles V of Sicily) and gained control of the region. He wanted to decorate his palace at Portici with classical marble statues and thus the first systematic excavations of Herculaneum began in 1738 under the command of military engineer Rocque Joaquim de Alcubierre. Excavations, led by a series of engineers including Karl Weber and Franceso la Vega, continued until 1764 and intermittently until 1780. Due to the nature of Herculaneum's burial, excavation was done through tunnels (*cunicoli*). Despite the orientational challenges this created, at least 14 plans of the town were made and most of the public buildings, in addition to the Villa of the Papyri, were explored. However, tunneling took place in a haphazard fashion and excavators broke through walls and floor surfaces in their search for statues, mosaics and frescos (Andrews 2006 1: 29-31; Wallace-Hadrill 2011a: 50-55, 2011b: 123-128).

By 1780 excavations had ceased entirely and the focus shifted to Pompeii due to the ease with which the lapilli could be removed. In 1828, a growing European interest in seeing ancient cities led the Bourbons to begin open-air excavations on the Cardo III.[33] The clearance work continued until 1837, stopped for a period due to lack of funds and finds and then began again in the 1850s for a brief three year campaign. In the 1860s the Bourbon kingdom collapsed and in 1869, the new king, Victor Emmanuel II, gave control of Herculaneum and Pompeii to Giuseppe Fiorelli (Wallace-Hadrill 2011a: 55). Fiorelli introduced strategraphic excavation and although documentation of finds improved, the find spots were not always mentioned. Parts of *Insulae* II, VI and VII were excavated at this time (Guidobaldi 2008: 20). When Fiorelli left for Rome in 1875 excavations once again halted.

The Maiuri years 1927-1961

The Fascist government in Italy came into power in 1922 with the election of Mussolini and following their ideology, sought to glorify ancient Rome for political purposes. Amedeo Maiuri was appointed superintendent of the excavations at Pompeii and Campania in 1924. Under his authority, open air excavations took place at Herculaneum continuously between 1927 and 1943 when the war forced work to stop. The expropriation of land from modern Ercolano (then called Resina) enabled him to expand the size of the site to the extent visible today (Wallace-Hadrill 2011b: 122-123). The excavations were extensive and during this time the remainder of *Insulae* III, IV and V, all of *Ins. Or.* I and II, a large part of *Insula* VI, the suburban sanctuaries and the suburban baths were uncovered (Maiuri 1958: 17; Andrews 2006, 1: 38). The speed of the excavation, along with Mauiri's desire to present a detailed and complete picture of Roman life to the public, meant that a

[33] It was not very feasible to have tourists, often wealthy aristocratic Europeans, climbing down tunnels.

considerable amount of the site was reconstructed and objects found in different locations were collected into rooms in order to tell a story.[34]

After WWII, excavations continued on a smaller scale. Between 1952 and 1958 the *palaestra* and the suburban baths continued to be cleared while 1960-1961 saw the excavation of the college of the *Augustales*, the House of the Tuscan Colonnade and the last parts of *Insula* VI (Andrews 2006 1: 37). Documentation in this period was considerably better and the five volumes of the *GdS*, although not strictly filled with records of archaeological finds, are a valuable source of information. Unfortunately, they have never been published and only cover the years from 1927-1940 and 1960-1961. In 1958 Maiuri published his first large volume on Herculaneum, *Ercolano: I nuove scavi (1927-1958).* He died in 1963 before he could publish his volume on the finds from the site. After his death, excavation slowed considerably until the 1970s.

Modern excavations – 1970 – 2000

The end of the Mauiri era marked the end of large scale open-air excavations at Herculaneum. Excavations in the 1970s focused only on the area south of the suburban baths (Maggi 1977). The beachfront was excavated in the early 1980s, providing much needed information about the impact of the eruption, the quarrying of the local tuff and fishing in the Bay of Naples (Maggi 1998).[35] The excavations also uncovered the skeletons of over 300 people that had taken shelter in the vaulted chambers beneath the seafront terrace (Lazer 2009: 62) (Fig. 2.26).[36] The focus of the excavations then shifted to the Villa of the Papyri in the 1990s and between 1993 and 1998 the front terrace and atrium of the villa were uncovered along with the well-preserved bath building just to the east (De

[34] See the story of the weaving girl in Wallace-Hadrill (2011a: 83-84).
[35] A small overturned fishing boat was found almost entirely intact on the beachfront. It is currently on display in the small museum adjacent to the site. For more on the 1980s excavations see Cerulli Irelli (1983) and Budetta (1987).
[36] The physical and nutritional data derived from the skeletons will be discussed in detail in chapter 7.

Simone 1987; De Simone *et al.* 1998; De Simone and Ruffo 2002). The excavations were only partially published and the finds have never been fully studied.

The Herculaneum Conservation Project – 2001-2013

Conservation and preservation have been an issue at Herculaneum since excavations began. Mauiri had a systematic approach to maintaining the site using various measures, including building roofs and shelters. However, while he aimed to protect the most delicate decorative features, he could not roof the entire site without compromising authenticity. After the Maiuri era, as the management system became increasingly unable to provide systematic maintenance (Thompson 2007: 193-194), the natural decay processes associated with open-air archaeological sites took their toll. In 2002 an international conference declared Herculaneum the worst archaeological site on the planet (Povoledo 2012). In 2001 the Herculaneum Conservation Project (HCP), a partnership between the Packard Humanities Institute, the Soprintendenza of Pompeii and the British School at Rome, was created to deal with the severe damage caused by decades and indeed centuries of neglect. The HCP, headed by Professor Andrew Wallace-Hadrill, is made up of Italian archaeologists, conservators, architects, engineers and other disciplines, to rectify conservation issues across the site, addressing problems related to infrastructure, structures and decorative features (Wallace-Hadrill 2006; HCP 2010). It is beyond the scope of this work to describe all the activities of the HCP and thus only those pertaining to the Cardo V sewer will be discussed here.[37]

Since the site of Herculaneum is now well below current sea level and the level of the modern town, rain and ground water tend to pool on the site. Without a proper drainage system, the pooling water was causing significant damage to both structural and decorative

[37] For detailed reports of the work undertaken by the HCP, please see their website. http://www.herculaneum.org/hcp-home/eng/index.html

features such as mosaics (Pesaresi and Castaldi 2006: 220-222). In order to drain water away from the site, the HCP water specialist, Ippolito Massari, suggested that reinstating the original Roman network of underground drains and sewers was the optimal solution. This method minimized disturbance to both the above- and below-ground archaeology and simultaneously preserved the aesthetics of the town. Subsequently, pipes were installed across the site, including one inside the Cardo V sewer (HCP 2010) (Fig. 2.21). The installation of this new pipe line necessitated the systematic excavation of all the organic and inorganic remains from the Cardo V sewer (Camardo 2006-2007).

2.8 History of the excavation of *Insula Orientalis* II

Despite its large size, *Ins. Or.* II has a short excavation history. The building was not extensively explored by Bourbon tunnels. The Bourbon workers came upon II.7, one room of II.9 and destroyed most of the eastern staircase in II.7. The walls in 7.2 and 7.5 have tunnel openings and there is also a tunnel that broke through the dividing wall between rooms 7.6 and 9.5 (Andrews 2006, 2: 344). For Herculaneum, this damage is minimal and the majority of what remained of *Ins. Or.* II was left to be uncovered by Maiuri.

Due to government funding and an extensive workforce, Maiuri and his men were able to excavate the entire building in only six years, from 1932-1937 (Table 2.3). Contemporary standards for documentation meant that recording was patchy and some units have the finds from the ground and upper floors extensively recorded while others have almost no description. For example, all the finds from II.13 have a recorded find spot while the location of only about a quarter of the artifacts from II.9 was written down.[38]

[38] For an excellent graph of the number of finds with and without recorded find spots see Monteix 2010a: 73.

Table 2.3. Excavation of II.6-14

Unit	Dates of excavation
6	1932-1933
7	1933, 1936
8	1933-1936
9	1933-1936
10	1933, 1936
11-12	1936
13	1936
14	1933, 1936

Andrews 2006, 2: 329; Monteix 2010a: 411-419

When the HCP was created, large parts of *Ins. Or.* II, just like the rest of Herculaneum, were in desperate need of conservation and repair. Between 2004 and 2009 the entire building was subject to an emergency works campaign and many of the ground floor shops and latrine shafts were cleaned. In addition, II.9, 10 and 11 had their decorative features repaired and conserved and II.8-11 had large portions of the roof fixed (HCP 2010: 69-74).

2.9 History of the excavation of the Cardo V sewer

Maiuri and the 1949 exploration

The Cardo V sewer was first uncovered and partially excavated by Maiuri and his workmen in 1949. The excavation is briefly recorded in his 1958 book, describing the location of the sewer, its construction and its relationship to *Ins. Or.* II and the *palaestra* (Maiuri 1958: 467-469). However, the report lacks any type of excavation methodology and it was left to the HCP to clarify the extent of the early work including areas of exploration and the amount of material removed.

The main entry point into the sewer, both in antiquity and in modern times, is through a large shaft located in the southwest corner of *Ins. Or.* II.1 (Fig. 2.22). Mauiri and his team had begun excavations there, removing material from the first 50 m of the N-S branch, from II.1-5, and completely emptying the E-W branch of the sewer (Camardo 2006-2007; Camardo 2008: 415-416). Using the ancient access shaft located in shop II.14, Maiuri then proceeded to excavate the northern side branch up to the point where it had collapsed in antiquity (Fig. 2.27). Leaving the middle portion of the sewer untouched, he mapped the remainder of the tunnel based on assessments of the southern and northern ends (Camardo 2006-2007). Thus in 1949 only a small portion of the N-S branch was excavated, leaving the organic material situated between II.6 to II.14 untouched (Fig. 2.28).

After the 1949 excavation was completed, the drains and latrine shafts located in *Ins. Or.* II were not blocked or closed off. Subsequently, the HCP found that the excavated portions were now covered by a meter of modern sandy soil that had been carried in by rainwater. At the intersections of the N-S and E-W branches, both the widest and flattest part of the tunnel, the modern deposit was over 1.5 m deep (Camardo 2008: 415).

HCP exploration and excavation preparation

The lack of detail provided by Maiuri and the absence of any work on the sewer since 1949 meant that the HCP's approach to the excavation of the sewer was two-fold. The primary goal was to ensure that the insertion of modern pipes for drainage purposes would not have a negative impact on the archaeology. The second goal involved an exploration of the sewer in order to determine the extent of the Maiuri investigations and the potential for further investigation (Camardo 2008: 415-416). Maiuri's (1958: 467-469) report simply states that there are organic remains and the HCP's discovery of such a large volume of well-preserved material was a pleasant but unexpected surprise.

The HCP started by removing the modern fill, beginning, like Maiuri, at II.1 and working towards the north. As the E-W branch had already been entirely excavated, the modern material was removed to the smallest point in this tunnel which narrowed to a height of only a few centimeters. In the N-S branch, the modern material was removed from the sections already explored by Mauiri. Beyond the first 50 m, the sewer was still filled with the volcanic material that had entered during the eruption and was untouched by earlier excavations (Fig. 2.29). The volcanic debris had hardened into a cement-hard deposit and a power drill was used to remove this build up of material. When taking out both the modern and ancient material, a layer of volcanic debris 5-10 cm thick was left on top of the organic material in order to protect it (Camardo 2006-2007). Once the modern material and the volcanic debris had been removed, the team could begin the careful and systematic excavation of the bioarchaeological remains (see section 4.2).

2.10 Conclusions

Herculaneum has long histories of occupation and excavation. Together, these two histories have shaped the way we see the town today, both physically and conceptually. Beginning with a street grid sometime during the 4th century BC, the town eventually grew to contain multiple *insulae*, streets, temples, baths and shops. The excellent preservation of the physical remains of the town have aided our understanding of topics such as urban water management, the use of domestic space and the production and consumption of goods. While excavation does expand our knowledge, if done poorly it can also complicate matters. The 280 years of rather poor excavation techniques (according to modern standards) used at Herculaneum has often meant that not only do we have to sort through the archaeological data, but the older excavation material as well. Nevertheless, nowhere is the relationship between the ancient city, early excavations and modern conservation better exemplified than at *Ins. Or*. II. In AD79, *Ins. Or.* II represented a microcosm of the city with its combination of shops, domestic residences and public spaces. The rapid excavation of the insula during the 1930s has meant that many of its artefacts have been lost or were poorly recorded. However, enough has survived to reconstruct the majority of the activities that were taking place in the shops in AD79 including a bakery and multiple food and drink outlets. The sizes of the domestic spaces and upper floor apartments ranged considerably in size, suggesting that *Ins. Or.* II provides a good cross-section of society from an economic standpoint. The construction of the Cardo V sewer, with its multiple branches and latrine shafts, reveals a direct structural and cultural connection with the building above. Fortunately, only a portion of the sewer was explored and excavated by Maiuri and he left behind an untouched wealth of artefactual and bioarchaeological material.

Chapter 3: Introduction to preservation and formation processes in botanical and faunal assemblages

This chapter will provide a brief overview of botanical and faunal preservation and formation processes so that the Herculaneum material can be understood within its proper archaeological and environmental contexts. The chapter will begin with an overview of the current state of research concerning botanical preservation and identification. The Cardo V sewer contains three of the four major types of preserved botanical material, namely carbonized, mineralized and waterlogged remains, and each will be described in detail.[39] Biases relating to these forms of preservation will also be discussed. There will then be a short section on the survival of faunal material including bones and shells. The second portion of the chapter is dedicated to a discussion of formation processes, focusing primarily on those that will be most relevant to the Cardo V material and subsequently discussed in chapter 6.

3.1 Current state of research on the preservation and identification of botanical material

Since the 1970s, a considerable amount of archaeobotanical research has focused on three interrelated topics: identification, experimental taphonomic archaeology, and conditions of preservation.[40] Several articles and handbooks have been published which focus on the identification of botanical material using a variety of methods including comparative collections, chemical analysis, SEM and morphometrics (Hillman 1984, 2001; Kühn 1991; Butler 1991; Hillman *et al.* 1996; Jacomet 2006; Cappers *et al.* 2009; Neef *et al.* 2012).

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[39] There was no desiccated material in the sewer and thus it will not be discussed in this chapter. For a good description of desiccated material see Van der Veen (2007).

[40] Archaeobotanical research is by no means limited to these three topics, but it is beyond the scope of this thesis to provide a full overview. For the latest range of archaeobotanical research see Jacomet and Kreuz (1999) and the 2013 International Work Group for Paleoethnobotany conference abstract book. http://iwgp-2013.web.auth.gr/images/abstract%20book%20revised.pdf

Cereals, due to their importance in the human diet, have received the most scholarly attention, particularly from Gordon Hillman and Stephanie Jacomet.[41] The different types of cereals are ideally identified by their chaff, although secure identifications can be achieved using the caryopses if they are in a good state of preservation (Hillman *et al.* 1996: 204-205; Jacomet 2006) (Figs. 3.1-2). Other plants, including legumes, fruits, seasonings and arable weeds are often identified by their seeds or stones, since that is usually the only part of the plant that survives in the archaeological record.

Archaeobotanical research using experimental taphonomic archaeology has focused almost exclusively upon carbonized material. It is quick and easy to reproduce carbonized remains using a muffle furnace or kiln. Boardman and Jones' (1990) recreation of ancient carbonized cereals provided valuable information as to the influence of charring conditions on the preservation and distortion of grains. Their work was continued by Braadbaart and colleagues who have published three articles in the last decade on the experimental charring of wheat (Braadbaart *et al.* 2005, Braadbaart and van Bergen 2005; Braadbaart 2008) and by Yang *et al.* (2011) who looked at the carbonization of millet. The University of Durham has recently created an outdoor experimental space where they are undertaking charring experiments on concrete hearths (Church 2013). The reproduction of mineralized and waterlogged material is time-consuming and, in the case of mineralization, is restricted by severe health and safety prohibitions, and subsequently, very few experiments have been undertaken.[42]

Our understanding of the conditions required for botanical preservation in the archaeological record varies considerably depending on material type. It is clear that a significant amount of research still needs to be done if all preservation processes are to be

[41] For a full list of Hillman's publications please go to http://www.homepages.ucl.ac.uk/~tcrndfu/hillman.htm. For a full list of Jacomet's publications please go to http://ipna.unibas.ch/archbot/address/jacomet.htm.

[42] Don O'Meara (2013) at the University of Durham has done some experimental work involving the survival of seeds through the human digestive tract but the results have not yet been published.

understood to the same degree. Carbonization is the best understood preservation process, probably because charred remains are the most common macrobotanical find and have therefore provided archaeobotanists with a large sample for study and comparison (Popper 1988: 56-57; Richard 2003: 28; Van der Veen 2007: 968-977) (Fig. 3.3). As stated above, ongoing experimental work is helping to clarify the effects of charring both on seeds and other plant structures.

Waterlogged preservation is also well understood, although few sites with waterlogged material have been sampled in the Mediterranean and thus we only have a good understanding of the survival of central and northern European material (McCobb *et al.* 2001; Bosi *et al.* 2013; Jacomet 2013).

Although the outcome is easily recognizable, research to clarify the actual process and conditions required for mineralization continues (McCobb *et al.* 2003; Marshall *et al.* 2008; Shillito and Almond 2010; Messager *et al.* 2010). After Green's seminal 1979 article, little research was conducted on the process of mineralization until the 1990s and 2000s when large quantities of mineralized material were recovered from the UK sites of York (Kenward and Hall 2000; McCobb *et al.* 2001), Potterne (Carruthers 2000; McCobb *et al.* 2003) and Silchester (Robinson 2006, 2011; Marshall *et al.* 2008). The scarcity of mineralized finds has made it difficult to identify the standard characteristics of a mineralized assemblage and to understand exactly what causes the process to occur. In addition, mineralization rarely occurs in large macrobotanical remains, such as peach stones or walnut shells, and therefore small mineralized finds can be easily overlooked during excavations and even missed by flotation unless small sieve sizes (500µm) are used. Research has been conducted on the mineralization of insects, but for the most part scholars have been concerned with the preservation of the fossil record (Girling 1979;

Briggs and Wilby 1996). It is hoped that the large amount of mineralized material found in the Herculaneum sewer will increase our understanding of the mineralization process.

3.2 Preservation

3.2.1 Carbonization

Carbonization is the most common form of botanical preservation, requiring only heat and oxygen-poor conditions. The rates of survivability, distortion, and subsequently identification, depend upon the temperature at the time of charring. Pristine carbonization, from an archaeobotanical perspective, occurs when an item is heated at 230°C in the absence of oxygen for six hours (Fraser *et al.* 2013: 4757). At this temperature the degree of distortion is minimal. Items burnt at higher temperatures, particularly above 250°C, can undergo distortion, making their identification more difficult (Braadbaart 2008: 163). Once plant material has been carbonized it will remain in a durable and unchanging state of preservation. The carbonization process turns material into a mass of carbon which does not decompose, is impervious to microbial attack and does not react with other minerals and chemicals (Hillman *et al.* 1993: 95). Although remains are still susceptible to mechanical damage such as wetting and drying, this stability enables carbonized material to survive in a variety of soil types and pH levels.

However, not all material that comes into contact with heat or fire will become carbonized. Archaeologists have recognized that carbonized assemblages, across time and space, show very distinct patterns. The most common carbonized remains from archaeological sites are cereal grains, cereal chaff, pulses, wild plants, nut shells and fruit stones (Van der Veen 2007: 977) (Figs 3.4-5). The soft-bodied portion of plants, most oil-rich seeds, fruits, condiments and vegetables, are less likely to become charred (Jacomet

2013: 499). Flimsy plant parts will oxidize fully and turn to ash while the oil-rich portion will explode upon heating.

The recognition of compositional similarities between assemblages has given rise to two general statements about carbonized finds. Firstly, that carbonized assemblage will only ever represent a small proportion of the variety of plants that were used at a site. Sites with multiple forms of preservation have the advantage of allowing carbonized and non-carbonized assemblages to be used in a complementary fashion. Secondly, when attempting a reconstruction of food consumption, carbonized assemblages will generally only provide information about the major staples and field weed flora (Van der Veen 2007: 978; Jacomet 2013: 499).

3.2.2 Mineralization

Mineralization occurs when plant material is replaced by inorganic substances, most commonly calcium phosphate ($Ca(PO_4)_6(OH)_2$) (Green 1979: 281).[43] Seeds form the largest category of mineralized material although other plant parts such as fruit skins can also become mineralized (Robinson 2006: 212). The process of calcium phosphate replacement usually results in one of three possible outcomes. Firstly and most commonly, molecules of calcium phosphate slowly replace the internal contents of a seed as it decays, producing a full internal cast of the seed's coat or embryo.[44] This cast preserves, although in a muted form, the cell pattern of the inside of the seed coat including distinguishing features such as ridges and grooves (Fig. 3.6). Mineralization can also create a pseudomorph cavity in the soil in which calcium phosphate is deposited around the seed as it decays completely. Alternatively, the entire seed coat and even the entire seed can

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[43] Mineralization due to bronze, iron, glauconite and gypsum have also been recorded (Helbaek 1969; Green 1982: 40; Wilkinson and Stevens 2003: 160).

[44] In species with thin, undifferentiated layers in their seed coats, such as *Urtica dioica*, the entire seed coat can remain intact. Often only the embryo will survive in species with complex or specialized structures within their seed coat, for example *Ranunculus* sp. (Carruthers 2000: 75).

become mineralized on a cell by cell basis, but this is extremely rare (Green 1979; Robinson 2006: 212). The mineralization process generally strips seeds of their original colour and most appear honey brown (Fig 3.7). Once mineralization has occurred the seeds are composed of light inorganic material with a poorly defined crystalline structure (Green 1979: 279).

In the absence of experimental taphonomic research, archaeologists have only been able to hypothesize about the mechanisms that produce mineralized material.[45] Firstly, the material must be deposited in an area with high concentrations of both calcium and phosphate ions in the surrounding matrix (Carruthers 2000: 75). Consequently, mineralized deposits are usually associated with areas of sewage such as latrines and sewers (Robinson 2006: 214; 2011: 288-289; Shillito and Almond 2010: 227). Human and animal faeces provide the necessary phosphate ions while calcium ions come from animal bones, seashells, and eggshells (Marshall *et al*. 2008: 860). After the seed dies, the membranes in the seed coat that control the movement of water and ions cease to function (McCobb *et al.* 2003). Calcium and phosphate ions can then enter the soft tissue portions of a seed, resulting in calcium phosphate replacement.

It has been suggested that mineralization is a rapid process, although the exact length of time required remains unknown (Allison 1988; Carruthers 2000: 75). Kenward and Hall (1995: 718) have suggested that the deposit must already be in a state of organic decay, with the phosphate and calcium ions present in the matrix, when the new botanical material is added. Once deposited, the material must be buried quickly as this creates an oxygen-poor environment and prevents bacterial and fungal degradation of this delicate

[45] The results from research and experimental work carried out on the mineralization of soft-bodied marine animals has often been applied to the mineralization of plants in archaeological deposits (Allison 1988; Allison and Briggs 1991).

material.[46] The rapid process of decay and mineralization is followed by a period of stabilization which results in long term survival (Kenward and Hall 2000: 523).

As well as decay, the movement of ground water and a narrow pH range are also essential for mineralization. Water dissolves the ions while a slightly acidic pH ensures that there will be phosphate substitution (Briggs and Wilby 1996: 665; Marshall *et al.* 2008: 855).[47] However, as the results from Coppergate (York) and Silchester demonstrate, complete waterlogging will actually hinder the mineralization process (McCobb *et al.* 2001: 939; Robinson 2011: 288).

In addition to the chemical requirements, there are also specific environmental factors required for mineralized material to form and survive in the archaeological record. Ideally, a deposit should be situated in a moderate to high temperature climate as this helps to facilitate the deposition of minerals into the seeds (Ciaraldi 2007: 50).[48] Surviving mineralized deposits are usually found in portions of a site that had a relatively calm and physically stable environment while the site was in use. The stability ensures that the physical components remain in contact and that the fragile mineralized material has not been damaged by human interaction such as trampling.

Finally, in a manner similar to carbonized material, the specific taphonomic requirements and seed coat characteristics required for mineralization mean that only certain items will become mineralized, even under ideal conditions. Mineralization occurs primarily in seeds that have a permeable but hard or woody coat (Helbaek 1969: 407-408; McCobb *et al.* 2001: 939). A hard or woody coat enables seeds to survive the passage through the human or animal digestive tract intact and delays decomposition in both

[46] In the context of a cess pit or latrine, rapid burial would occur if additional human or cooking waste was added to the deposit.
[47] A more neutral pH will result in calcium carbonate substitution and a lesser degree of morphological detail within the seed (Briggs and Wilby 1996: 667).
[48] It is possible that bacterial activity helps drive mineralization and the higher temperatures promote bacterial growth. However, this hypothesis remains untested. Future laboratory work will be required to determine the relationship between bacteria and mineralization.

swallowed and unswallowed seeds. The permeability allows ions to accumulate more readily in the embryo of the seed, thereby creating the internal cast (Green 1982: 43; Charles 1996: 112). Mineralization is also more likely to occur in seeds that lack lignins, tannins and proteins in their coats (McCobb *et al.* 2003: 1279; Wilkinson and Stevens 2003: 159-161).

As a consequence of requiring such precise conditions, mineralized assemblages are usually composed of the seeds of fruits, flavourings, the weeds of arable crops, and ruderal plants (McCobb 2003: 1269; Robinson 2011: 289) (Figs 3.8-9). Cereal grains have a starchy structure which is not favourable to the deposition of minerals (Carruthers 2000: 75). They also have an epidermis that is commonly broken during milling, making them highly vulnerable to decay. Consequently, they will be broken down entirely by microbial action and are usually only preserved through carbonization. Thus diet cannot be reconstructed from the mineralized assemblage alone and although a wider range of food plants may survive in mineralized than in carbonized deposits, the finds represent only a fraction of the variety of plants and plant material that were used at a site.

3.2.2.1 The mineralization of invertebrates

Latrines, cesspits and sewers provide an ideal habitat for several invertebrate species. Many of these creatures live, breed and die within such environments and therefore adults, juveniles and pupae are often found in deposits with mineralized material. Similar to the mineralization of seeds, the mineralization of an invertebrate’s exoskeleton through calcium phosphate replacement is a selective process (Briggs and Wilby 1996: 665; Carruthers 2000: 75-76). Differences in the biochemical composition of the exoskeleton make certain species particularly prone to mineralization after death. Fly puparia are typically the most ubiquitous mineralized insect found at archaeological sites (Robinson

2011: 290) (Fig. 3.10). Girling (1979: 311) theorized that the hydrophilic nature of their exoskeleton enables calcium carbonate (although we now know it is calcium phosphate) to easily enter and subsequently replace the cells. The absence of external exoskeletal features such as wings also means that the calcium phosphate enters the body cavity directly, forming an internal cast of the insect. The arthropod exoskeletons of woodlice and millipedes, due to the minimal presence of waxy layers, are very receptive to calcium phosphate (Girling 1979). Moreover, their exoskeletons already contain calcium carbonate, thus further facilitating the process.

3.2.3 Waterlogged preservation

Waterlogged material survives in anoxic environments where the material has remained in a constantly submerged state since its deposition into the archaeological record. Waterlogged deposits can be found in lakes, marshes, wells and any area where the archaeological material or site is below the water table (Heer 1865; Pollmann *et al.* 2005; Tolar *et al.* 2010; Karsten *et al.* 2012: 3). The anoxic environment hinders the ability of bacteria and fungi to break down plant material and often the level of preservation can be quite high with plants remaining in an unaltered state (Dimbleby 1978: 93; Dincauze 2000: 440; Jacomet 2013: 500) (Fig. 3.11). In theory, all the parts of a plant can be preserved including the leaves and petals and there can be several thousand seeds per litre of sampled soil. Although cereals and pulses do not preserve well, the range of preserved species can be larger than those of mineralized or carbonized assemblages and more delicate items including condiments and oil rich plants will survive. Carbonized material, particularly in settlement areas, can also enter and survive in waterlogged deposits (Jacomet 2013: 499-501).

3.2.4 Faunal material

Faunal material consists of animal remains, such as shells and bones, in which calcium carbonate and calcium phosphate are laid down respectively. The survival of these items depends heavily upon the depositional context and particularly the pH of the soil or surrounding environment. Soils with an alkaline or neutral pH promote good preservation. Soils with a pH lower than 5.5 are too acidic and will cause bones and particularly shells to disintegrate entirely (Campbell *et al.* 2011: 5, 15).

3.2.4.1 Fish otoliths and scales

Otoliths or ‘earstones’ are calcium carbonate structures in the form of aragonite located in the skull of bony fish. Each fish has three pairs of otoliths, the sagittae, asteriscus and the lapillus, which function together to provide the fish with a sense of orientation in the water. In most bony fish, the sagittae are far larger than the asteriscus and lapillus and are the type most frequently used for identification, sizing and aging. The shape of an otolith is highly species-specific with the left and right sides often acting as mirror images of each other (except in the case of the flatfish) (Campana 2004: 3) (Fig 3.12). Archaeologically, they are fragile items that require precise preservation conditions. Consequently, they often do not survive in contexts where other faunal material, notably fish bones, do preserve. A study by van Neer *et al.* (2002: 62) found that otoliths preserve best in waterlogged or damp contexts such as cesspits or refuse pits that are protected from environmental fluctuations. Otoliths are susceptible to dissolution in acidic environments and must be deposited quickly in a matrix with only mildly acidic or alkaline conditions that is protected from acid rain and rain water percolation (Wheeler 1978: 71; Colley 1990: 214; van Neer *et al.* 2002: 62). Fish scales are similarly fragile and experiments by Nicholson (1996) have shown that they may be even more susceptible to acidic conditions than otoliths. Consequently, they are also rarely recovered from archaeological sites. When scales are found they are often too badly damaged, particularly at the margins, to allow for an accurate identification (Wheeler 1978: 70-71) (Fig. 3.13).

3.3 Biases in a botanical assemblage

Each process of botanical preservation generates its own set of biases. It is often the preservation process itself that causes the most bias, but human interaction both at the time of preservation and excavation can also cause alterations to the assemblage. The formation of an assemblage as well as the likelihood that an item is truly absent from a site cannot be understood without acknowledging the most common sources of bias (Green 1982: 40-41). Moreover, the recognition of these biases is crucial when attempting to extrapolate social and environmental data from the botanical remains.

3.3.1 Biases in a carbonized assemblage

Carbonized material is subject to three preservation biases. First, only the more durable portions of a plant will become carbonized and an assemblage is therefore biased by the likelihood of a specific plant part being exposed to fire and surviving (Green 1982: 41; Wright 2003: 581). For example, the seeds from an apple will carbonize while the flesh (unless the apple has been dried) will be reduced entirely to ash.

Extreme variations in temperature and duration of exposure can also cause commonly carbonized material to be absent. Boardman and Jones (1990) found that material heated at a low temperature for a short period of time did not carbonize and would simply become brown, shrivelled and fragile. However, carbonization occurred in material heated at a low temperature for long periods of time. Grains displayed the widest variety of survival conditions compared to glumes, rachis and whole spikelets. Einkorn wheat was the most resilient at high temperatures while bread wheat and barley were the first to carbonize and the first to be destroyed. In addition, they found that the first component of cereal lost to charring was the chaff of free-threshing wheat (Boardman and Jones 1990: 6-9).[49] Thus the temperature and length of exposure can significantly impact what is present in a carbonized assemblage.[50]

The third form of bias is a consequence of the excavation process, specifically flotation. While finds may be missed by the naked eye, comprehensive sampling procedures should eliminate any collection bias. Sampling, while more effective than hand picking, means that flotation is used to separate the carbonized material from the surrounding soil matrix (Matterne and Derreumaux 2008: 107). Through experimentation, Wright (2005: 25) has determined that soil type has the largest influence on recovery rates when using flotation machines. Light matrices, such as sandy loam, yielded much higher recovery rates than denser material such as clay loam. The washover technique, whereby processing is done by hand using buckets and sieves, can be used as a more gentle alternative. Finally, repeated wetting and drying, when the material is in its depositional environment and during processing can severely damage carbonized remains (Wright 2005: 25).

3.3.2 Biases in a mineralized assemblage

Biases in a mineralized assemblage are produced by both human and environmental interaction with the material. Firstly, human activities delineate which items will be deposited in a location conducive to mineralization. Although, as stated in section 3.2.2,

[49] It should be noted that these experiments were performed under ideal lab conditions and although their results are valid, newer experimental work, such the use of concrete hearths at Durham (Church 2013), will produce results that more accurately reflect the formation and survival of carbonized material in antiquity.
[50] Unfortunately, there has not been any experimental archaeology performed on the carbonization of weed seeds. Since they are frequently associated with arable crops, knowing their maximum and minimum carbonization temperatures and exposure lengths would help determine the types of grains present, even if the grains were absent from the assemblage.

the characteristics of varying seed species also bias their likelihood of undergoing mineralization despite deposition within a suitable context. Since the depositional location is usually related to faecal matter, mineralized assemblages are heavily biased towards edible taxa that can pass through the human digestive tract intact (McCobb *et al.* 2003: 1269; Robinson 2006: 215). If, for example, an individual consumes a fig then the majority of the pips will pass through the individual unbroken and end up in the deposit (assuming it is a latrine or cesspit). As there are thousands of pips per fig, and the pips mineralized quite easily, hundreds will be preserved and found in a sample. Seeds broken by mastication or food processing techniques such as boiling, grinding, crushing and milling do not readily become mineralized (Robinson 2006: 215). If an individual boils and consumes lentils, the boiling and mastication processes will have softened the lentils to the point where none will survive intact. Only a very small number will enter the deposit when lost or dropped during the cooking process. Thus it is deposition through consumption that produces large volumes of mineralized material and can cause archaeologists to overemphasize the importance of certain items. Moreover, these anthropogenic practices bias the assemblage towards foods that do not require preparation and instead are consumed whole, such as fruits. Although they are associated with cereal grains, weed seeds are small enough to escape the milling process and therefore are also often well represented in mineralized samples (Robinson 2006: 215).

3.3.3 Biases in a waterlogged assemblage

Unlike mineralization and carbonization, where only certain items become preserved, most plant remains will survive when waterlogged. Subsequently, the major biases related to waterlogged assemblages have more to do with the depositional history of the material than the actual preservation process itself. A changing water table with cycles of wetting and drying will significantly damage the remains, as will rough processing methods or accidental drying out of the material.[51] In less than ideal conditions, it is the woodier and more robust seeds that are likely to survive.

3.4 Formation processes

In the past, a simple categorization of the type of archaeobotanical finds, as carbonized, mineralized or waterlogged, was considered satisfactory. This is no longer the case. Archaeobotanists cannot recover botanical remains without asking how the finds entered the archaeological record. Were these plants used as fuel? Was this an accidental or intentional burning? Does the assemblage represent a primary deposit of human waste or reused midden soil? The benefits that come from answering these questions are not limited to archaeobotanists. Archaeologists can use the information to gain a better understanding of subjects such as social and cultural food practices, agricultural production and long distance trade. However, in order for the archaeologist to obtain this information, the formation processes that took place to create and preserve the botanical material must be studied in detail.

Formation processes, determining how an item both entered and survived in the archaeological record, can be divided into two types: cultural and environmental (Schiffer 1983: 676). Cultural factors are the result of human interaction with the plant material such as processing, consumption and discard. Modern human disturbance such as excavation, tourism and warfare, as exemplified by the World War II bombings at Pompeii, can also have a significant, if often negative impact on the botanical assemblage. (Miksickek 1987: 212; Cooley 2003: 101; Jones and Robinson 2004: 109) Environmental factors have been categorized into faunal turbation, floral turbation and aeolian and alluvial processes

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[51] In order to collect waterlogged plants for environmental data, a 250μm mesh must be used and it is recommended to use only bucket flotation as a flotation machine is often considered too harsh.

(Miksickek 1987: 231-233). The impact of these environmental processes, more than the cultural factors, depends upon the entire history of a site, from the time of its occupation until the time of its excavation.

The influence of cultural and environmental factors on a botanical assemblage, both individually and in combination, varies greatly between sites. While books have been written about the physical formation processes for specific archaeological sites and geographic regions (Schiffer 1983; Kristiansen 1985; Restelli 2001; Jacomet 2013), patterns in the formation of archaeobotanical assemblages between geographically and chronologically distant sites are rarely noted and to date there is no comprehensive work on the topic. Nevertheless, archaeobotanists can use their knowledge concerning the mechanics of botanical preservation, in association with information derived from the archaeological context of an assemblage, to determine physical formation processes.

3.4.1 The relationship between archaeological contexts and archaeobotanical assemblages

The composition of an archaeobotanical assemblage is often directly related to context type. A fire pit will usually contain only carbonized remains while mudbrick may contain both carbonized and desiccated material. Although it seems obvious, recognizing such relationships helps to narrow down the types of processes that could have occurred to create the assemblage (Green 1982: 40). When two contexts contain only one type of preserved archaeobotanical material it is possible to make a direct comparison between assemblages. For example, a pit containing carbonized cereal, chaff and weed seeds suggests a store of unprocessed grain while a pit consisting solely of carbonized cereal with relatively few weed seeds suggests a store of cleaned grain.

When a single context contains two different forms of preserved material it is important to keep in mind that these two botanical assemblages cannot be compared directly without producing vastly skewed results. For example, comparing mineralized and carbonized assemblages directly would make both forms of preservation appear poor as the mineralized material would be missing cereal grains and the carbonized material would be missing items such as condiments. An analysis of diet or access to food resources would also be skewed for similar reasons.

In addition to intra-site context comparison, inter-site analysis is often helpful in ensuring that formation processes are being understood correctly. For example, the pattern of finding mineralized remains associated with contexts that contain human waste can be seen both within sites, such as at Pompeii, and between sites, such as at Pompeii, Utica (Tunisia), Silchester (UK) and Überlingen (Germany) (Märkle 2005; Robinson 2006; Ciaraldi 2007; Murphy *et al.* 2013; Rowan 2013). Thus finding mineralized remains, regardless of the geographical location of the site, usually indicates areas where human waste was deposited or re-deposited (Fig. 3.14). Without recognizing this pattern, it would be difficult, particularly on sites where there are few to no standing structures, for example at Utica, to identify a food storage pit that had been later used as a dump for human and cooking waste (Rowan 2013).

3.4.2 Formation of a carbonized assemblage

Due to the uniformity of carbonized assemblages, their formation processes are relatively straightforward and well understood (Green 1982: 43). According to Van der Veen (2007: 978-979), the species most likely to be carbonized can be divided into three groups and will enter the archaeological record through a limited number of processes. The first group consists of plants and seeds that are used as fuel or burnt as waste. This includes wood, charcoal and any other material intentionally or casually burnt such as olive oil pressing waste (pomace), animal dung, chaff and nut shells (Charles 1996; Wikander 2008: 139;

Rowan 2015). The second group is composed of foods that are typically involved in or require fire in their preparation. Finds may consist of hulled grains burnt in the parching process or pulses that accidentally fell into the cooking fire. The charred remains in this group appear frequently in an assemblage and include mostly edible material. Both the first and second groups represent daily activities. The third group is composed of rare material that, due to its scarcity, suggests accidental burning as the result of a single event. Such events include food or fodder destroyed by accidental fire, material that was burnt during the cleaning of storage pits, and diseased or infested crops that needed to be destroyed by burning (Van der Veen 2007: 977-979).

3.4.3 Formation of a mineralized assemblage

The processes leading to the formation of a mineralized assemblage are at once both more complicated and more simple than the creation of a carbonized assemblage. The mineralization of plant material after deposition eliminates, to a large extent, the impact of human intervention on the preservation process. Items in a sewer or cesspit become mineralized because humans, through the deposition of waste, faunal material and plant matter, created a suitable environment for mineralization to take place. People do not actively create mineralized assemblages as they do for carbonized material. The formation of a mineralized assemblage is simply the result of microbial and chemical interactions with the plant material (Carruthers 2000: 73).

However, the absence of direct human involvement makes it extremely difficult to determine how the people at a site were using the plant material and what processes took place to create the assemblage. Do finds of fat-hen (*Chenopodium album*) represent accidental inclusions in flour or do they represent the deliberate use of this plant as a food source? Mineralized assemblages are further complicated by the fact that they are generally restricted to latrine type deposits where a variety of biological material, including cooking and food processing waste, can be mixed together (Robinson 2006: 214). Consequently, it is important to determine the function of the deposit by using the evidence provided by the composition of the bioarchaeological and artefact assemblages. If it was a latrine, was it used exclusively for the collection of human waste or did it also act as a midden? Are there ceramics and inedible faunal remains such as seashells within the deposit or is it formed exclusively of digestible material? At Roman period sites, toilets and kitchens are often found in close proximity since the latrine functioned both as a toilet and a kitchen garbage. Thus within a Roman context, a botanical assemblage probably represents a mixture of human, food and cooking waste. Once these methods of deposition have been established, the method of entry of each item can be hypothesized. The mineralized component of human waste consists primarily of seeds such as fig pips, which pass through the human digestive tract whole. Food refuse includes items that can be eaten without prior preparation or cooking such as the seeds and pits of apples, plums and cherries.[52] Finally, cooking waste consists of foodstuffs that do require cooking, such as pulses, but that ended up in the deposit without encountering a fire, probably due to accidental loss.

3.4.4 Formation of a waterlogged assemblage

As long as an area remains consistently wet there is the potential for a waterlogged assemblage to form. Thus the environmental factors are straightforward; the water table needs to remain high enough to keep that material submerged throughout most of its depositional history. The human impact on the formation of a waterlogged assemblage can be complicated and the composition is significantly influenced by its proximity and relationship to people. The assemblage from a well at a rural site may consist primarily of

[52] These food items are often too big to be swallowed comfortably or frequently.

the surrounding vegetation while a well within an urban site can be composed of a mixture of the surrounding vegetation as well as food plants, chaff and the dung of domesticated animals (Robinson 2011: 284-286; Lodwick 2013). Entirely submerged settlements, such as those on lakeshores in Switzerland, may contain almost all the plants used by those that occupied the site as well as the wild plants that grew within and around the area (Hosch and Jacomet 2004: 113-115; Tolar *et al.* 2010: 54-55). Thus the greatest challenge with waterlogged material is determining, firstly, which plants were intentionally used by humans and, secondly, how these plants were used and for what purposes, although at times this is not always possible (Green 1982: 42).

3.5 Modern contamination of a botanical assemblage

Deposits of ancient botanical material can be contaminated by modern plant matter. Human and environmental activities such as ploughing, down washing and earthworm activity can allow modern material to seep down into deep deposits. Keepax (1977) carried out experiments on modern contamination and found that it is particularly noticeable when flotation is used since it ensures a high botanical recovery rate. The appearance, colour and frequency of modern contaminants mean that they can often be distinguished from the ancient material. However, that is not always the case, especially if the seed is black as it then appears carbonized. It is useful to be aware of the plants currently growing around a site as many plants of disturbed ground, such as *Utica dioica* and *Portulaca oleracea* have small seeds that can easily enter archaeological contexts.

Chapter 4: Methodology

4.1 The methodological approach

The Cardo V sewer is a paradox in terms of both Roman archaeology and archaeobotany. It represents the largest single find of bioarchaeological material in the Roman world while at the same time it is compositionally simply a larger version of the cess pits found in homes throughout nearby Pompeii (Jansen 2000: 38). However, unlike the multiple cess pits in Pompeii, the Cardo V assemblage is the only one of its kind in Herculaneum. Since they drained onto the ancient beach, no bioarchaeological finds were recovered from the Cardo III and IV sewers (Camardo 2007: 180; Camardo 2011: 90). As described in section 2.2, the hard tuff beneath the town precluded the use of deep cess pits and instead the ones in Herculaneum were frequently cleaned out (Camardo *et al*. 2006: 190). Additionally, whereas at Pompeii the cess pit material had been deposited vertically, in the Cardo V sewer the material was deposited vertically but subsequently moved horizontally. This movement, in effect, means that the sewer must be considered a single context containing thousands of litres of excellently preserved biological material.

The methodological approach presented here reflects both the benefits and challenges of dealing with such a unique context. Ironically, the quantity and excellent state of preservation of much of the bioarchaeological remains has meant that new approaches to the material had to be derived. The identification of the fish otoliths are a case in point (section 4.4.3). The methodology generally follows standard environmental and botanical sampling procedures where they are applicable (Campbell *et al.* 2011). Data analysis has been tailored to the research questions and the quantity of material available.

4.2 Excavation of the Cardo V sewer by the HCP

The following description applies to the material in the N-S branch of the sewer, running between *Ins. Or.* II.6-14 (Fig. 2.28). The HCP divided this section of the sewer into 53 one-meter quadrants (Fig. 4.1). Each of the 53 quadrants was excavated based on the stratigraphy of the whole sewer, with similar layers receiving identical identification numbers. Hence Q13-14, US40 refers to quadrant 13-14, stratigraphic layer 40 while Q23-24, US40 refers to quadrant 23-24, stratigraphic layer 40 (Fig. 4.2). Stratigraphic layers were defined by the composition, colour and texture of the soil. The stratigraphy, however, was not always continuous and not all quadrants contain the identical set of US numbers.

4.2.1 Sampling of the bioarchaeological material

All the material in the sewer had to be removed to allow for the installation of modern pipes. In total, over 11,625 L of soil containing environmental material was collected into 775 15 L sample bags. The sieving and flotation of this material was done on-site in September 2007 by Professor Mark Robinson and a team from the University of Oxford. After a brief preliminary examination of the finds, Professor Robinson (2007a, b) concluded that sorting approximately 10% of the material would be sufficient for that field season, as it was both impractical and unnecessary to process all the bioarchaeological material at any one time. Due to the incredibly rich nature of the deposit, all the unprocessed soil from the sewer has been retained in storage in Herculaneum. During excavation large non-biological items such as pottery fragments were removed by hand.

It was decided that one 15 L bag from each stratigraphic layer from alternating quadrants, starting with Q1-2, would be processed on-site.[53] Thus, Q3-4 and Q5-6 were sorted while Q4-5 remains unsorted in storage. Ten litres from each bag were processed

[53] This resulted in a total of 76 bags or 76 samples.

while an additional litre was wet sieved through a 0.5 mm mesh and left to dry. This material has been held in reserve should the need for further study arise. The remaining four litres were left unprocessed. During the field season the team processed approximately 1140 L of soil.

For each 10 L sample both flotation and sieving were done by hand to separate the lighter materials, such as seeds, from the heavier deposits. A machine operated flotation system, while perhaps more efficient, could not be used due to water constraints on the site. Instead, the following field procedure was adopted by Professor Mark Robinson to extract bioarchaeological remains from the samples. Each sample was first washed through an 8.5 mm mesh into a large plastic drum. This served to break up the sample and enabled larger items, including both bioarchaeological remains and artefacts to be recovered (the coarse fraction). The contents of the drum were agitated, further water was added, and the less dense items which floated onto the surface were poured onto a 0.5 mm sieve (the flot). The remaining sediment in the drum, the residue, was then sieved over a 1 mm mesh. The coarse fractions, flots and residues were dried (Fig. 4.3). The dry residues were further divided using 2 mm and 1 mm sieves. The coarse fraction and the residues greater than 2 mm were sorted in full on site for bioarchaeological remains such as carbonized and mineralized material, shells and fish bones. One quarter of each residue smaller than 2 mm was sorted for biological remains, using a microscope as necessary, while the remaining three quarters was held in reserve. The flots were bagged up to await laboratory analysis. At the end of the excavation the biological items from the coarse fraction, the 2 mm residue and the quarter sample residue along with the unsorted flot material were brought back to Oxford.

4.2.2 Modern contamination

The flotation and sieving methods used here proved to be exceptionally effective. Delicate mineralized seeds such as *Papaver somniferum* and *Utica dioica* remained intact. There was very little modern contamination with only four *Portulaca oleracea* seeds and one Asteraceae seed identified as modern (Fig. 4.4). The nature of the processed material, coming from the fully sealed and previously unexcavated portion of the sewer (see section 2.9), no doubt reduced the possibility of modern contamination prior to sample processing.

4.3 Sampling strategy and quadrant selection

As the excavation and on-site processing procedures demonstrate, the sewer contained an enormous quantity of bioarchaeological material. Over 699 bags, each containing 15 L samples, currently remain in storage in Herculaneum (Fig. 4.5). Flot samples often contained seeds less than a millimetre in size and therefore sorting had to be done thoroughly and carefully. In order to answer the proposed research questions within a reasonable amount of time, a sampling strategy had to be derived that took into account both the length of the sewer and the quantity of material.

A total of six quadrants were examined for this thesis, representing approximately 30% of the total volume of processed material (Fig 4.1). Accordingly, a 10 L sample from each stratigraphic layer from each of the six quadrants was sorted in full, resulting in a total of 22 samples (Table 4.1). Quadrant selection was based on data concerning both the other artefacts in the sewer and the nature of the insula block situated above. Ceramic analysis had demonstrated that there was some degree of movement of the material in a southerly direction down the sewer towards *Ins. Or.* I. The archaeological remains of items such as dolia, counters and millstones in the shops above the sewer suggested that certain food items were created and sold in large quantities within *Ins. Or.* II (Maiuri 1970: 49-50;

Monteix 2010a: 97-98, 278). Despite the horizontal shift in the material, it was at first believed that there was the potential to correlate the finds directly below a latrine shaft to the apartment or shop above. Therefore, due to the quantity of material and the diverse size and character of the shops and apartments above the sewer, it was decided that random sampling was not a viable option. While this would have provided an unbiased view of the sewer, there was also a significant risk that the production of certain shops and the diet of those living in either the smaller or larger apartments would be missed. Instead, specific quadrants were selected to gain a better understanding of both material movement and the food consumption practices that took place in the building above.

Table 4.1. List of quadrants and stratigraphic layers examined in this study

Stratigraphic layer	**Quadrant**					
38	3-4	5-6	13-14	23-24	37-38	49-50
39	3-4	5-6	13-14	23-24		49-50
40	3-4	5-6	13-14	23-24	37-38	49-50
41	3-4					
42		5-6				49-50
43		5-6				
52						49-50

The material from Q3-4 was sorted and identified first as stratigraphic layer 38 from Q3-4 had already been studied for the author’s MSt. thesis (Rowan 2010). The quadrant, situated beneath shop II.6, contained a large variety of carbonized and mineralized species, including several food plants. However, the amount of carbonized grain recovered was unusually small considering the excellent level of preservation in the sewer. It was at first thought that perhaps there was very little movement of the sewer material. Q3-4 was situated downstream from the bakery at Ins. Or. II.8 yet contained only one barley grain, one grain of emmer wheat and four fragments of poorly preserved cereal caryopses. Q13-14, which is situated directly beneath the bakery, was therefore selected as the next quadrant (Fig. 4.6). It too contained a wide variety of plant species but very few grains (the absence of grains is discussed in section 6.2.1.2).

Since Q3-4 and Q13-14 are relatively close together, Q23-24, 37-38 and 49-50 were then chosen to ensure a thorough examination of the whole sewer and its contents. These three quadrants are spaced at even intervals to each other and were selected based entirely on their location within the sewer and not the structures above (Figs. 4.1 and 4.6).

During the sorting process it quickly became apparent that the diversity and quantity of material increased as the quadrant numbers decreased (towards the lower end of the slope). It was hypothesized that the increase in bioarchaeological material at the southern end of the sewer was due to the slope of the tunnel (Fig. 4.7). When the sewer was still in use, water would have carried the lighter bioarchaeological material down the channel, towards the larger E-W drain. Therefore, Q5-6 was studied in an attempt to ensure that large numbers of species were not missed.

4.4 Sorting, identification and quantification procedures

All of the bioarchaeological material from each of the six quadrants was examined in full. This material included the mineralized, carbonized and dried waterlogged assemblages (if present) as well as the eggshell, seashell, fish bones and otoliths. The relatively small number of any one item per sample meant that subsampling was not necessary and quantification techniques were relatively straightforward. Any techniques that required more than simple counting are described below.

4.4.1 The botanical material

Sorting was conducted using a binocular microscope with a x6 to x50 magnification range. The identifications of the mineralized, carbonized and dried waterlogged material were made by comparison with modern reference material in Professor Robinson's personal seed collection (Oxford University Museum of Natural History) and by reference to Jacomet's (2006) guide to cereal identification, the *Handbook of Plant Paleoecology* (Cappers and Neef 2012) and the digital seed atlases produced by the University of Groningen (Cappers *et al.* 2009; Neef *et al.* 2012). Dr. Alison Crowther's personal seed collection was used to confirm the identification of sorghum. The dried waterlogged material was identified as such by comparing the material to accidentally dried-out waterlogged material from the site of Marcham, UK (Kamash *et al.* 2011; Rowan 2011). All the results were first recorded on finds sheet and then entered into an Access 2007 database.

4.4.2 Quantification of the botanical material

The small numbers of seeds (other than fig pips) in each sample meant that simple counting was often sufficient. The number of whole and fragmentary seeds was recorded in the database, but for calculation purposes the total number of any given seed in a sample was considered to be the sum of the whole and fragmentary items (assuming the fragments had identifiable features and were not small enough to be reconstructed into a single seed). Hence, two whole and three fragments of *Urtica dioca* would count as five seeds. Grape was the only species with fragments that could not be counted as individual seeds and instead either the central bridge or furrows on the ventral side were counted. In some of the larger seeds, such as apple or pear, fragmentary apical ends were noted to prevent an overestimation of the quantities. If the smaller fragments of any seed were not part of an identifiable feature then the combined fragments were given an MNI of one. The mineralized fig pips were not sorted and counted, as this would have been too time-consuming, but were simply recorded as being present or absent from a sample (See section 3.3.2 for the preservation of fig pips). Moreover, the methods used to analyse the botanical material (see section 4.6 below) did not require the isolation and quantification of the thousands of fig pips present in each sample. Since only a quarter sample of the residue material sorted to 2mm was brought back to Oxford, any residue material less than 2mm has been multiplied by four (these taxa are noted in tables 5.2 and 5.4).

Carbonized olive stones

It was necessary to determine the number of whole olive stones based on the fragments for the later analyses presented in sections 6.2.1.1 and 8.2. Archaeobotanists can determine the number of whole olive stones by adding the number of apices or by estimating the fragmentation rate (Ciaraldi 2007: 60; Kislev and Simonchi 2008). The olive stones in the Cardo V assemblage were often very fragmentary, making the apex difficult to identify, and, proportionally, contained far more 'body' fragments than apices. Moreover, while Kislev and Simonchi (2008) have estimated that an olive stone, on average, breaks into 11.2 fragments, differing olive stone assemblages can have dissimilar breakage patterns and there is no way to determine if a rate of 11.2 is applicable to the Cardo V material (Margaritis and Jones 2008a: 396).[54] As a result two different quantification methods were used to determine the total number of olive stones.

Samples with over 100 fragments were weighed. A similar method was used by Margaritis and Jones (2008a: 396) on the carbonized olive stones recovered from the Hellenistic farm site of Tria Platania in Greece. Ten whole carbonized olive stones from Q3-4, US41 were weighed individually using a Sartorius R200D scale. The average weight of one olive stone was calculated to be 0.0849 g and this weight was used as the reference point. The weight of each sample was then divided by 0.0849 g. For samples containing

[54] Olive stones can become broken due to olive oil production, trampling and modern sample processing (Rowan 2015).

less than 100 fragments, a reconstruction method was deemed sufficient.[55] All the whole and fragmentary pieces were counted and recorded and then, using a whole olive stone as a point of reference, the fragments were placed into groups approximating the size of the whole stone. The number of groups was counted and added to the number of whole stones to provide a total number. The original number of fragments for all samples can be found in the raw data tables in Appendix F.

4.4.3 The faunal remains (excluding animal bones)

Eggshell

All eggshell fragments were separated from the seashells and placed in bags. Since each quadrant and stratigraphic layer contained eggshell, and the number of fragments was often in the hundreds, it was decided that counting would be an ineffective method of quantification. Instead, a method similar to that used for the olive stones, quantification based on weight, was employed. Since the entire shell of a Roman bird egg, whether intact or fragmentary, was not available for comparison, modern eggs had to be used. The shells of three modern large organic chicken eggs were weighed individually, resulting in an average weight of 6.4g. The weight of the eggshells from each Herculaneum sample was obtained using a Sartorius R200D scale, and divided by 6.4. This method provided a rough estimate for the number of eggs in each sample, or in other words, the approximate number of large modern chicken eggs. This assumes that the ancient shell material comes from domestic fowl, which is supported by the evidence obtained from the shell thickness measurements described below.

In the last two decades there has been a growing interest in the identification of eggshell from archaeological sites. Thickness measurements and SEM photography of both

[55] Some samples with less than 100 fragments were weighed to test the accuracy of the reconstruction method and it was found that when the number of fragments is less than 100 the two methods provide roughly the same results with a maximum difference of only +/-5 whole olives.

modern reference material and ancient eggshell have been used to identify the shell types down to species (Siddell 1993, 1997; Mikhailov 1997; Boyer 1999). Although thickness measurements alone cannot provide secure species identifications, they enable archaeologists to determine the number of different species of bird eggs consumed by the inhabitants of a site.

Following the methodology used by Boyer (1999) and Siddell (1993, 1997), all eggshell samples were quickly scanned under x10 magnification for any fragments that appeared to be significantly thinner or thicker than the rest. However, the thickness difference between, for example, chicken and goose eggs can be as little as 0.175mm and can easily be missed by the human eye (Siddell 1993: 13). Subsequently, five eggshell fragments from each eggshell sample were measured for thickness using an eyepiece graticule under x20 magnification. In total, 100 fragments were measured.

Fish bones

As several of the fish bones were less than a centimetre in length, they were recovered during flotation and residue sieving and the majority were sorted on-site. During sorting in Oxford, the author collected any remaining fish bones from the flot and residue material. They were identified by Dr. Rebecca Nicholson at Oxford Archaeology.

Fish otoliths

The fish otoliths were separated from the other shell material and placed in glass tubes. They were sufficiently well preserved and recovered in high enough quantities to warrant further study and an attempt at identification.

The otoliths were identified using the Anàlisi de Formes d'Otòlits (AFORO) online database (Lombarte *et al.* 2006). The database contains a collection of modern otoliths from 1105 species and 208 fish families from around the world including the Mediterranean. The database's reference material was created by photographing the otoliths and subsequently using the Otsu Thresholding plugin of the Image Processing and Analysis Library Java programme to measure each otolith's contour. Otolith photographs are submitted to the database and the contour is measured and compared to the reference collection (Fig. 4.8). A list of nine results is produced along with contour images and an Euclidean distance measuring the relationship between the submitted otolith and the reference material. Within the nine results, the same species can be listed multiple times. Thus, for example, a low Euclidean number, and hence close identification, might list the same species in three of the nine possible options (Fig. 4.9).

For this thesis, the number of whole otoliths and fragments were recorded and intact otoliths from Q3-4, 5-6, 13-14, 23-24 and 49-50 were photographed.[56] Only those with a well preserved contour were entered into the database as those with smoothed edges would have given incorrect results. Photographs were taken of the selected otoliths using a Leica EZ4D microscope. It should be noted that the database only accepts photographs of the left sagitta. Therefore, when left sagitta were not present in the sewer sample, well preserved right sagitta were photographed, flipped, and the mirror image was used.

The Herculaneum otolith photographs were submitted to the AFORO database and the results were sent to the author by email. As stated above, nine potential options were provided by the database. Any fish species from outside the Mediterranean and western coasts of Europe and North Africa were immediately eliminated. Species distribution data and maps were obtained from the SeaLifeBase database (Palomares and Pauly 2013). Contours and photographs of the suggested species provided by the database were compared visually with the Herculaneum otolith (Fig. 4.10). Once the best choice had been

[56] Q37-38 did not contain any otoliths.

selected the Herculaneum sample was compared to a reference otolith provided by Dr. Rebecca Nicholson at Oxford Archaeology (if a reference specimen was available) (Fig. 4.11).

The remaining otoliths in each Herculaneum sample were grouped together by shape and size and identified based on the now securely identified (and photographed) otoliths. The number of left and right sagitta were counted to provide an MNI. All identifications were checked by Dr. Nicholson.

Marine molluscs

Once the eggshell and otoliths had been removed the marine molluscs were sorted. Preliminary identification was by the author and all identifications were confirmed by Jennifer Robinson. The World Register of Marine Species (WoRMS) database was utilized to ensure that the most up to date taxonomic names have been used (Appeltans *et al.* 2012). Except for limpets and clams, the majority of the shells were in fragmentary form and MNI was calculated for each species using quantifying features such as the operculum, apex, columella and valves (Claassen 1998: 20-21).

The sea urchin material was extremely well preserved and along with spines and body fragments, pieces of their jaw apparatus, commonly referred to as Aristotle's lantern, occurred frequently in the samples. For each sample the most commonly occurring jaw piece, either the pyramid plates, rotulae or teeth were used to calculate MNI (McRae 1959: 211; Märkel 1979: 5) (Figs. 4.12-4.13). Finally, all the shell material, except the sea urchin, was entered into a second database. The sea urchin material, due to the multiplicity of fragment types, was recorded as its own data set and the jaw piece used to count MNI was noted.

4.5 Measuring taxonomic richness

With the unexpected identification of the dried waterlogged material in Q13-14 it became apparent that the taphonomic processes acting on the material in the sewer were extremely variable even within a single quadrant (see section 6.1.3). Quadrants had been strategically selected based on their potential richness and position within the sewer. However, the taphonomic variability of the sewer material meant that there was still a chance that the six quadrants would not provide an accurate representation of the species richness present in the whole assemblage and a method to test species richness had to be constructed.

The desire to measure taxonomic richness in a given area first originated in the field of ecology. Ecologists have long recognized that as sample size increases so does the number of taxa. However, in ecology, as in archaeology, it is usually impossible and impractical to try to sample an entire area. Both diciplines have derived a range of methods to determine when a sufficient amount of material has been examined (Van der Veen and Fieller 1982; Lepofsky and Lertzman 2005: 176; Lee 2012). In recent years, bioarchaeologists have begun to recognize the usefulness of ecological techniques and have incorporated them into their own sampling strategies (Meltzer *et al.* 1992; Gotelli and Colwell 2001; Lepofsky and Lyons 2003; Lyman and Ames 2007; Veal 2009). In examining zooarchaeological assemblages, Lyman and Ames (2004) utilized the method of sampling to redundancy; when species richness is plotted against sample size the graph will rise sharply at first as new species are added and then eventually it will reach an asymptote. At this point, when the graph has levelled off, further sampling would not add any new species and would therefore be redundant. In the literature, graphs of this type are referred to as taxon or species accumulation curves with the y-axis represented by the cumulative number of species and the x-axis by individual or sample based counts (Lyman and Ames 2007: 1986). For the remainder of this thesis they shall be referred to as species accumulation curves (SAC).

The need to assess multiple types of bioarchaeological material, including botanical and faunal remains, each with vastly different abundance levels, meant that creating a target population to test sampling sufficiency, as suggested by Van der Veen and Fieller (1982: 293-295), was not feasible. In order to determine if the six quadrants had provided a sufficient overview of species richness, a method of sampling to redundancy was adopted and species accumulation curves were created for the carbonized, mineralized and shell material. The order in which samples are added to an SAC is crucial for later analysis (Lyman and Ames 2007: 1987). To account for the fact that the study quadrants were not selected at random, two curves were created for each material type, one with the x-axis in the order the samples were studied and one with the x-axis in random order (Section 5.1). The x-axis for the random order SACs was created by picking samples out of a hat. The generation of two separate curves enabled the results to be compared and to assess the impact of selection bias (Lepofsky and Lertzman 2005:185). The processing of all the material in 10 L samples meant that there was no difference in sample volume and rarefaction did not need to be used (Lyman and Ames 2007: 1985).

4.6 Calculations used in the analyses of the bioarchaeological material

4.6.1 Density calculations

Density ratios were calculated as the number of items per litre. MNI was used whenever possible, especially for fragmentary items such as land snails. Items listed as cf. were simply added to the total number of taxa and those residue items smaller than 2 mm were multiplied by four. For example, the *Stellaria media* seeds from Q5-6 are composed of seven seeds identified as *Stellaria media* and one seed as cf. *Stellaria media*¸ all recovered from the flot. An additional *Stellaria media* was identified in the residue, but as it is smaller than 2mm, four *Stellaria media* are recorded, giving a combined flot and residue total of 12. Fig pips have not been included in the density calculations as they would severely skew the results. Unidentified items were also not included.

4.6.2 Scales of abundance

A coarse scale of abundance was used to quantify the number of items of each taxon per sample and assess taphonomy. Taxa were sorted into three groups: those with between 1-9 items, 10-99 items and those with over 100 items. Similar to the density calculations, MNIs were used whenever possible. Unidentified items were included in the calculations.

4.6.3 Ubiquity calculations

Ubiquity scores were calculated for the quadrants, samples and stratigraphic layers. MNIs were used whenever possible and items identified as cf. were added to the total. It is important to note that all the items of a particular preservation type were scored including objects such as mineralized leaf fragments and carbonized bread fragments. Thus throughout the discussions of ubiquity, the terms item and taxa have been used interchangeably, although in the strictest sense items that cannot be considered taxa are being discussed. Lastly, unidentified items have not been included in the ubiquity calculations.

Chapter 5: Results

This thesis is designed to assess the nutritional composition of the diet of the inhabitants of *Ins. Or.* II and to highlight some of their food consumption practices using the bioarchaeological data. The following chapter has been structured so as to allow for a seamless discussion later on, unhindered by numerical calculations such as density ratios and ubiquity scores. Therefore, along with the basic results, a brief analysis of the composition and movement of the sewer material is provided in this chapter when deemed appropriate.

The chapter begins with a discussion of the SAC curves in order to establish that a sufficient amount of sampling has taken place. This discussion is followed by a presentation of the botanical remains both categorically and spatially. Full taxon lists for each preservation type have been provided, along with the presence, MNI and the maximum number of items per sample. Finds tables showing raw counts on an item by item basis can be found in Appendix F. The ubiquity, density and abundance scores for the mineralized and carbonized assemblages are discussed separately and then together as part of an analysis of the stratigraphic layers. The botanical remains are subsequently divided into food groups and related categories including cereals, fruits and ornamental plants. Next, the eggshell and seashell results are discussed, followed by a quadrant-by-quadrant examination of the fish bones and otoliths.

5.1 Taxonomic richness and species accumulation curves (SACs)

Two SACs each were created for the carbonized, mineralized and shell material, one in sample order and one in random order (Figs. 5.1-3).

5.1.1 SACs for the carbonized material

Sample order

The SAC appeared to have reached an asymptote at Q49-50, US39 with 26 taxa, although Q5-6, US39 produced one additional taxon giving a total of 27 (Fig. 5.1). Q5-6 was chosen because the previous quadrants had demonstrated horizontal movement of the material and it was believed that Q5-6 would contain a significant level of taxonomic diversity. Thus, this slight increase at the end of the curve was expected. The sorting and identification of the final eight samples resulted in the recovery of only one new taxon and as the curve leveled off for the remainder of Q5-6, it can be argued that a sufficient amount of material has been examined.

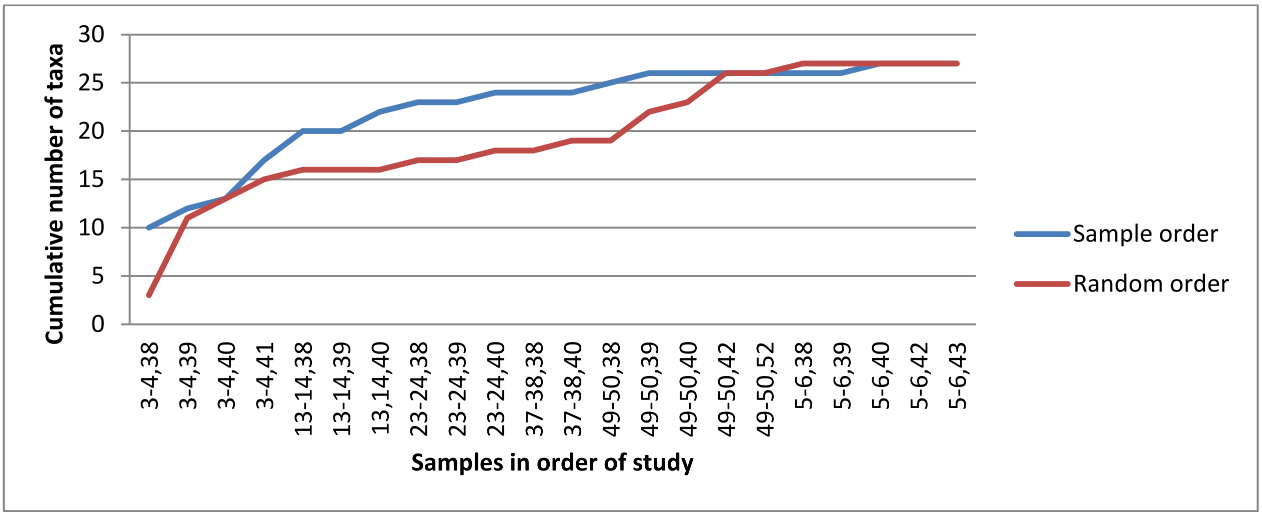


Figure 5.1. SACs of the carbonized material calculated in sample order and in random order

Random order

The SAC with the samples selected in random order achieved an asymptote after 19 samples had been sorted and identified. The curve is completely flat for the final four samples and prior to that, starting with Q13-14, US38, the increase in new taxa had begun to slow significantly. Although it cannot be stated with definitive certainty, these two curves demonstrate that is unlikely any new species of carbonized plant matter would be found without sorting through a considerably large number of samples.

5.1.2 SACs for the mineralized material

The mineralized material recovered from the sewer is the most diverse of the bioarchaeological remains but is also the most difficult to sort and identify. Thousands of fig pips were present in the flotation samples and while it was not necessary to isolate them, they slowed the sorting process. As mentioned in Section 3.2.2, mineralization causes seeds to lose their colour and appear honey brown. Several of the taxa, such as *Urtica dioica* or *Chenopodium* sp. are smaller or equal in size to fig pips and subsequently sorting must be done very carefully. The large amount of taxonomic diversity meant that the mineralized material was the most important to recover, especially for the nutritional assessment of the diet. However, due to the challenges of sorting and identification, it also acted as the rate limiting factor. The two SACs reflect the challenges inherent in the mineralized assemblage and are not as straightforward as those created for the carbonized and shell material.

Sample order

The SAC for the mineralized material in sample order does not reach an asymptote (Fig. 5.2). This does not mean that sampling was not sufficient, as the random sampling SAC will demonstrate. Instead, this curve reflects material movement and the probable locations for high species diversity. The graph begins at Q3-4, US38 with 41 taxa identified in the first stratigraphic layer studied. Since Q3-4 was at the southern end of the sewer it was expected to have a large variety of taxa. Between Q3-4 and Q13-14 a further 20 species are identified. The number of new taxa recovered then slows until only ten additional taxa are found from the start of Q23-24 to the end of Q49-50. This represents an increase of only one new species per sample, which includes both the flot and residue material. The deceleration of the curve suggests that, if sampled at random, the effort required to find a new taxon is beginning to be outweighed by the time it takes to sort a sample. The rise at the end of the curve, from 69 taxa to a final of 84 taxa is due solely to Q5-6. Since this quadrant was chosen for the purpose of ensuring a high level of species richness, the absence of an asymptote was expected. Overall, the graph suggests that increased sampling to the north would prove futile and that if there is any more diversity to be found it would be most efficient to look at the southern quadrants.

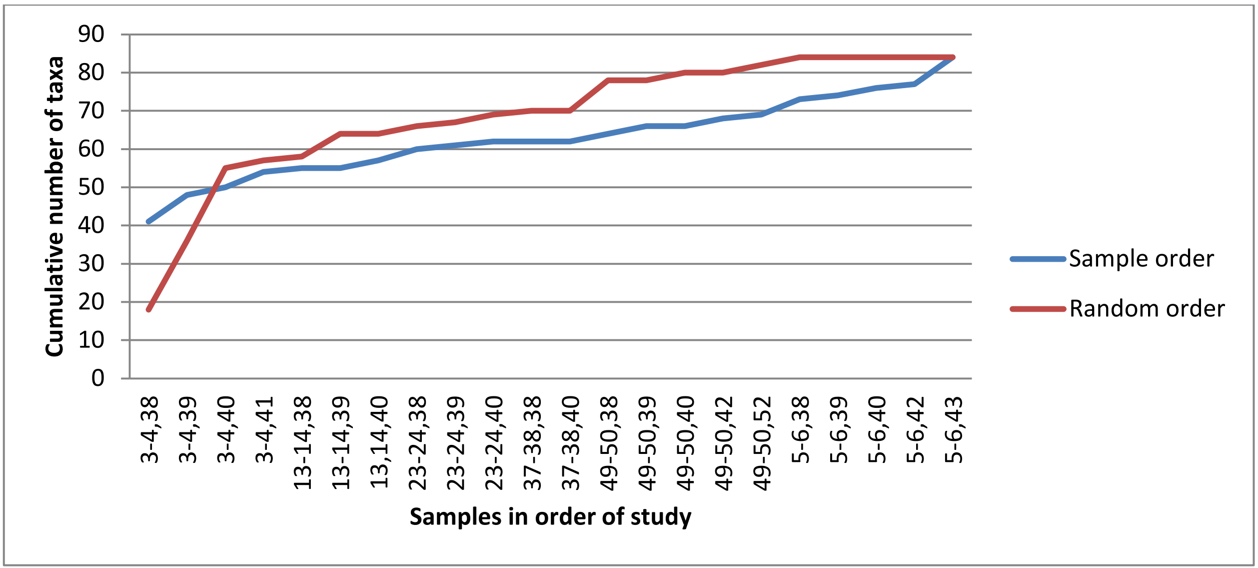


Figure 5.2. SAC for the mineralized material calculated in sample order and in random order

Random order

Unlike the SAC for sample order, the SAC with samples listed in random order does achieve an asymptote. The curve rises steeply at first and then begins to level off after 13 samples. The final five samples represent the asymptote and strongly suggest that a sufficient amount of material has been examined.

5.1.3 SACs for the marine molluscs

Sample order

The SAC for the molluscs follows the trend found in the SACs for the carbonized and mineralized material (Fig. 5.3). The curve climbs steeply at first before reaching an asymptote midway through Q23-24. The curve then remains at 48 taxa for nine samples before climbing again with the introduction of five new taxa from Q5-6 to give a total of 53 taxa. As with the carbonized and mineralized samples, it was expected that Q5-6 would increase overall species richness and that the curve would not achieve a final asymptote. Moreover, the absence of any new shell species in Q37-38 and Q49-50 indicates that if further sampling were to take place it would be best to look in the southern quadrants.

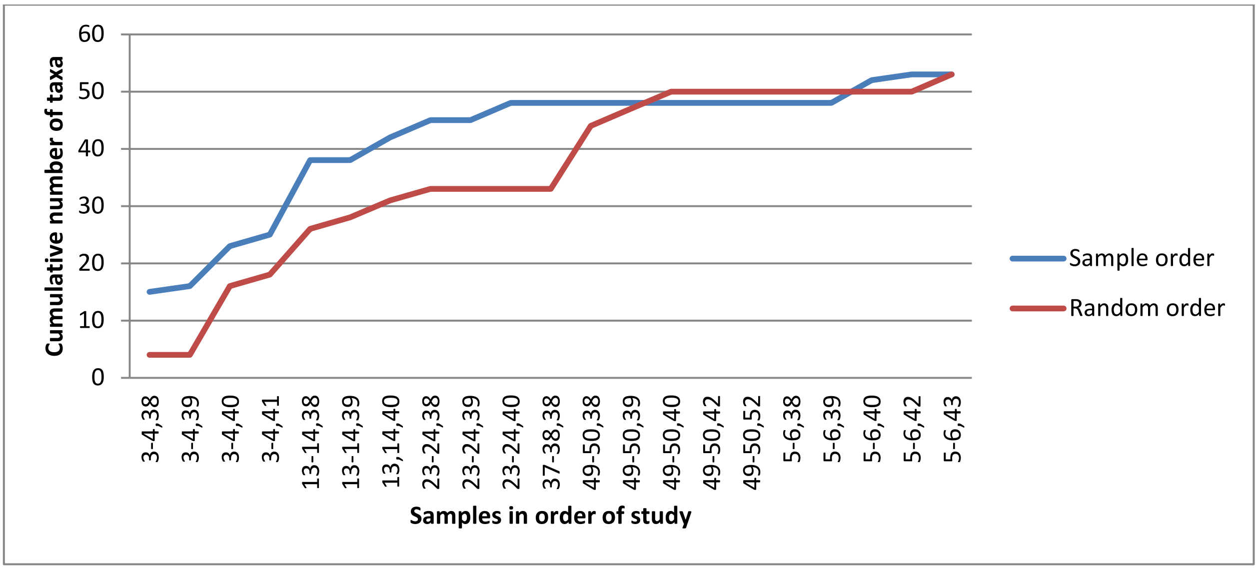


Figure 5.3. SAC for the shell material calculated in sample order and in random order

Random order

The SAC for the seashells recorded in random order appears to reach an asymptote after 13 samples, remaining constant for a further seven samples. However, at the very end an additional three taxa are added, causing the curve to rise slightly. This rise is probably due to the fact that the samples were selected randomly. However, the stability of the curve in the prior seven samples suggests that the majority of the taxa in the sewer have been identified.

5.1.4 Summary

In sum, the graphs shown above indicate that SACs are an effective way of measuring taxonomic richness when multiple categories of bioarchaeoloigcal material are present in the same sample and/or context. They signify that the selected methodology, of choosing quadrants based on location, has been an effective way of recovering the largest number of taxa in a time-efficient manner. Consequently, a sufficient amount of material has been examined in order to ensure an accurate analysis of the Cardo V material as it relates to both taphonomy and Roman diet.[57] While not all the curves reached an asymptote, the SACs have shown that the number of samples that would have to be sorted in order to find new taxa was too great to be of value in this study. Additional samples could have been sorted and only the new taxa picked out, but this method was not in-line with the methodological aims of this thesis: to study Roman diet but also to systematically study the taphonomy and formation of the Cardo V assemblage. However, the curves have had the beneficial effect of showing that if further work were to be done, it would be most efficient to look at quadrants in the southern end of the sewer, thus narrowing down the probable location of new finds.

5.2 Preservation of the botanical remains

A total of 94 plant categories were recovered from 22 Cardo V sewer samples. There were 84 mineralized, 27 carbonized and 9 waterlogged taxa (Table 5.1). There was a considerable degree of overlap between the assemblages with 19 taxa present in both the carbonized and mineralized assemblages (Fig. 5.4). The importance of this overlap will be discussed in section 6.2.2.

[57] The absence of an analysis of the animal bones from the sewer, in relation to an assessment of diet is addressed in section 7.3.3.

Table 5.1. Number of taxa based on preservation type

Number of mineralized taxa	84
Number of taxa unique to mineralized preservation	65
Number of carbonized taxa	27
Number of taxa unique to carbonized preservation	8
Taxa present in both the carbonized and mineralized assemblages	19
Number of waterlogged taxa	9
Number of taxa unique to waterlogging	2

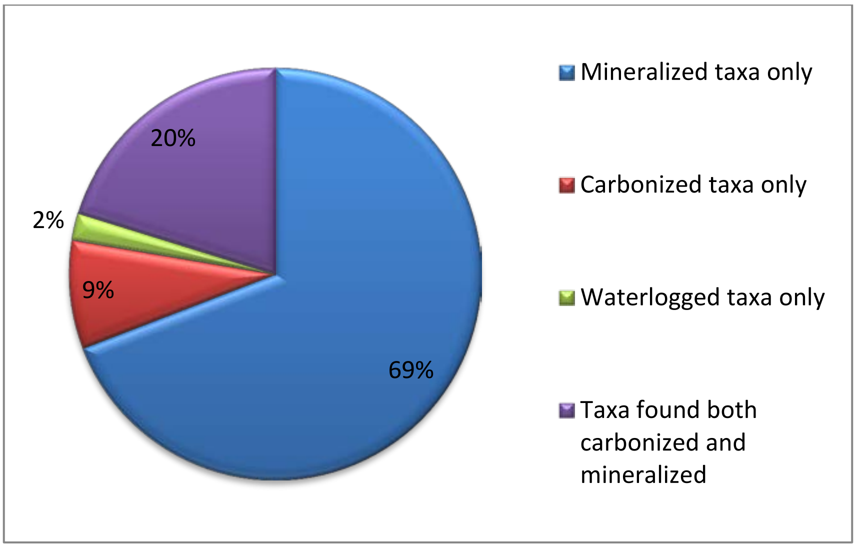


Figure 5.4. Contribution to the total number of taxa by preservation type

5.3 The mineralized material

The mineralized assemblage consists of 37 taxa identified to species, 34 to genus and 13 to family (Table 5.2). There are 90 entries listed below as some items could not always be identified to a single genus or family.

Table 5.2. Identified mineralized material from the Cardo V sewer

Taxonomic name	Common name	Presence*	Sum**	Max/sample**
Cereals				
Panicum miliaceum^ L.	Common millet	7	52	20
Panicum miliaceum^ L. or *Setaria italica*^ Beauv.	Common or foxtail millet	10	196	95
Setaria italica^ Beauv.	Foxtail millet	8	34	12
cf. *Sorghum* sp.	Sorghum	1	7	7
Triticum cf. *dicoccum* Schübl.	Emmer wheat	1	1	1
Cereal grain	Cereal	2	3	2
Pulses				
Lens culinaris Medik.	Lentil	6	16	6
Vicia faba var. *minuta* L.	Broad bean	2	3	1
Vicia or *Lathyrus* sp.	Vetch or pea	1	1	1
Vicia sp.	Vetch	1	1	1
Nuts				
Corylus avellana L.	Hazelnut	2	2	1
cf. *Pinus pinea* L.	Stone pine	1	1	1
Fruit				
cf. *Celtis australis* L.	Mediterranean hackberry	1	1	1
Cucumis melo L. or *sativus* L.	Melon or cucumber	1	4	1
Ficus carica L.	Fig	22	Thousands	N/A
Malus or *Pyrus* sp.	Apple or pear	11	33	24
Malus sp.	Apple	1	1	1
Morus nigra L.	Black mulberry	7	11	3
Olea europaea L.	Olive	3	19	15
Phoenix dactylifera L.	Date	1	1	1
Prunus avium or *cerasus* L.	Wild or sour cherry	1	3	3
Prunus domestica L.	Plum	2	4	3
Prunus sp.	Stone fruit	5	9	3
Rubus fruticosus (agg)	Blackberry	2	12	11
***Vitis vinifera* L.**	Grape	18	150	49
Herbs and seasonings				
cf. *Anethum graveolens* L.	Dill	4	5	2
Apium graveolens^ (Mills.) Pers.	Celery	8	47	12
Brassica sp. ^	Cabbage or mustard	6	41	16
Coriandrum sativum L.	Coriander	3	3	1
Foeniculum vulgare Mill.	Fennel	6	20	8
Linum usitatissimum L.	Flax/linseed	3	4	2
Mentha sp.	Mint	8	11	3
Papaver somniferum^ L.	Opium poppy	16	83	17
Piper nigrum L.	Black pepper	2	2	1
Other potential foodstuffs				
Ceratonia siliqua L.	Carob	1	1	1
Malva sp.	Mallow	6	26	7
Medicago sp.	Medick	5	10	5
Weeds, ruderals and other taxa				
Amaranthaceae	Amaranth family	10	36	6
Anagallis sp.	Pimpernel	2	2	1
Anthemis arvensis L.	Corn chamomile	5	12	4
Aphanes sp.	Parsley-piert	1	1	1
Apiaceae	Parsley family	12	138	58
Asteraceae	Daisy family	3	4	3
Boraginaceae	Borage family	2	2	1

Taxonomic name	Common name	Presence*	Sum**	Max/sample**
Brassicaceae	Cabbage family	2	2	1
Carduus sp.	Thistle	1	2	2
Carex sp.	Sedge	10	21	6
Carex sp. or *Rumex* sp.	Sedge or dock	1	2	2
Caryophyllaceae	Carnation family	18	99	15
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot	1	5	5
cf. *Centaurea* sp.	Knapweed	1	1	1
Chara sp.	Green algae	1	1	1
Chenopodium album^ L.	Fat-hen	1	4	4
Chenopodium^ sp.	Goosefoot	15	53	10
Cyperaceae	Sedge family	2	2	1
Cyperaceae or Polygonaceae	Sedge or knotweed	2	6	4
Fabaceae	Legume family	3	3	1
Lamiaceae^	Mint	13	42	17
Linum sp. (not usitatissimum)	Flax	1	2	2
Lithospermum arvense L.	Field gromwell	1	1	1
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot	1	1	1
Ornithopus sp.	Bird's foot	4	7	4
Ornithopus sp. or *Medicago* sp.	Bird’s foot or medick	1	1	1
Papaver sp.	Poppy	10	22	10
Papaveraceae	Poppy family	1	1	1
cf. *Plantago* sp.	Plantain	1	1	1
Poaceae	True grasses	11	11	1
Polygonaceae^	Knotweed family	2	35	34
Polygonum aviculare^ (agg) L.	Knotgrass	3	14	4
Polygonum^ sp.	Knotweed	6	25	15
Pteridium aquilinum (L.) Kuhn	Bracken	2	3	2
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup	1	2	2
Ranunculus^ sp.	Buttercup	5	16	8
Ranunculus subgens. *Ranunculus*	Buttercup	2	4	3
Reseda sp.	Mignonette	11	52	13
cf. *Rubus* sp.	Bramble	1	2	2
Rumex acetosella agg. L.	Sheep's sorrel	3	3	1
Rumex sp.	Dock	6	8	2
Sambucus sp.	Elder	1	1	1
Scrophulariaceae	Figwort family	2	2	1
Sherardia arvensis^ L.	Field madder	4	21	9
Silene gallica L.	Small-flowered catchfly	8	10	2
Silene sp.	Campion	2	2	1
Stellaria media^ (L.) Vill.	Common chickweed	13	30	4
Stellaria sp.	Chickweed	2	2	1
Urtica dioica^ L.	Common stinging nettle	17	79	20
Urtica^ sp.	Nettle	16	56	13
Viola sp. (subgen.) *Melanium*	Pansy	1	1	1
Ornamental plants				
Buxus sp.	Box	1	1	1
Cupressus sempervirens L.	Mediterranean cypress	4	7	2
Unknown	Unknown	22	509	82
Total (excluding fig pips)			**2188**	

Bold entries = total of all material (ex. seed + stalk)
* Out of 22 samples
** Based on MNI totals for all sample
^ Sum has been multiplied by 4 when item in the residue samples was smaller than 2mm

5.3.1 Density

Since the mineralized remains are the smallest of the bioarchaeological material, it was hypothesized that they would move down the sewer with the greatest ease and for the greatest distance. As figure 5.5 shows, the number of seeds per litre of soil increased as the quadrant numbers decreased, thereby supporting this theory.

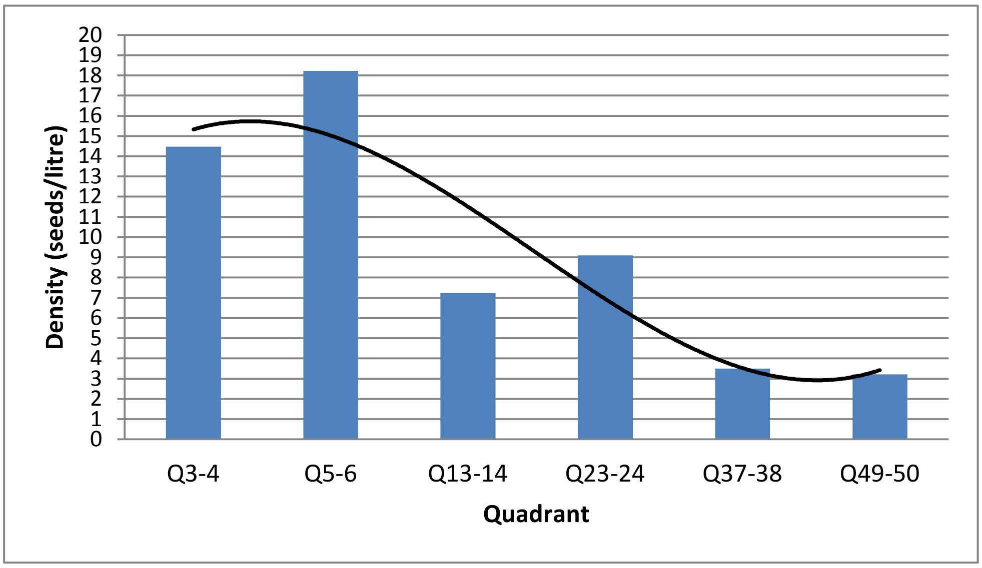


Figure 5.5. Density ratios of the mineralized material by quadrant in spatial order

However, figure 5.5 also shows that the density per quadrant does not decrease consistently and Q5-6 and Q23-24 have higher densities than their surrounding quadrants. The taphonomic conditions in the sewer can vary and it is possible that these peaks are simply due to chance. Alternatively, Q5-6 is situated almost equal distance from drains B10 and B11 (Figs. 4.6-4.7). The gap between these two latrines, running from Q8-9 to Q2-3, represents the longest section of the Cardo V sewer without a latrine or drain shaft. The solid contents could have become lodged at this point, around Q5-6, and then slowly moved farther downwards to Q3-4. This would explain the increased density at Q5-6, despite it being upstream from Q3-4.

The material in Q23-24 may have collected differently. It is situated just downstream from rain water drain B5/1 and the latrine in *Ins. Or.* II.9. Between *Ins. Or*

*II.*10 and 8 the slope of the sewer decreases from 7.9% to 6.5%, making it one of the flattest portions of the tunnel (Figs. 4.6-4.7). Although Q23-24 is located just below rain water collection pipe B5/1, the decrease in slope may have slowed the shift in solid contents, causing it to collect in the area around Q23-24.

5.3.2 Categories of abundance

While each of the six quadrants displayed a high degree of taxonomic diversity, the abundance levels were low. Raw seed counts show that on average a quadrant contained 360 individual mineralized botanical items (excluding the fig pips). As figure 5.6 demonstrates, the vast majority of the seeds were recovered in quantities of nine or fewer per sample. Only 19% of the taxa produced between 10-100 items and only 4% produced over 100 items any one sample. The fig pips and the unidentified remains were the only items with counts over 100.

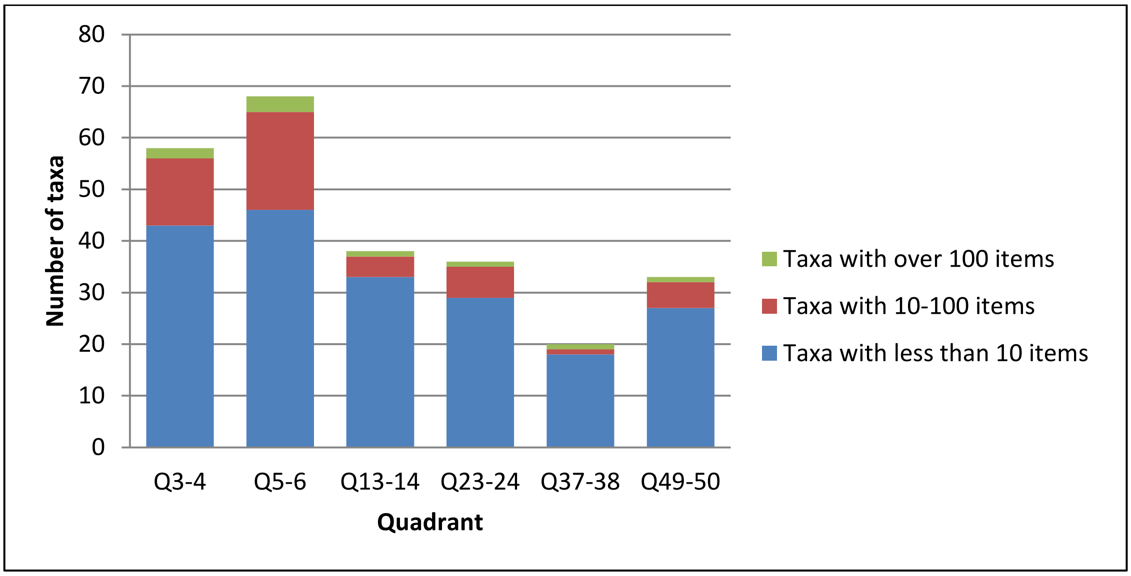


Figure 5.6. Abundance of the mineralized material within samples and grouped by quadrant

5.3.3 Ubiquity

The majority of the mineralized material had moderate ubiquity levels when calculated by both quadrant and individual sample. Just under half (47%) of the taxa were present in three or more quadrants (Fig. 5.7).

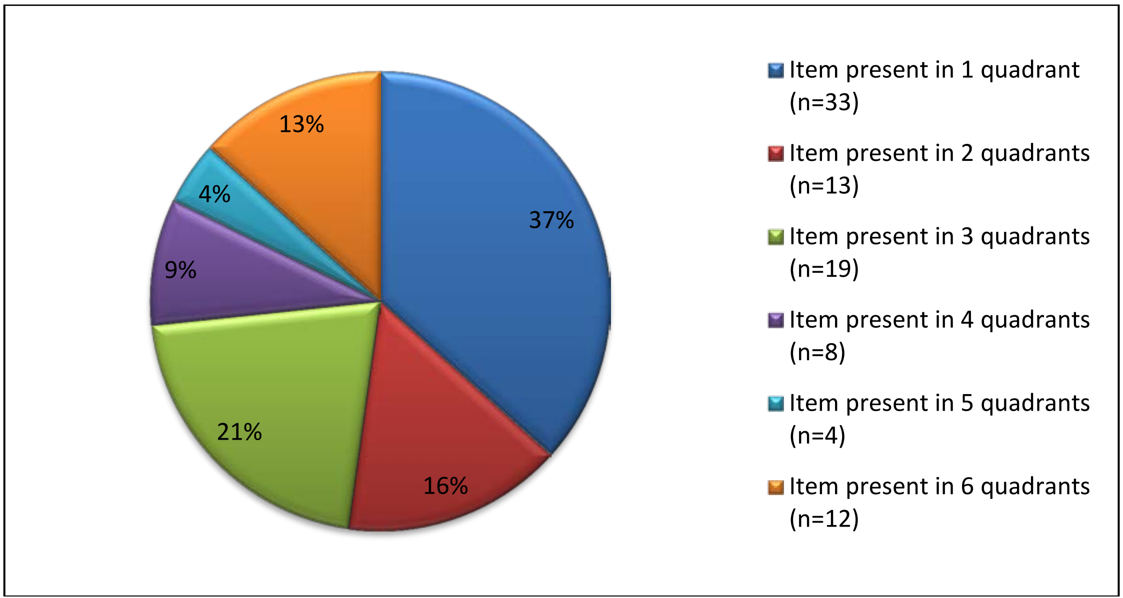


Figure 5.7. Ubiquity of the mineralized assemblage by quadrant

The 12 most ubiquitous items, recovered from all six quadrants, were those that tend to preserve well under mineralizing conditions such as *Ficus carica*, could only be identified to family or are from prolific seed producing plants such as *Urtica dioica* (Table 5.3).

Table 5.3 Mineralized taxa present in all six quadrants

Amaranthaceae	*Papaver* sp.
Caryophyllaceae	Poaceae
Chenopodium sp.	*Stellaria media*
Ficus carica	*Urtica dioica*
Lamiaceae	*Urtica* sp.
Papaver somniferum	*Vitis vinifera*

As movement in the sewer was generally horizontal and not vertical, individual quadrants provide helpful information about how the material moved within the sewer, revealing the direction of flow and areas of buildup. In order to understand the popularity of consumption and/or use of these plants, it is beneficial to also look at ubiquity scores based on sample number.[58] The horizontal flow dispersed items along the length of the sewer, but only in a single direction. Thus an item with a high ubiquity score for both the quadrants and samples was deposited in the sewer at multiple points in space and time and was therefore probably widely consumed, although some of the differences will no doubt be due to taphonomic variability (see section 6.2.2).

Most of the items from the Cardo V sewer were present in a limited number of samples. There were 17 taxa (18.8%) found in 10 or more of the 22 samples studied while 41.1% were found in 4 or more samples (Fig. 5.8). Despite the lower scores, all the taxa found in multiple samples were also found in multiple quadrants. This suggests that while these items may not have been used on a regular basis, they were used by multiple inhabitants of *Ins. Or.* II. When examined on an individual basis, it is clear that the few taxa present in a large number of samples were also present in a large number of quadrants. These results indicate that a limited number of plants were widely and frequently used and/or consumed and that these particular taxa also have a high rate of preservation (Fig. 5.9).

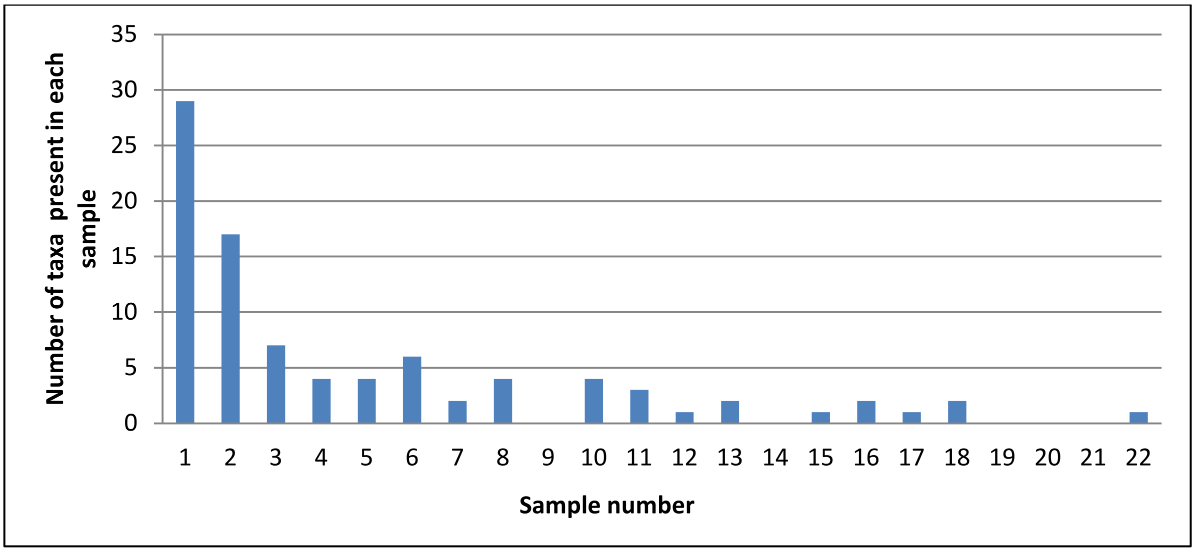


Figure 5.8. Ubiquity of the mineralized material by sample

[58] Q5-6, US38, for example, is a single sample.

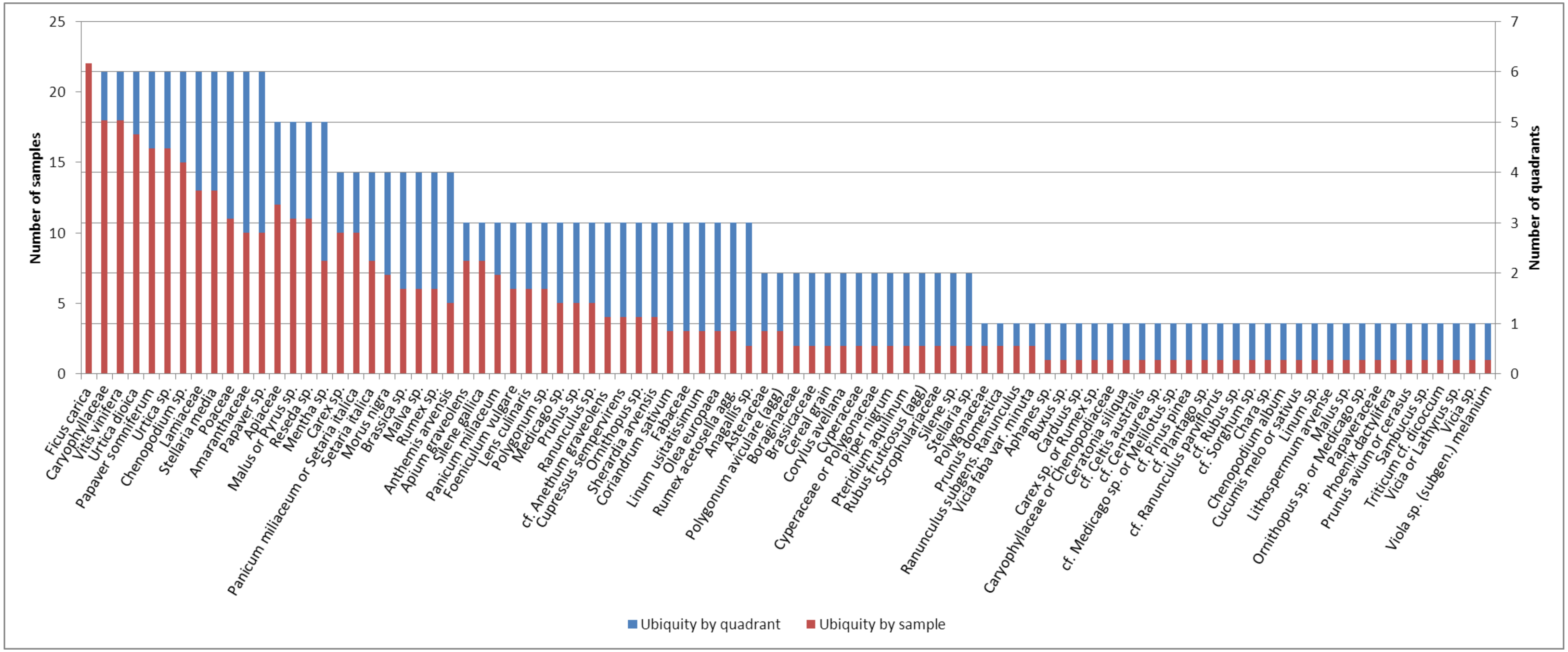


Figure 5.9. Ubiquity of the mineralized assemblage by individual taxa

5.4 The carbonized material

The carbonized assemblage was composed of 15 taxa identified to species, 10 to genus and two to family (Table 5.4). There are 31 entries listed below as some items could not always be identified to a single genera or family.

Table 5.4. Identified carbonized material from the Cardo V sewer

Taxonomic name	Common name	Presence*	Sum**	Max/sample**
Cereals				
Hordeum sp.	Barley	3	3	1
Panicum miliaceum^ L. or *Setaria italica*^ Beauv.	Common or foxtail millet	1	1	1
Setaria italica^ Beauv.	Foxtail millet	1	1	1
Triticum aestivum L.	Bread wheat	1	1	1
Triticum dicoccum Schübl.	Emmer wheat	1	1	1
Triticum dicoccum Schübl. or *Triticum monococcum* L.	Emmer or einkorn wheat	1	2	2
Triticum monococcum L.	Einkorn wheat	1	1	1
Triticum sp.	Wheat	1	1	1
Bread fragments	Bread	2	2	1
Cereal grain	Cereal	2	3	2
Pulses				
Lens culinaris Medik.	Lentil	2	2	1
Vicia or *Lathyrus* sp.	Vetch or pea	2	3	2
Nuts				
Corylus avellana L.	Hazelnut	1	1	1
Juglans regia L.	Walnut	4	6	3
***Pinus pinea* L.**	Stone pine	6	8	2
Fruit				
***Ficus carica* L.**	Fig	3	12	6
Malus or *Pyrus* sp.	Apple or pear	2	3	2
Olea europaea L.	Olive	18	666	194
Phoenix dactylifera L.	Date	1	1	1
Pyrus sp.	Pear	1	1	1
***Vitis vinifera* L.**	Grape	19	59	8
Other potential foodstuffs				
Vicia ervilia (L.) Willd.	Bitter vetch	1	1	1
Weeds, ruderals and other taxa				
Apiaceae	Parsley family	1	1	1
cf. *Avena* sp.	Oat	1	1	1
Chenopodium^ sp.	Goosefoot	2	2	1
Ornithopus sp.	Bird's foot	1	1	1
Poaceae	True grasses	7	11	4
Rumex sp.	Dock	1	1	1
Stellaria media^ (L.) Vill.	Common chickweed	1	1	1
Ornamental plants				
Cupressus sempervirens L.	Mediterranean cypress	5	5	1
Unknown	Unknown	6	31	3
Total			**833**	

Bold entries = total of all material (ex. seed + stalk)
* Out of 22 samples
** Based on MNI totals for all sample
^ Sum has been multiplied by 4 when item in the residue samples was smaller than 2mm

5.4.1 Density

The density ratios for the carbonized material show a broadly similar pattern to the ratios calculated for the mineralized material; as the quadrant numbers decrease (move downslope), the density ratios increase (Fig. 5.10).

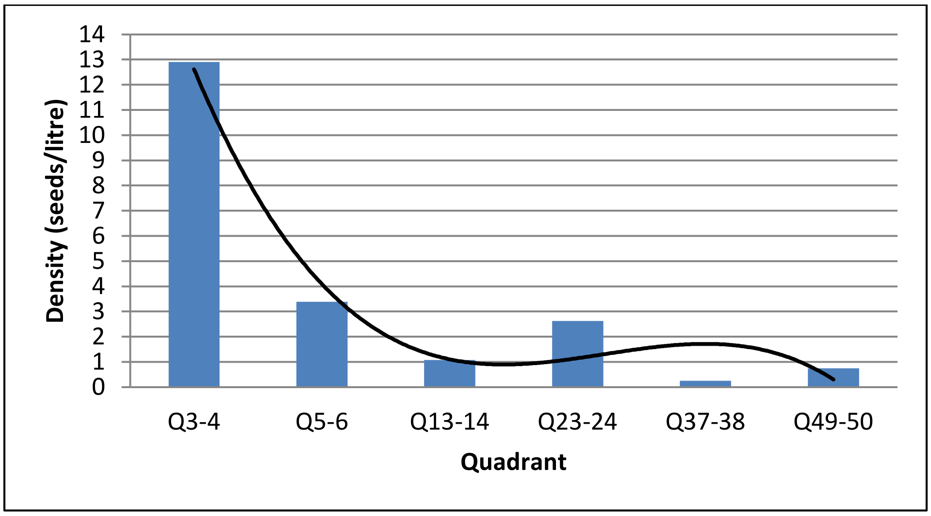


Figure 5.10. Density ratios of the carbonized material by quadrant in spatial order

These results again confirm a downward shift in material. The rather low density levels, especially compared to the mineralized material, are due partly to the nature of the material and partly to the calculation methods. As discussed in section 3.2.1, the type of botanical material that becomes carbonized is usually related to subsistence or fuel including grains, legumes and olive stones. As a result, the carbonized material from the sewer is, for the most part, larger in size than the mineralized remains, which consists of small items such as weed seeds, herbs and fig pips. Since the carbonized material is both larger and less susceptible to complete disintegration than the mineralized material, there is a greater chance that fragmented seeds and pits will survive. However, a large number of fragments does not always correspond to a high MNI, as, for example, with the highly fragmented olive stones. If the density ratios for the carbonized material had been calculated using the number of fragments instead of MNI, then the ratios would have been significantly higher.

5.4.2 Density – The carbonized and mineralized assemblages compared

Firstly, it should be noted that a comparison between the carbonized and mineralized material is possible due to the nature of the sewer assemblage. Although these two assemblages were created through differing formation processes, once the material entered the sewer (and had become preserved in the case of the mineralized material), it was subject to the same local conditions.

When the carbonized and mineralized density ratios are compared, there are obvious similarities and discrepancies amongst the quadrants (Fig. 5.11). The peak in carbonized material at Q23-24 is likely due to the same reasons as the peak in the mineralized remains (see 5.3.1). The slight increase in density in the carbonized material at Q49-50, relative to Q37-38, corresponds to less than one seed per litre and is probably due to chance.

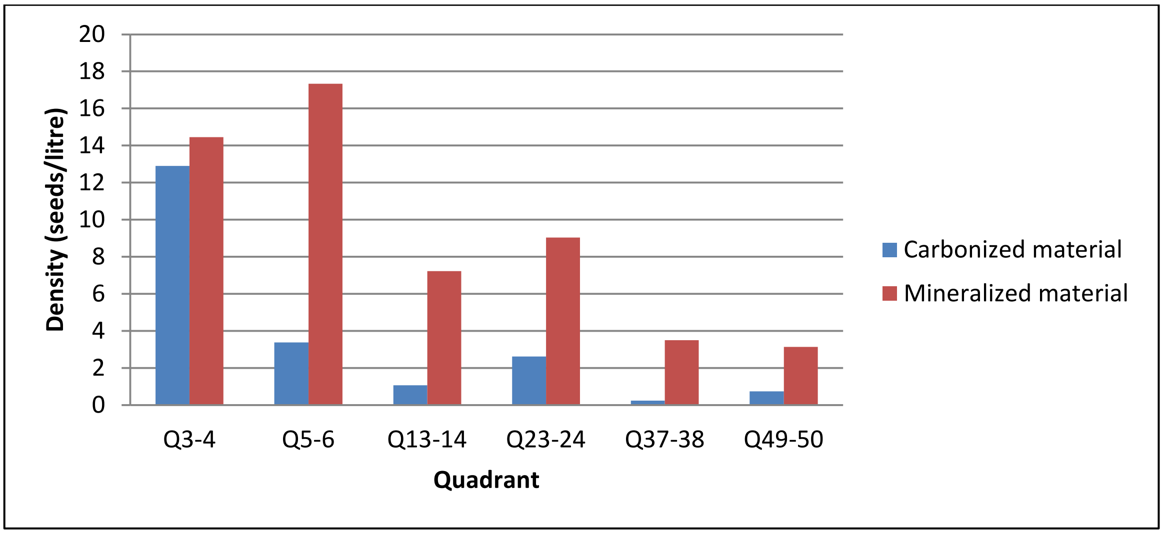


Figure 5.11. Comparison of the density ratios of the carbonized and mineralized assemblages by quadrant in spatial order

It is at Q5-6 where the most significant difference can be found. From Q3-4 to Q5-6, the densities change from 14.45 to 17.34 for the mineralized material and from 3.38 to 12.9 for the carbonized material. In section 5.3.1, it was suggested that the increase in the density of mineralized material at Q5-6 was due either to chance or to the buildup of material between drains B10 and B11 (Figs. 4.6-4.7). After a closer examination of the carbonized material, it appears that a buildup is the more likely cause. The change in density in the carbonized material is due almost entirely to a difference in the number of olive stones. While both assemblages are dominated by olives, Q3-4 has 446 olive stones while Q5-6 has only 122. There are also a larger number of grape pips in Q3-4 than Q5-6. Thus when the buildup occurred, it is probable that the smaller mineralized items were still trapped in the sediment and human faeces while the more buoyant carbonized items, especially the olive stones and grape pips were pushed farther down the sewer.

5.4.3 Categories of abundance

The carbonized assemblages of all six quadrants were found to have a moderate range of taxa but low abundance levels (Fig. 5.12). Similar to the mineralized material, the majority of the taxa were found in counts of nine or fewer items per sample. Only 9.6% of the taxa had more than nine items and olives were the only species with counts over 100 (see Table 5.4).

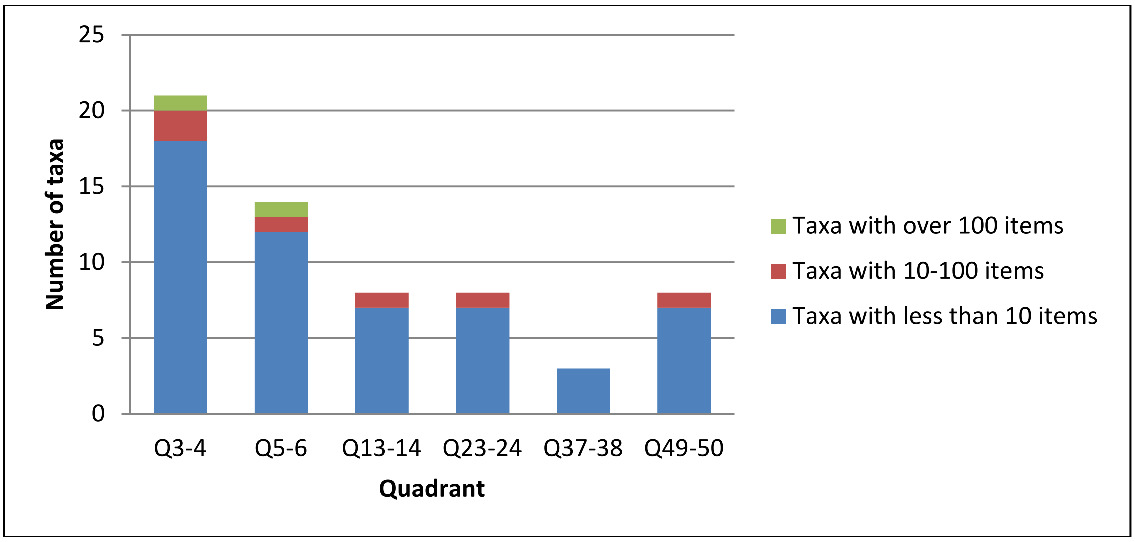


Figure 5.12. Abundance of the carbonized material within samples and grouped by quadrant

5.4.4 Ubiquity

The carbonized material produced lower ubiquity scores than the mineralized material with only 37% of the items found in more than one quadrant (Fig. 5.13). Only grapes and olives were found in all six quadrants. As these two species quantitatively dominate the carbonized assemblage it is not surprising that they were also the most ubiquitous (see Table 5.4).

The ubiquity scores calculated by sample were relatively low with only 26.6% of the taxa found in three or more samples (Fig. 5.14). None of the taxa were found in every sample and again, grape and olive were the most ubiquitous, present in 19 and 18 samples respectively. Similar to the mineralized material, when the taxa are looked at individually, the presence of a particular taxon in multiple samples frequently corresponded to its presence in multiple quadrants (Fig. 5.15). Hence the most ubiquitous items were those most commonly deposited in the sewer by the residents of *Ins. Or.* II and were also able to survive the carbonization process.

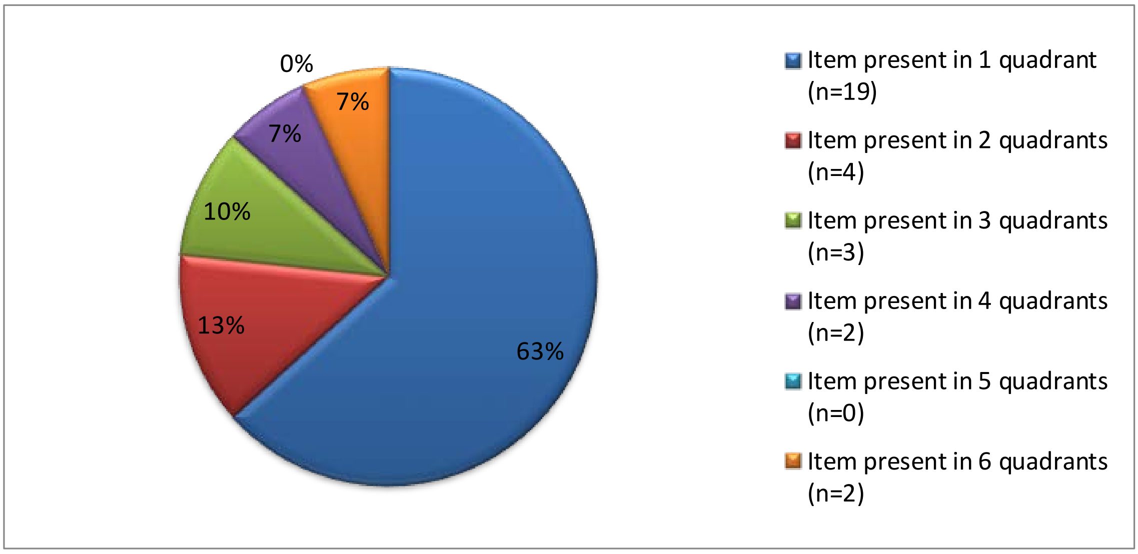


Figure 5.13. Ubiquity of the carbonized assemblage by quadrant

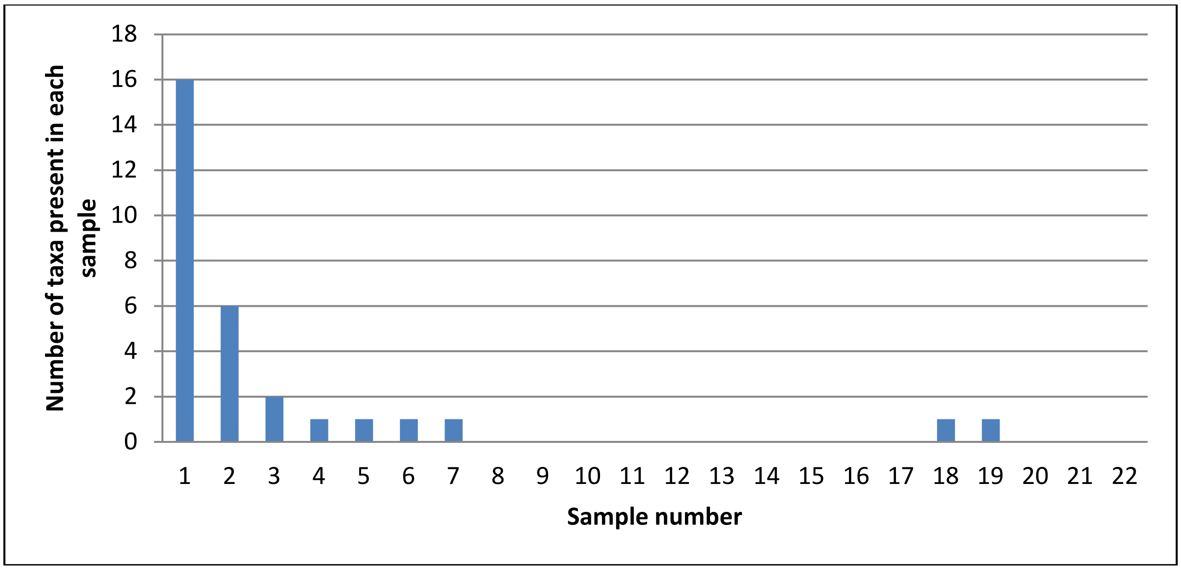


Figure 5.14. Ubiquity of the carbonized assemblage by sample

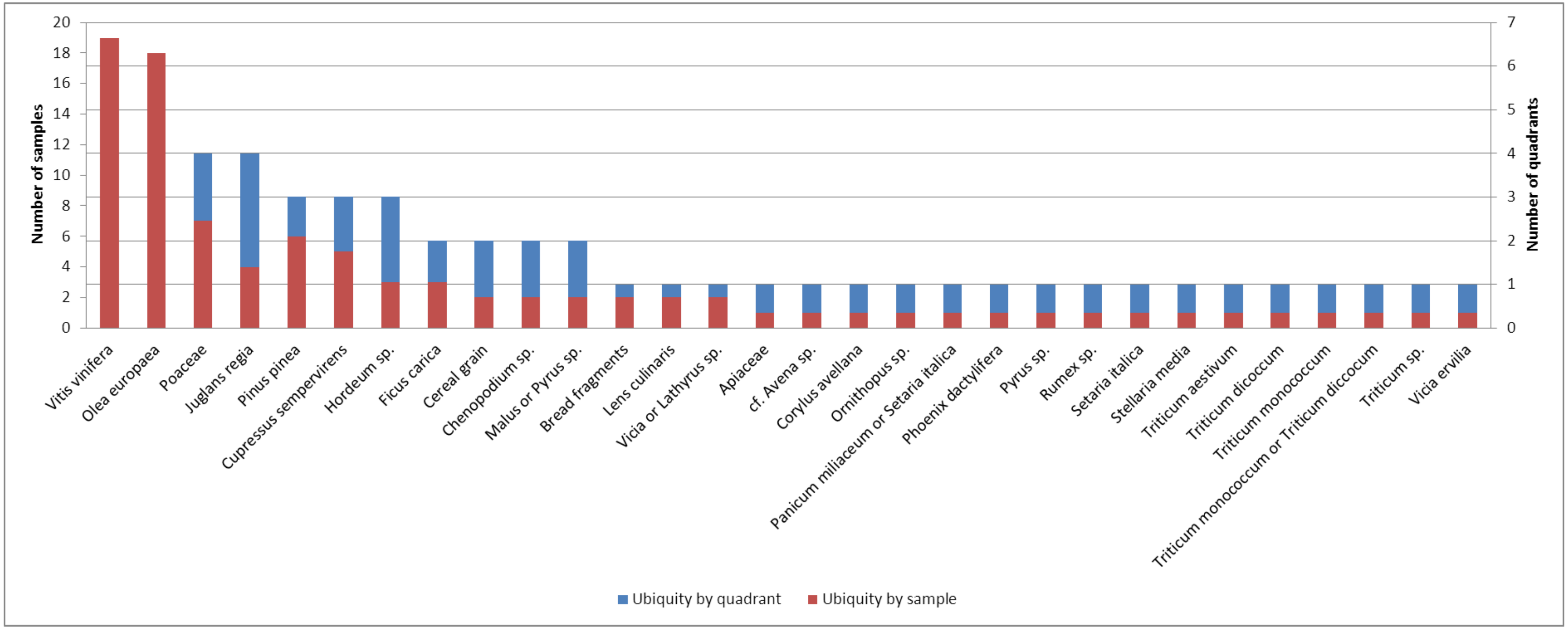


Figure 5.15. Ubiquity of the carbonized material by individual taxa

5.5 Overlap between the carbonized and mineralized material

There are 19 taxa with botanical material present in both the carbonized and mineralized assemblages (Table 5.5). This represents 20% of the total number of taxa, leaving only 8 taxa unique to carbonization (See Table 5.1).

Table 5.5. Taxa recovered from both the carbonized and mineralized assemblages

Apiaceae	*Phoenix dactylifera*
Chenopodium sp.	*Pinus pinea*
Corylus avellana	Poaceae
Cupressus sempervirens	*Pyrus* sp.
Ficus carica	*Rumex* sp.
Lens culinaris	*Setaria italica*
Malus or *Pyrus* sp.	*Stellaria media*
Olea europaea	*Triticum dicoccum*
Ornithopus sp.	*Vicia* or *Lathyrus* sp.
Panicum miliaceum or *Setaria italica*	*Vitis vinifera*

The number of overlapping taxa is large and these items act as evidence of the high degree of mineralized preservation in the sewer (**Fig. 5.16**[59]). Within the 19 taxa are items that are almost always exclusively found as carbonized remains in any non-waterlogged archaeological context. Emmer wheat, olives and hazelnuts are found elsewhere in Herculaneum and Pompeii but only preserved through carbonization (Borgongino 2006; Ciaraldi 2007). Additionally, the presence of carbonized and mineralized items such as lentil and foxtail millet will later assist in untangling the complex formation processes that occurred to create these two assemblages (See section 6.2.2).

[59] Figures in **bold** in this chapter can be found in Volume II.

5.6 The waterlogged material

The waterlogged assemblage consists of five taxa identified to species, two to genus and two to family (Table 5.6). Since the waterlogged material was preserved in a sporadic fashion (see section 6.1.3 for a full description), it was decided that additional calculations such as abundance or ubiquity would not provide any useful information concerning the taphonomy or formation of this assemblage. Therefore, no analyses were performed on the waterlogged assemblage.

Table 5.6. Identified waterlogged material from the Cardo V sewer

Taxonomic name	Common name	Presence*	Sum^**	Max/sample**
Fruit				
Malus or *Pyrus* sp.	Apple or pear	1	3	3
***Rubus fruticosus* (agg)**	Blackberry	1	3	2
Vitis vinifera L.	Grape	4	8	4
Herbs and seasonings				
Apium graveolens (Mill.) Pers.	Celery	1	1	1
Weeds, ruderals and other taxa				
Apiaceae	Parsley family	1	7	1
Daucus carota L.	Wild carrot	2	5	4
Fumaria sp.	Fumitory	1	1	1
Lamiaceae	Mint family	1	1	1
Stellaria media (L.) Vill.	Common chickweed	1	2	2
Total			**31**	

Bold entries = total of all material (ex. seed + stalk)
* Out of 22 samples
** Based on MNI totals for all samples
^ Sum has been multiplied by 4 when item in the residue samples was smaller than 2mm

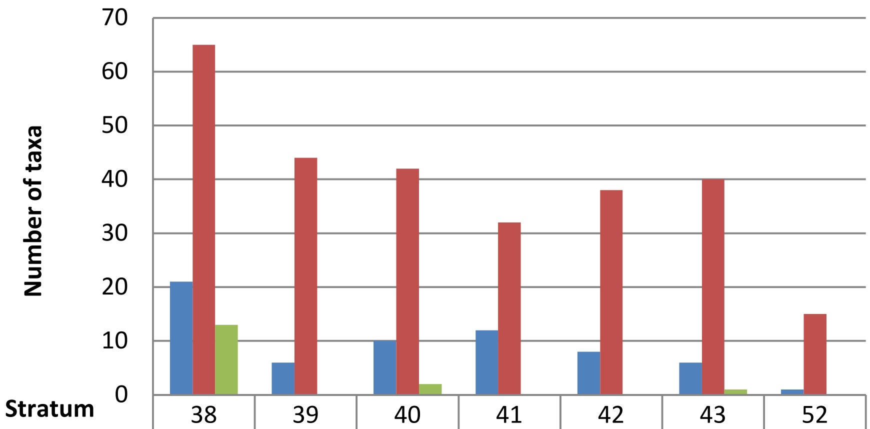
5.7 Stratigraphic analysis of the botanical material

The density scores for the quadrants discussed above demonstrated how the material moved, where the sewer material became blocked and the influences of the different latrines and rainwater shafts. The calculations by sample, particularly the abundance levels, provide a rough estimate of the concentration of the deposit at a particular moment in time. Although there is movement, it is slow, and a large volume of an item within a sample suggests frequent use and/or consumption within a short time span. In order to further explore the spatial and chronological deposition and concentration of the material within the sewer, each of the seven stratigraphic layers was also analysed for the diversity, density, abundance and ubiquity of its mineralized and carbonized assemblages. The waterlogged material has been included where relevant.

5.7.1 Diversity

Mineralized and carbonized material was recovered from all seven strata. Waterlogged remains were identified in US38, 40 and 43. Since US38 is one of the two most prevalent layers (Table 4.1), it is not surprising that it is the most diverse stratum for all three material types (Fig. 5.17). At the opposite end of the scale, US52 had the least amount of diversity. The US52 layer is found only in Q49-50, which itself is rather sparse in botanical finds due to its location at the northern end of the sewer. The diversity of the mineralized material in the remaining five strata was high, ranging from 32 items in US41 to 44 items in US39. These results indicate that a wide range of taxa were consistently deposited along the length of the sewer for the length of time it required the material to accumulate.

The carbonized taxa, however, had low diversity ranges. The most diverse stratum was again US38 with 21 taxa, almost double that of the remaining six layers. Excluding US52 which had only one carbonized taxon, the variety in carbonized material ranged from six to 12 taxa. This means that on average only 32% of the total variety of carbonized material was found in each stratum compared to an average of 46% for the mineralized material. This suggests that for the carbonized material, a small number of botanical items, such as grapes and olives, were being burnt on a consistent basis while the remaining material was only occasionally present in the apartments or subjected to accidental or intentional burning.



Stratum	38	39	40	41	42	43	52
Number of carbonized taxa	21	6	10	12	8	6	1
Number of mineralized taxa	65	44	42	32	38	40	15
Number of waterlogged taxa	13	0	2	0	0	1	0

Figure 5.17. Taxonomic diversity amongst the seven strata

5.7.2 Density

The density ratios vary greatly between stratigraphic layers and between preservation types. As Figure 5.18 demonstrates, US38, 39 and 40 have moderate to low density levels in both the carbonized and mineralized material. These are the three strata that run the length of the sewer. Their density levels suggest deposition on a moderate but consistent basis across space and time. The remaining strata are the localized deposits, whose varying density ratios can be explained by their spatial orientation within the sewer.

US41 has the highest densities of mineralized and carbonized material. This strata is present only in Q3-4, a quadrant at the very southern end of the sewer and thus a collecting point for the slowing shifting material. The high density of carbonized material is due to the 272 olive stones, the largest number from any stratum. The olives may represent a period of particularly heavy deposition farther up the sewer or the tendency of the carbonized material to shift farther downstream than the mineralized remains. The high volume of mineralized material in US42 and 43 may also represent periods of more intense deposition. US43 is localized to Q5-6, the quadrant with the highest density and second largest range of taxa. Similarly, US42 is found in Q49-50 but also Q5-6. US52 has the lowest density as it is present only in Q49-50.

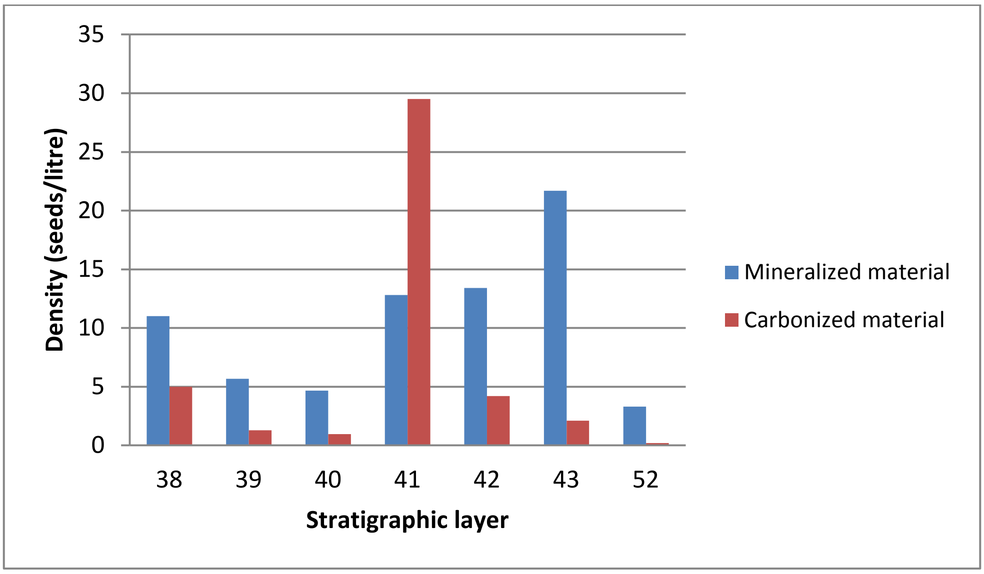


Figure 5.18. Density ratios of the mineralized and carbonized material by strata

5.7.3 Categories of abundance

There is a large degree of consistency in the abundance levels for both material types (Figs. 5.19-5.20). The vast majority of the items, 85% for the mineralized material and 86% for the carbonized material, are found in counts of nine or less. Within the mineralized material, US38 and 40 have the highest number of taxa within the 10-100 range. US42, although it has the highest density level, has only three taxa represented by more than 10 items. Mineralized taxa with counts of over 100 are represented primarily by the fig pips while in US38 the two most abundant items are fig pips and the number of unidentified seeds. In the carbonized assemblages it is the grape pips and olive stones that have counts of over ten or 100 (Fig. 5.20).

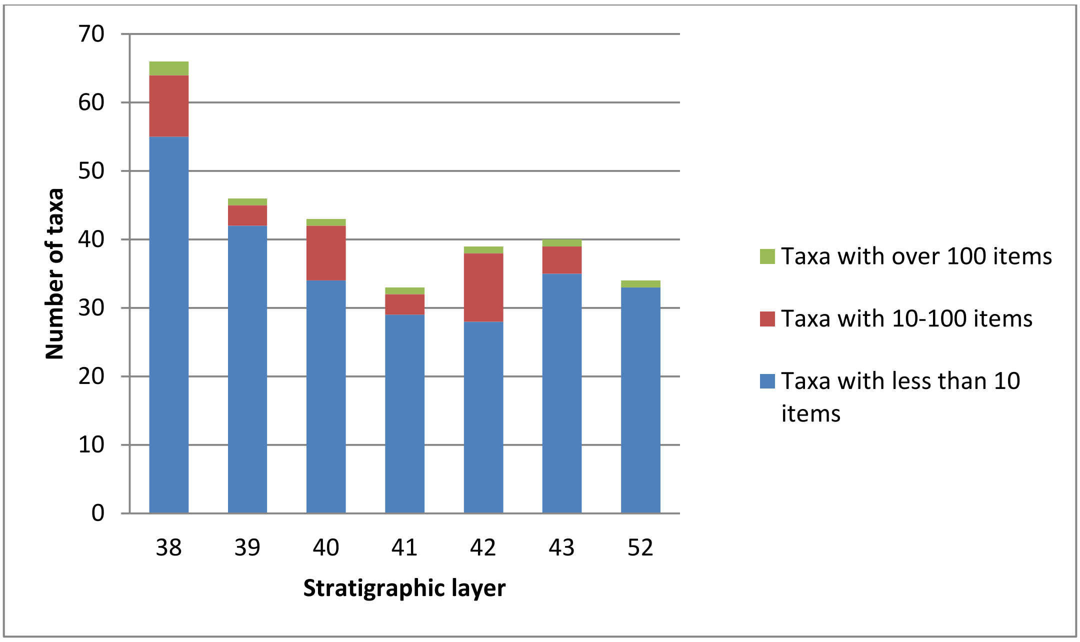


Figure 5.19. Abundance of the mineralized material within samples and grouped by strata

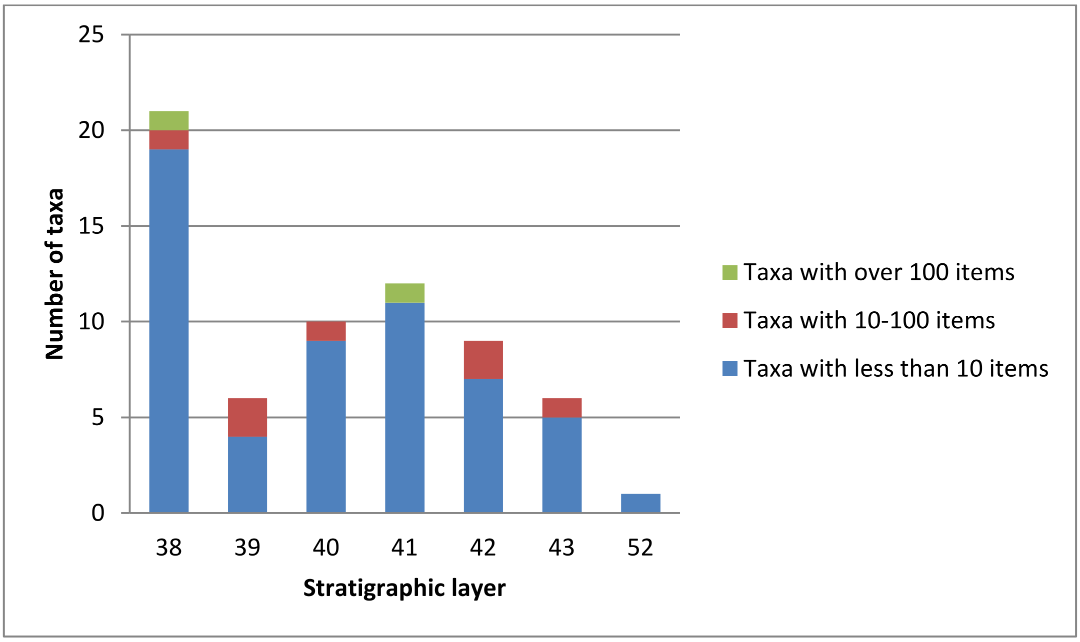


Figure 5.20. Abundance of the carbonized material within samples and grouped by strata

5.7.4 Categories of abundance – Quadrant vs. strata

The strata represent deposition over space and time while the quadrants function as a vertical snapshot of these depositional activities. As Figures 5.21-5.24 show, for both the carbonized and mineralized material, the percentages of taxa within each abundance level are almost identical. Regardless of quadrant or stratigraphic level, the majority of the material is found in very low abundance while the larger counts are represented by the same few taxa. This consistency seems to suggest that there was little change in the variety and frequency of the plants being used by the inhabitants of *Ins. Or.* II between AD69-79.

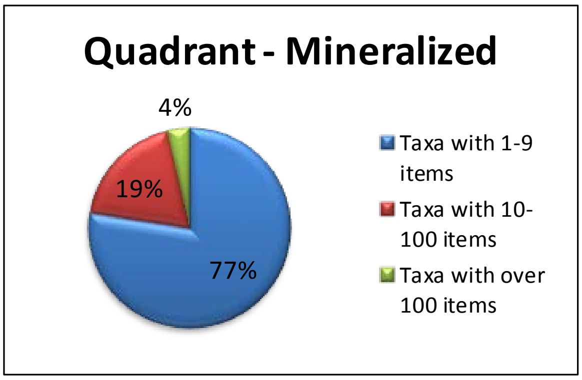


Figure 5.21. Mineralized abundance levels by quadrant

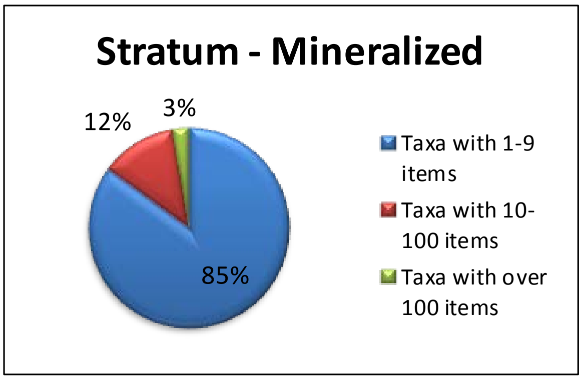


Figure 5.22. Mineralized abundance levels by stratum

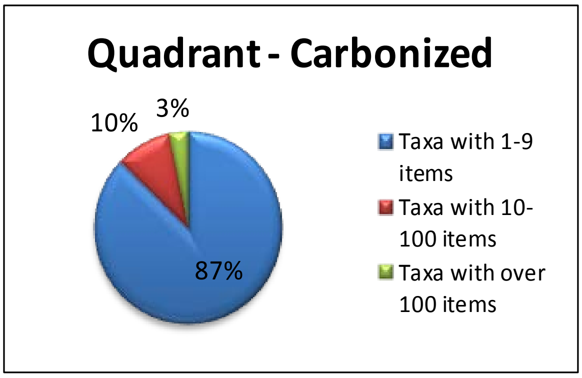


Figure 5.23. Carbonized abundance levels by quadrant

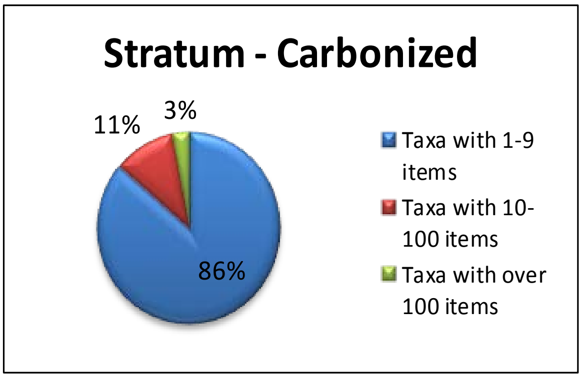


Figure 5.24. Carbonized abundance levels by stratum

5.7.4 Ubiquity

Within the seven stratigraphic units, 46% of the carbonized material was found in more than one stratum while 37% was found in multiple quadrants (Figs. 5.25 and 5.26). However, within both the strata and the quadrants the only carbonized taxa with extremely high ubiquity scores were the grapes and olives.

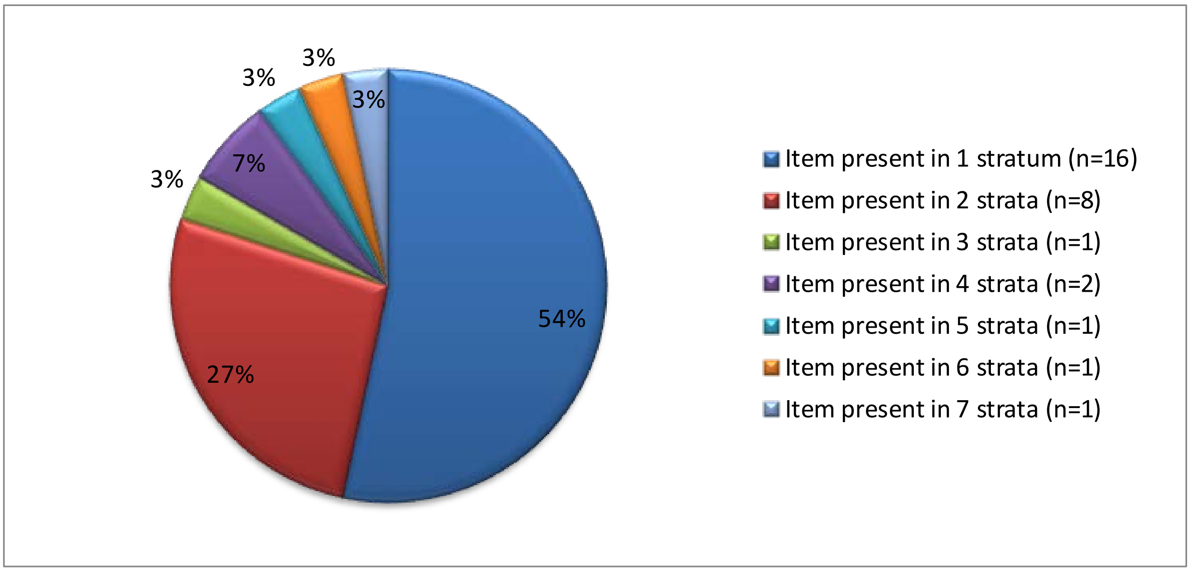


Figure 5.25. Ubiquity scores for the carbonized material by strata

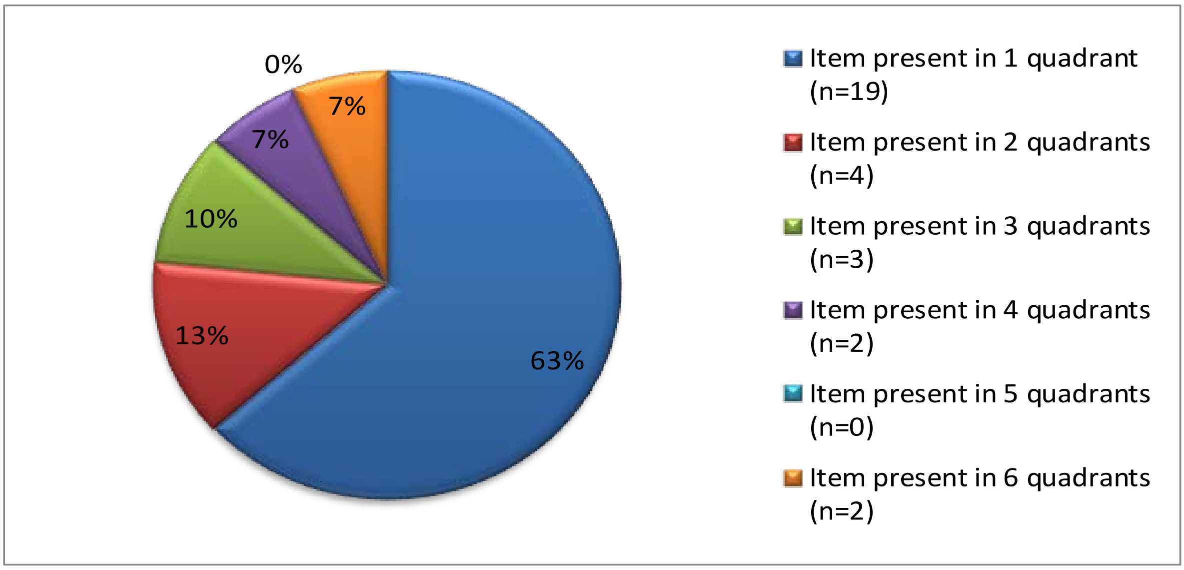


Figure 5.26. Ubiquity scores for the carbonized material by quadrant

The mineralized material had higher ubiquity scores than the carbonized material. In both the strata and the quadrants, 64% and 63 % of the taxa were found in a multiple layers or quadrants respectively (Figs. 5.27 and 5.28). Six taxa were found in all seven strata while 13 taxa were recovered from every quadrant. Five of the six most ubiquitous taxa by stratigraphic layer were also part of the 13 most ubiquitous taxa by quadrant.

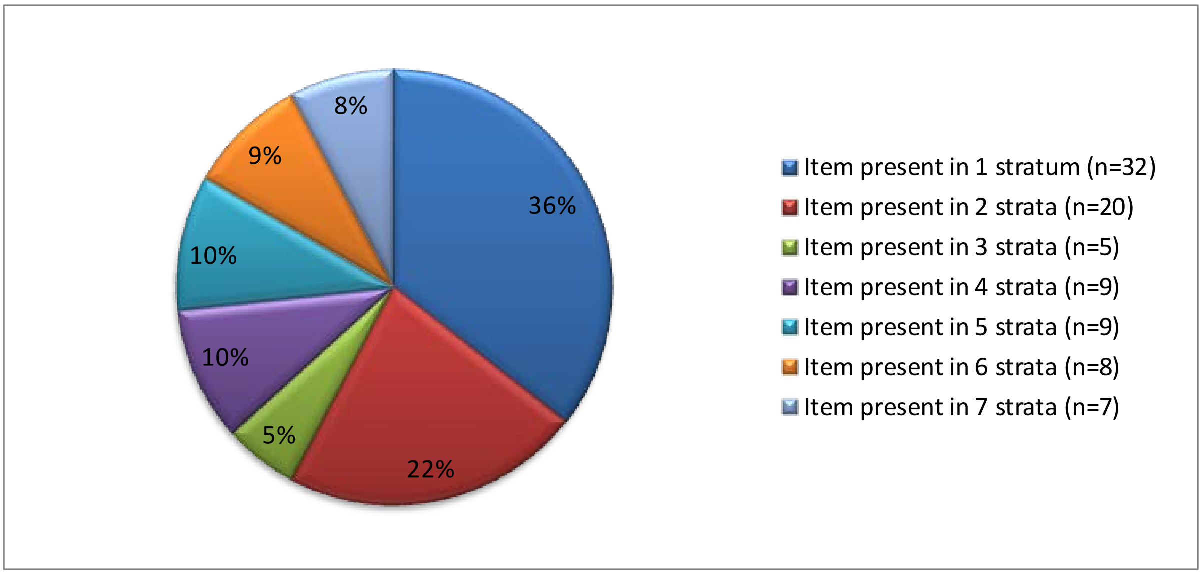


Figure 5.27. Ubiquity scores for the mineralized material by strata

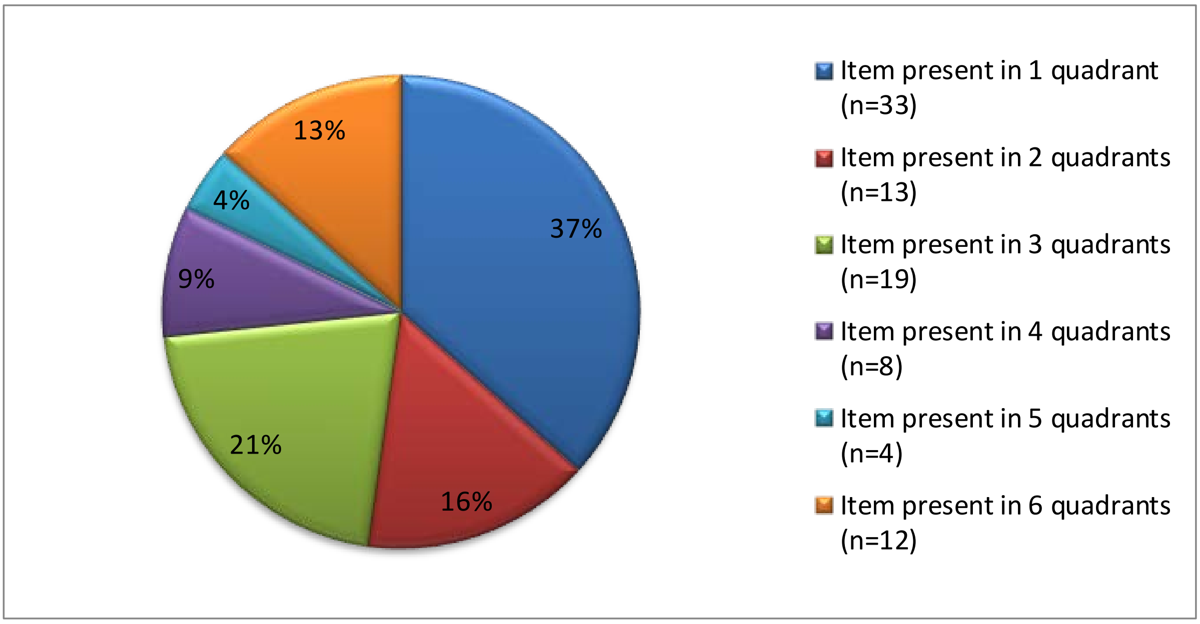


Figure 5.28. Ubiquity scores for the mineralized material by quadrant

Thus while the ubiquity scores for the carbonized and mineralized assemblages varied significantly from each other, they were similar to the scores calculated for their quadrant counterparts, and almost identical in the case of the mineralized material. This is due, in part, to the fact that many taxa were recovered from only a single sample, and therefore from only one quadrant and stratum (Tables 5.2. and 5.4). Nevertheless, both the high and low ubiquity scores remain constant across the quadrants, strata and samples, and therefore remain constant across space and time. These findings again suggest that a wide range of plants were used by the majority of those living in *Ins. Or.* II for the length of time it required the Cardo V assemblage to accumulate. Regarding food consumption, these findings indicate a diet consisting of a few staple foods (high ubiquity scores), supplemented on a frequent basis by a wide range of other edible goods (low ubiquity scores).

5.8 Categorization of the botanical material

The botanical material has been divided up into ten categories based on anthropomorphic use or environmental characteristics. The edible items have been separated into cereals, pulses, nuts, fruit, herbs and seasoning with each table showing the total number of items (MNI) per preservational type (Tables 5.7-5.14). An additional group labelled 'Other potential foodstuffs' has been added. Portions of these plants can be consumed by people but their popularity and frequency in the Roman diet is debatable. The remaining categories consist of weed seeds and ornamental plants. Ubiquity scores and abundance levels are discussed briefly.

5.8.1 Cereals

There are at least seven cereal types including three varieties of wheat. The wheat and barley are found primarily carbonized while the millet is typically found in a mineralized state (Table 5.7, **Fig. 5.29**). Except for the millets, the cereals had very low ubiquity scores. Barley was found in three samples, each from a different quadrant. The wheat varieties were recovered from single samples and thus single quadrants. Combined, the millets were identified in five quadrants, 14 samples and all seven stratigraphic layers.

5.8.2 Pulses and legumes

Three varieties of pulses and legumes have been identified (Table 5.8). The vetches may have been consumed by humans but they can also appear as grain contaminants or be used as a fodder crop. The lentils and vetch/pea were found both mineralized and carbonized while the vetch and broad beans were recovered only in carbonized form. All the pulses from the Cardo V sewer had low abundance and ubiquity levels. Lentil is by far the most common, found mineralized in six samples and three quadrants.

5.8.3 Nuts

Fragments from three nut taxa were recovered (Table 5.9). Hazelnut and pine nut were found mineralized and carbonized while walnut was preserved only through carbonization. At most Roman sites nuts are found carbonized and the presences of mineralized fragments attests to the quality of preservation within the sewer. Both pine cone bracts and nuts of stone pine were found, suggesting a possible use in ritual burnt offerings. Stone pine also had the highest abundance and ubiquity levels, followed closely by walnut.

5.8.4 Fruit

The fruits are taxonomically the most diverse and abundant category of foodstuffs found in the assemblage. There are 12 types recovered in a variety of preservational states and quantities. All of the fruit has been preserved through mineralization except for a pear seed which was recovered only in carbonized form (Table 5.10). Seeds of apple or pear and grape were found carbonized, mineralized and waterlogged (**Fig. 5.30**).

The abundance and ubiquity levels amongst the fruit remains varied enormously. The figs, olives and grapes were the most abundant and ubiquitous food items recovered from the sewer. They were followed closely by seeds of apple/pear, which were found in

11 samples, five quadrants and all seven stratigraphic layers. Black mulberry and blackberry had moderate levels of abundance and ubiquity. The other eight fruits were found intermittently throughout the samples.

5.8.5 Herbs and seasonings

In total there are nine taxa in this category (Table 5.11). The celery, dill, fennel, coriander and mint can be classified as herbs while the cabbage or mustard, black pepper and opium poppy are considered seasonings.[60] The flax/linseed seeds from the sample could have been used to flavour food but it is also possible that the plant was being harvested for its fibers.

All the items in this category, except for the celery, were preserved through mineralization. The celery seeds were preserved through mineralization and waterlogging. Within the herb category, mint had the highest ubiquity score, found in eight samples and five quadrants (**Fig. 5.31**). It was followed closely by celery and fennel. The most abundant herb was fennel with 20 seeds (**Fig. 5.32**). The other four herbs had on average nine seeds spread throughout the sewer. Opium poppy had the highest ubiquity and density level of the seasonings. Poppy seeds were recovered from 16 samples and all six quadrants and seven stratigraphic layers (**Fig. 5.33**). The black pepper and cabbage/mustard seeds were found in much lower concentrations, in only two and six samples, respectively (**Fig. 5.34**).

5.8.6 Other potential foodstuffs

Mallow has been placed in this category because it is unknown if it was intentionally consumed as a food item or if it was simply part of the weed flora that entered the sewer. Although carrots are edible, the carrot seeds probably entered the sewer unintentionally.

[60] Black pepper is actually a dried berry and hence a fruit, but as it is used solely to flavour food it has been placed in the herbs and seasonings category.

Once the plant has seeded the root is no longer edible. Carob and medick can be eaten by humans but they can also be used as fodder foods.

5.8.7 Weeds, ruderals and other plants

Weeds and ruderals are the largest category of botanical material with 36 taxa (Table 5.13). This group contains plants that grow in cultivated and uncultivated soils, pasture, scrubland and numerous other Mediterranean habitats (Pignatti 1982) (see section 8.3). The majority of the seeds are preserved through mineralization although some taxa can also be found in the carbonized and waterlogged assemblages. The common stinging nettle seeds are the most ubiquitous, followed closely by nettle, goosefoot and common chickweed (**Fig. 5.35**). The other taxa in this category have low to moderate abundance levels, generally containing fewer than 10 items per sample.

5.8.8 Ornamental plants

Only cypress and box can safely be placed in this category. It is possible that some of the taxa in the weed and ruderal plant category could also have been used as ornamental garden plants. However, there was no garden space within *Ins. Or*. II, and while they could have been planted elsewhere in Herculaneum, it is unlikely that they were present in the apartments above the sewer. The box stem was found mineralized while twigs of cypress were found both carbonized and mineralized (**Fig. 5.36**). The presence of cypress in both assemblages, within the sealed context of the sewer, suggests that it may have served three purposes: as an aromatic plant, a broom and as part of ritual burnt offerings (Mark Robinson Feb. 21, 2012, pers. comm.) (see section 6.2.1.1).

Table 5.7. Cereals

Taxonomic name	Common name	Mineralized	Carbonized
Hordeum sp.	Barley	-	3
Panicum miliaceum	Common millet	52	-
Panicum miliaceum or *Setaria italica*	Common or foxtail millet	196	1
Setaria italica	Foxtail millet	34	1
cf. *Sorghum* sp.	Sorghum	7	-
Triticum aestivum	Bread wheat	-	1
Triticum dicoccum	Emmer wheat	1	1
Triticum dicoccum or *Triticum monococcum*	Emmer or einkorn wheat	-	2
Triticum monococcum	Einkorn wheat	-	1
Triticum sp.	Wheat	-	1
Cereal grain	Cereal grain	3	3

Table 5.8. Pulses and legumes

Taxonomic name	Common name	Mineralized	Carbonized
Lens culinaris	Lentil	16	2
Vicia faba var. *minuta*	Broad bean	3	-
Vicia or *Lathyrus* sp.	Vetch or pea	1	3
Vicia sp.	Vetch	1	-

Table 5.9. Nuts

Taxonomic name	Common name	Mineralized	Carbonized
Corylus avellana	Hazelnut	2	1
Juglans regia	Walnut	-	6
Pinus pinea	Stone pine	1	8

Table 5.10. Fruit

Taxonomic name	Common name	Mineralized	Carbonized	Waterlogged
cf. *Celtis australis*	Mediterranean hackberry	1	-	-
Cucumis melo or *sativus*	Melon or cucumber	4	-	-
Ficus carica	Fig	*	12	-
Malus or *Pyrus* sp.	Apple or pear	33	3	3
Malus sp.	Apple	1	-	-
Morus nigra	Black mulberry	11	-	-
Olea europaea	Olive	19	666	-
Phoenix dactylifera	Date	1	1	-
Prunus avium or *cerasus*	Wild or dwarf cherry	3	-	-
Prunus domestica	Wild plum	4	-	-
Prunus sp.	Stone fruit	9	-	-
Pyrus sp.	Pear		1	-
Rubus fruticosus (agg)	Blackberry	12	-	3
Vitis vinifera	Grape	150	59	8

*Several thousand

Table 5.11. Herbs and seasonings

Taxonomic name	Common name	Mineralized	Waterlogged
cf. *Anethum graveolens*	Dill	5	-
Apium graveolens	Wild celery	47	1
Brassica sp.	Cabbage or mustard	41	-
Coriandrum sativum	Coriander	3	-
Foeniculum vulgare	Fennel	20	-
Linum usitatissimum	Flax/linseed	4	-
Mentha sp.	Mint	11	-
Papaver somniferum	Opium poppy	83	-
Piper nigrum	Black pepper	2	-

Table 5.12. Other potential foodstuffs

Taxonomic name	Common name	Mineralized	Waterlogged
Ceratonia siliqua	Carob – fodder?	1	-
Daucus carota	Wild carrot	-	5
Malva sp.	Mallow	26	-
Medicago sp.	Medick – fodder?	10	-

Table 5.13. Weeds, ruderals and others taxa

Taxonomic name	Common name	Mineralized	Carbonized	Waterlogged
Anagallis sp.	Pimpernel	2	-	-
Anthemis arvensis	Corn chamomile	12	-	-
Aphanes sp.	Parsley-piert	1	-	-
Apiaceae	Parsley family	138	1	7
Asteraceae	Daisy family	4	-	-
cf. *Avena* sp.	Wild oat	-	1	-
Boraginaceae	Borage family	2	-	-
Brassicaceae	Cabbage family	2	-	-
Carduus sp.	Thistle	2	-	-
Carex sp.	Sedge	21	-	-
Caryophyllaceae	Carnation family	99	-	-
cf. *Centaurea* sp.	Knapweed	1	-	-
Chara sp.	Green algae	1	-	-
Chenopodium album	Fat-hen	4	-	-
Chenopodium sp.	Goosefoot	53	2	-
Cyperaceae	Sedge family	2	-	-
Fabaceae	Legume family	3	-	-
Fumaria sp.	Fumitory	-	-	1
Lamiaceae	Mint	42	-	1
Linum sp.	Flax	2	-	-
Lithospermum arvense	Field gromwell	1	-	-
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot	1	-	-
Ornithopus sp.	Bird's foot	7	1	-
Papaver sp.	Poppy	22	-	-
Papaveraceae	Poppy family	1	-	-
cf. *Plantago* sp.	Plantain	1	-	-

Taxonomic name	Common name	Mineralized	Carbonized	Waterlogged
Poaceae	Wild grass	11	11	-
Polygonaceae	Knotweed family	35	-	-
Polygonum aviculare (agg)	Knotgrass	14	-	-
Polygonum sp.	Knotweed	25	-	-
Pteridium aquilinum (L.) Kuhn	Bracken	3	-	-
cf. *Ranunculus parviflorus*	Small-flowered buttercup	2	-	-
Ranunculus sp.	Buttercup	16	-	-
Ranunculus subgens. *Ranunculus*	Buttercup	4	-	-
Reseda sp.	Mignonette	52	-	-
cf. *Rubus* sp.	Bramble	2	-	-
Rumex acetosella agg.	Sheep's sorrel	3	-	-
Rumex sp.	Dock	8	1	-
Sambucus sp.	Elder	1	-	-
Scrophulariaceae	Figwort family	2	-	-
Sherardia arvensis	Field madder	21	-	-
Silene gallica	Small-flowered catchfly	10	-	-
Silene sp.	Campion	2	-	-
Stellaria media	Common chickweed	30	1	2
Stellaria sp.	Chickweed	2	-	-
Urtica dioica	Common stinging nettle	79	-	-
Urtica sp.	Nettle	56	-	-
Vicia ervilia	Bitter vetch	-	1	-
Viola sp. (subgen.) *Melanium*	Pansy	1	-	-

Table 5.14. Ornamental plants

Taxonomic Name	Common Name	Mineralized	Carbonized
Buxus sp.	Box	1	-
Cupressus sempervirens	Mediterranean cypress	7	5

5.9 Eggshell results

Based on the weight of the shells a total of 21.82 eggs were recovered with an average of 4.364 per quadrant (see Appendix F). Q3-4 had the largest number with 8.78 eggs while Q13-14 had the smallest with only 1.37. No shells were recovered from Q37-38.

The eggshell thickness measurements showed two distinct clusters (**Fig. 5.37**). All but two of the measured fragments had a thickness range between 0.25 mm and 0.35 mm with an average thickness of 0.3 mm (Fig. 5.38). The other two fragments (green bands) had thicknesses ranging from 0.52 mm and 0.6 mm with an average of 0.56 mm. This difference is significant enough to suggest that two different species of bird eggs were being consumed. The thinner band falls into the range of domestic chicken or duck as the eggs of these two species measure between 0.22-0.48 mm (Keepax 1981: 323; Boyer 1999: 330). Chicken bones were found in the sewer, making it the more probable species. The thicker specimens in the Herculaneum samples may have come from domestic goose as their shells are between 0.525-0.65 mm thick (Siddell 1993: 13).

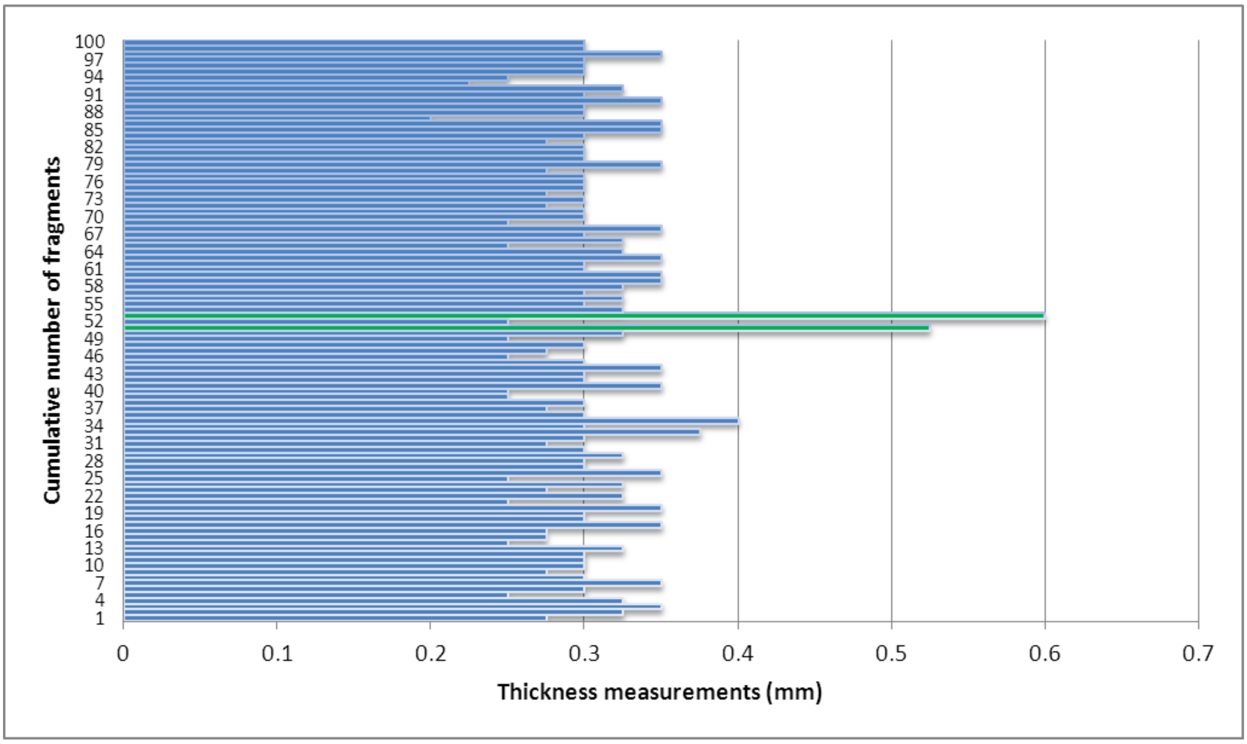


Figure 5.38. Thickness of 100 Cardo V eggshell fragments. Green bands indicate shell fragments with thicknesses outside the range of domestic fowl.

A study of the eggshell recovered from excavations at Roman and Medieval Leicester has produced similar results (Boyer 1999: 329-333). During these excavations over 2,200 fragments were obtained from the sieved material with 67% coming from the Roman context, 31.8% from the Medieval and 0.5% from the post-Medieval period. Thickness measurements were taken from 1514 Roman and 711 Medieval fragments. The majority of the Roman eggshells were between 0.25-0.3 mm. Using these measurements and SEM photographs Boyer (1999: 330) concluded that the samples came from domestic fowl with some of the thinner ones likely coming from domestic duck. Similar to the material from Herculaneum, a small proportion of the Roman shells from Leicester fell into a thicker band. Boyer (1999: 331-333) suggests that these fragments are from the eggs of geese or guinea fowl.[61]

5.10 Shellfish

A total of 53 categories were identified, including 38 to species, eight to genera, five to family, one taxa to order and one to subphylum (Table 5.15). There are 32 edible taxa, 19 inedible and two are unknown.

[61] It is unlikely that the thicker Herculaneum shells are from guinea fowl since they were considered an exotic item and would therefore have been very expensive (Dalby 2003: 169-170).

Table 5.15. Identified shellfish taxa from the Cardo V sewer

Taxonomic name	Common name	Edible (Y/N)	Presence*	Sum**	Max/sample**
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	Y	1	1	1
Acanthocardia tuberculata (L.)	Rough cockle	Y	4	4	1
Aequipecten opercularis (L.)	Queen scallop	Y	13	21	4
Arca noae (L.)	Noah's ark shell	Y	7	7	1
Bittium reticulatum (da C.)	Needle whelk	N	1	1	1
Bittium sp. (*tesselatum* (Mts.))	Horn snail	N	2	2	1
Bolinus brandaris (L.)	Purple dye murex	Y	11	14	3
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible cockle	Y	5	6	2
Cerithiidae indet.	Cerith	N	1	1	1
cf. *Cerithium* sp.	Cerith	N	1	1	1
Chamelea gallina (L.)	Striped venus	Y	4	4	1
Columbella rustica (L.)	Rustic dove-shell	N	2	2	1
Crustacea	Crustacean	Y	3	3	1
Diodora italica (Def.)	Limpet	Y	3	5	2
Donacilla cornea (Poli)	Corneous wedge clam	Y	19	255	58
Donax trunculus (L.)	Truncate donax	Y	6	12	3
Ensis minor (Che.)	Minor jackknife clam	Y	1	1	1
cf. *Eriphia verrucosa*	Warty crab	Y	1	1	1
Fusinus pulchellus (Phil.)	Spindle snail	N	1	1	1
Gibbula albida (Gmel.)	Whitish gibbula	N	3	3	2
Gibbula philberti (Récl.)	Top snail	N	1	2	2
Gibbula sp.	Top snail	Y/N?	3	3	1
Glycymeris sp.	Bittersweet clams	Y	5	5	1
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	Y/N?	2	2	1
Helicidae	Land snail	Y	19	39	5
Helix pomatia or *aspersa*	Edible or garden snail	Y	1	4	4
Hexaplex trunculus (L.)	Trunculus murex	Y	7	8	2
Lucinella divaricata (L.)	None	N	1	1	1
Modiolula phaseolina (Phi.)	None	N	1	1	1
Muricidae indet.	Murex family	Y	2	2	1
Mytilaster cf. *minimus* (Poli.)	Mussel	Y	6	57	36
Mytilidae indet.	Mussel	Y	4	4	1
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	Y	2	2	1
Nassarius cf. *costulatus* (Ren.)	Dog welk	N	1	1	1
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	N	1	2	2
Nassarius cf. *corniculum* (Olivi)	Horn nassa	N	1	1	1
Naticidae indet.	Moon shells	N	1	1	1
Ocenebra erinaceus (L.)	Hedgehog murex	Y	2	2	1
Ocinebrina aciculata (Lam.)	Sea snail	N	1	1	1
Ocinebrina edwardsii (Pay.)	Sea snail	N	1	1	1
Odostomia eulimoides (Han.)	Pyram	N	2	2	1
Ostrea edulis (L.)	Common/edible oyster	Y	3	4	2
Paracentrotus lividus (Lam.)	Purple sea urchin	Y	20	49	18
Patella sp.	Limpet	Y	14	86	23
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	Y	12	12	1
Polititapes aureus (Gmel.)	Golden carpet shell	Y	1	1	1
Sepia sp.	Cuttlefish	Y	2	1	1

Taxonomic name	Common name	Edible (Y/N)	Presence*	Sum**	Max/sample**
Spatangoida	Heart urchins	Y	1	1	1
Spondylus gaederopus (L.)	European thorny oyster	Y	1	1	1
Timoclea ovata (Pen.)	Oval venus	N	1	1	1
Tonna galea (L.)	Giant tun	Y	2	2	1
Turritella communis (Riss.)	Auger shell	N	2	2	1
Venerupis decussata (L.)	Chequered carpet shell	Y	7	10	3

* Out of 22 samples
** Based on MNI totals for all samples

5.10.1 Density

The shellfish have very low density levels, ranging from 6.5 to 1.6 shells per litre (Fig. 5.39). In some cases the shells are in fragmentary form and while there may be hundreds of fragments, the MNI remains small. This is especially true for the land snails, where there are frequently over 100 fragments per sample. However, not all the shells are fragmented and the density levels accurately reflect the moderate number of shells present in the sewer. Interestingly, higher density ratios do not appear to be associated with an increase in the number of taxa recovered from each quadrant. These results indicate that an increase in density levels corresponds to an increase in a limited number of taxa, primarily corneous wedge clam, limpets and purple sea urchin.

The shell remains do not follow the distribution patterns set by the mineralized and carbonized material whereby density increases as quadrant number decreases. Instead, the density of the shell material steadily increases from Q3-4, reaching a peak at Q23-24 and then descending sharply at Q49-50. As described in section 5.3.1, the decrease in slope at Q23-24 could have contributed to the buildup of material in this area (Fig. 4.7). Since shells are both larger and heavier than mineralized or carbonized material, it is possible that they did not move as easily down the length of the sewer.

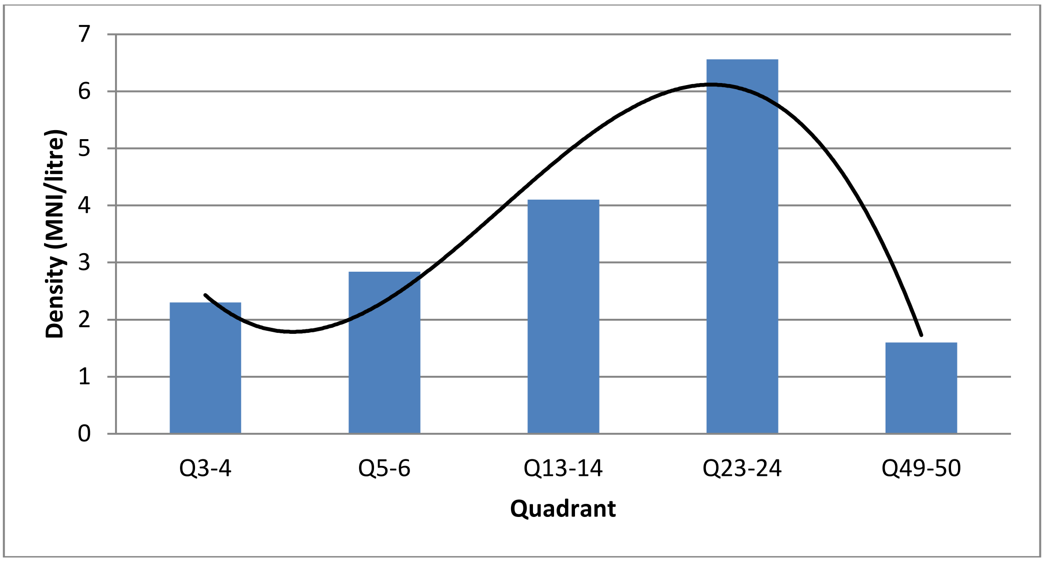


Figure 5.39. Density ratios of the shell material by quadrant in spatial order

5.10.2 Categories of abundance

The low quantity but high diversity of the shellfish meant that abundance levels were low. None of the taxa had over 100 items in a single sample and only 10% had over 10 items (Fig. 5.40). As one would expect, those with the highest abundance levels were generally the edible shellfish taxa such as limpets, clams and scallops.

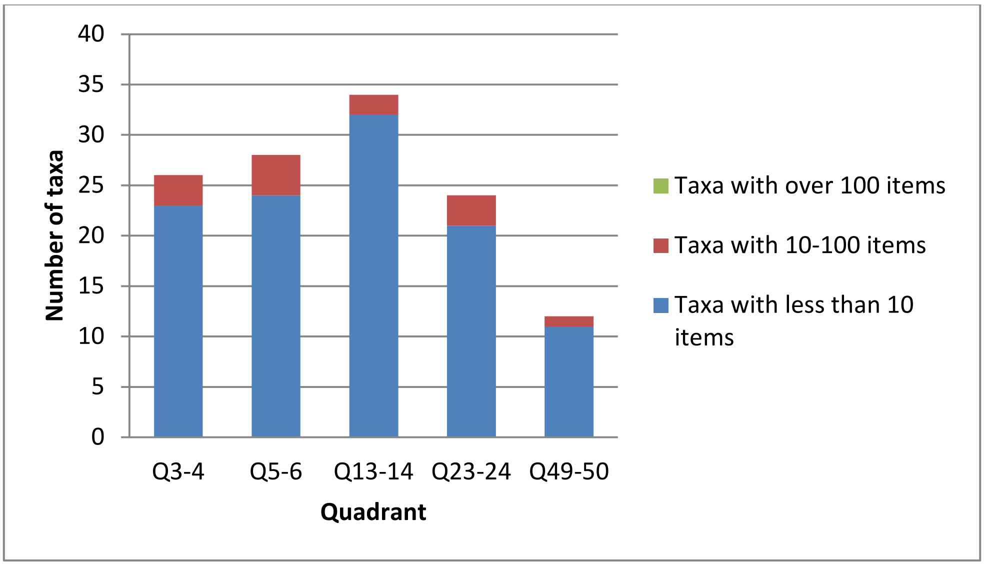


Figure 5.40. Abundance of the shell material within samples and grouped by quadrant

5.10.3 Ubiquity

The ubiquity scores followed the same patterns as the botanical material. The majority of the scores were moderate to low with 59% and 52% of the taxa found in multiple quadrants and stratigraphic layers respectively while only 32% were found in four or more of the 22 analysed samples (Figs. 5.41-5.43). Low sample scores frequently corresponded to low quadrant or stratum scores. The Noah's ark shells are the only exception, found in seven samples but only three quadrants.

The seven most ubiquitous items by quadrant and sample number were all edible. Four of these items, the purple sea urchin, land snails, corneous wedge shells and Pilgrim's scallop, were also recovered from all seven strata.[62] Combined with the density ratios, where an increase in density did not correspond to an increase in taxonomic diversity, these finding suggest that a small range of shellfish were consumed regularly by those living in the multiple apartments above the sewer.

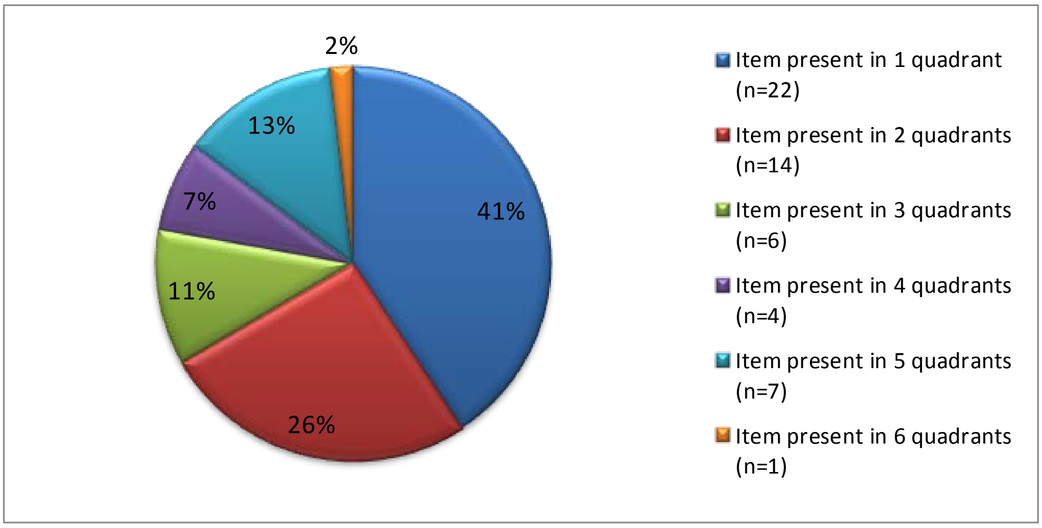


Figure 5.41. Shell ubiquity by quadrant

[62] The other three taxa were limpets, queen scallop and purple dye murex.

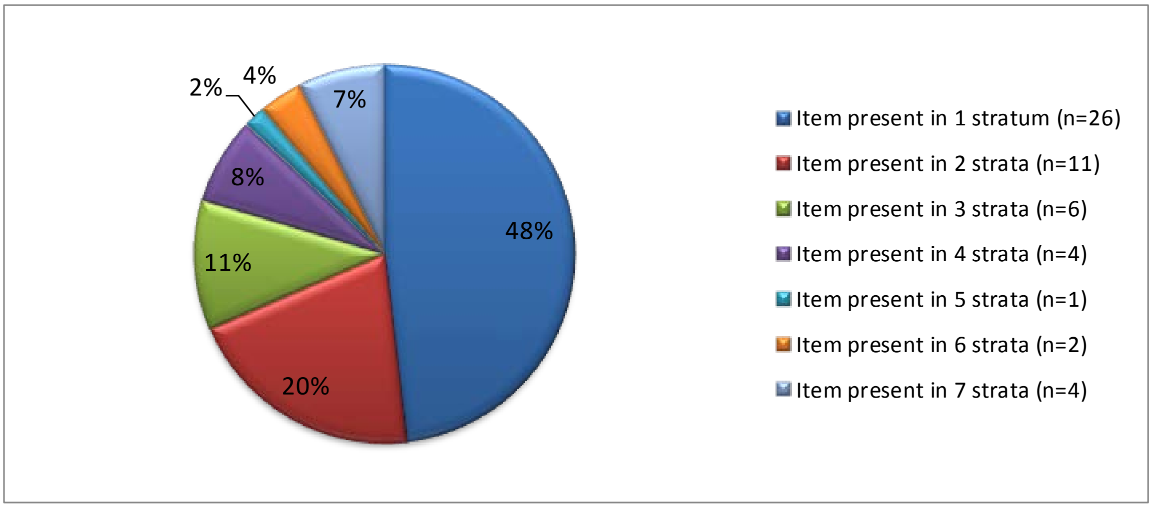


Figure 5.42. Shell ubiquity by stratigraphic layer

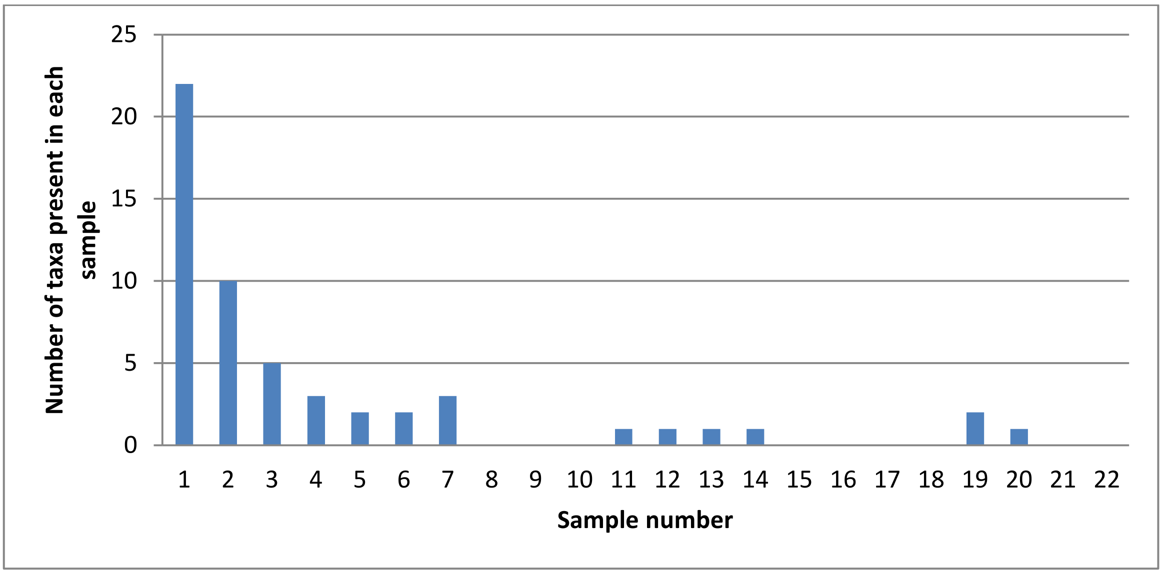


Figure 5.43. Shell ubiquity by sample

5.11 Fish bones

Rebecca Nicholson identified the fish bones from nine samples, representing four quadrants and six strata (Table 5.16). There were 31 taxa within the samples with 12 identifiable to species, seven to genus, nine to family, one to order and two to subclass (Table 5.18). The bones were generally from small or juvenile fish and many showed signs of having been chewed and partially digested. Q49-50, US42 has a larger proportion of burnt bones than the other samples, which may suggest ritual burning or cooking. Finally, the number of bones per species and calculations of MNI were not recorded as there was only time for a quick scan of the remains. Thus density and abundance calculations were not possible.

Table 5.16. Identified fish bone and otolith samples. Bold numbers indicate samples where only the otoliths were identified.

Stratigraphic layer	Quadrant				
38	3-4		**13-14**	**23-24**	
39	3-4		13-14		**49-50**
40	3-4	5-6	13-14	23-24	
41	3-4				
42					49-50
43					
52					49-50

5.11.1 Ubiquity of the fish bones

Although the samples represent only a portion of the total volume of fish bones present in the sewer, it was possible to calculate ubiquity scores based on quadrants, strata and samples. The majority of the taxa (61%) were found in multiple quadrants (Fig. 5.44).

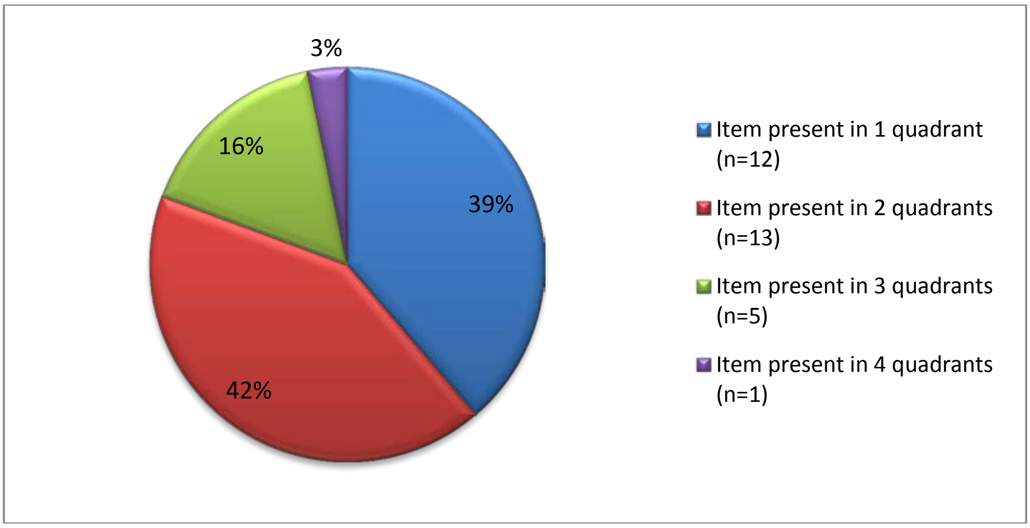


Figure 5.44. Fish bone ubiquity by quadrant

Moreover, the fish assemblage had higher overall scores than the botanical material with regards to ubiquity by strata (Fig. 5.45, compare with figs. 5.25 and 5.27). Twenty-one of the 32 fish taxa were recovered from multiple stratigraphic layers. Together, the quadrant and strata scores suggest that fish were eaten by multiple inhabitants living along the length of *Ins. Or.* II for the length of time it required the biological assemblage to accumulate. The ubiquity sample scores help to refine this picture (Fig. 5.46). None of the taxa were found in all nine samples and only five taxa were recovered from more than half the samples. Thus while fish in general were eaten widely over space and time, it appears that only a narrow range of taxa, those appearing in over half the samples, notably sea breams, horse mackerel and anchovies, were consumed on a regular basis.

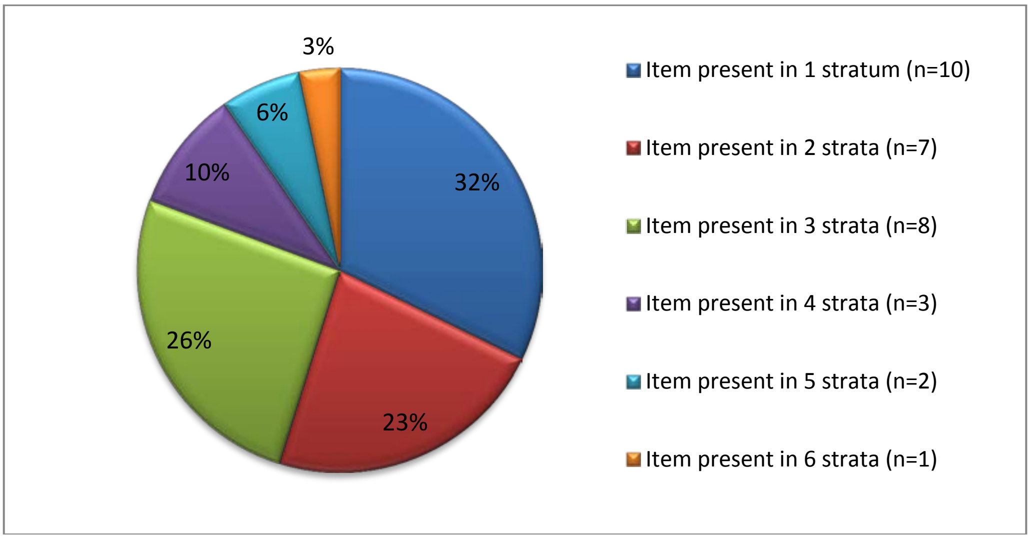


Figure 5.45. Fish bone ubiquity by stratigraphic layer

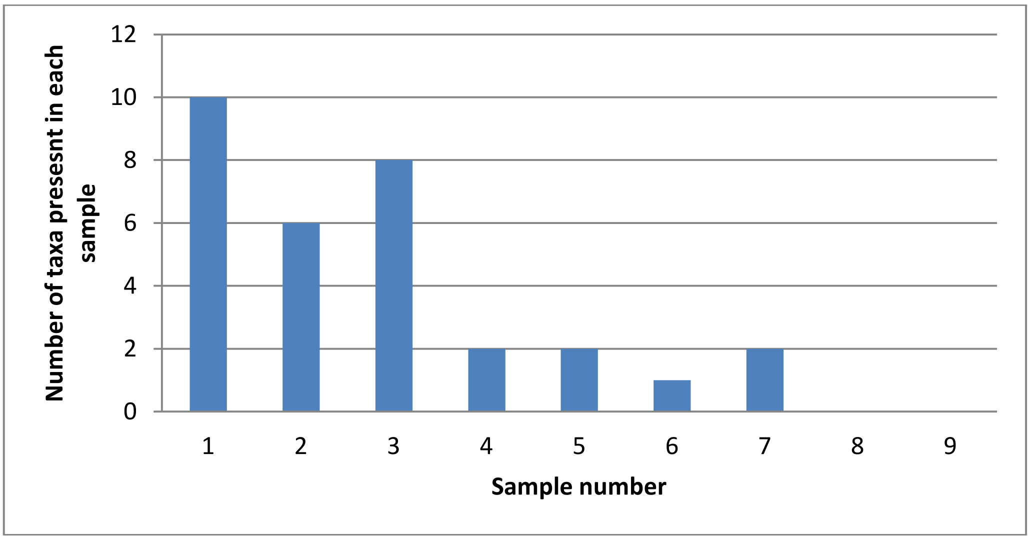


Figure 5.46. Fish bone ubiquity by sample

5.12 Fish otoliths

In total, 338 whole and 183 fragmentary otoliths were recovered from 13 samples, representing five quadrants (Table 5.16). Q37-38 did not contain any otoliths. Using the Leica EZ4D microscope, 87 otoliths were photographed and 76 were identified using the AFORO database. By comparing those 76 otoliths with the remaining whole ones in the samples, a further 94 specimens were identified (Table 5.17).[63] This method has produced a total of 170 identified otoliths or 56% of the total number recovered. Overall, 23 taxa were identified including 13 to species, six to genus, three to family and one to order (Table 5.18).

Table 5.17. Otolith counts

Total number of whole otoliths	338
Total number of fragmentary otoliths	183
Number of otoliths photographed	87
Number of otoliths identified using AFORO	76
Number of photographed otoliths that could not be identified using AFORO	11
Total number of identified otoliths	170
Total number of unidentified otoliths	134

[63] In the interest of time, the whole otoliths from Q5-6 were not compared to those identified by the database. As only one otolith from Q5-6 was unique for the sampled material, Q5-6 has been left out of further calculations.

Table 5.18. Identified fish and otolith taxa from the Cardo V sewer

Taxonomic name	Common name	Presence (bones)*	Presence (otoliths)**	Sum (MNI/raw count)^	Max/sample^^
Anguilla anguilla L.	European eel	4	--	--	--
Anguillidae/ Congridae	Eels	3	--	--	--
Belone belone L.	Garfish	3	--	--	--
Boops boops L.	Bogue	3	4	4/5	2
Chromis chromis L.	Damsel fish	--	4	17/20	9
Clupeidae	Herring/sardines	6	--	--	--
Conger conger L.	European conger eel	4	--	--	--
Dicentrarchus labrax L.	European seabass	3	--	--	--
Diplodus sp.	Sea bream	1	4	5/5	2
Elasmobranch	Sharks and rays	3	N/A	--	--
Elasmobranch	Dog fish	2	N/A	--	--
Engraulis encrasicholus L.	European anchovy	6	2	3/4	3
Gadidae	Gadids	3	2	2/2	1
Labridae	Wrasses	2	--	--	--
cf. *Labrus mixtus* L.	Cuckoo wrasse	1	--	--	--
Merluccius merluccius L.	Hake	2	1	1/1	1
Mugilidae	Mullets	3	--	--	--
cf. *Mullus* sp.	Goatfish	1	--	--	--
cf. *Muraena helena* L.	Mediterranean moray eel	1	--	--	--
Pagellus bogaraveo Brunnich	Red sea bream	--	2	4/4	3
Pagellus erythrinus L.	Common pandora	--	2	2/2	1
Pagellus sp.	Pandora	--	5	15/19	13
Pagrus pagrus L.	Red porgy	--	1	1/1	1
cf. Percidae	Perch	1	--	--	--
Pleuronectiformes	Flatfishes	5	1	1/1	
Rajidae	Skates	1	N/A	--	--
Sardina pilchardus Walbaum	European pilchard	1	--	--	--
cf. *Sardinella* sp.	Sardinella	1	--	--	--
cf. Sciaenidae	Drums	--	1	1/1	1
Scomber sp.	Mackerel	2	--	--	--
Scophthalmidae	Left-sided flatfish	--	1	1/1	
Sparidae	Sea breams	7	6	46/66	29
cf. *Sparus* sp.	Sea bream	2	--	--	--
cf. *Spicara maena* L.	Blotched picarel	3	--	--	--
Spicara sp.	Picarel	--	5	8/11	3
Spondyliosoma cantharus L.	Black sea bream	--	4	7/8	5
Trachinus draco L.	Greater weever	--	4	6/8	3
Trachinus sp.	Weevers	1	--	--	--
cf. *Trachurus mediterraneus* Steindachner	Mediterranean horse mackerel	--	1	1/1	1
Trachurus trachurus L.	Horse mackerel	7	1	1/2	2
Trachurus sp.	Mackerel	--	1	1/1	1
Triglidae	Gurnards	2	--	--	--
Trisopterus luscus L.	Pouting	--	3	5/5	2
Trisopterus sp.	Pout	1	1	1/1	1
cf. *Xyrichtys novacula* L.	Pearly razorfish	--	1	1/1	1

*Out of 9 samples
**Out of 13 samples
^Based only on the otoliths, totals for all sample
^^ Based on otolith raw counts (not MNI)

5.12.1 Analysis of the otoliths by quadrant

Quadrant 3-4

This quadrant contained 12 different taxa, represented by 21 fish. It is the second largest quadrant in terms of total number of taxa and otoliths (Fig. 5.47). The black sea bream and the damsel fish are the most common species having MNIs of five and four respectively.

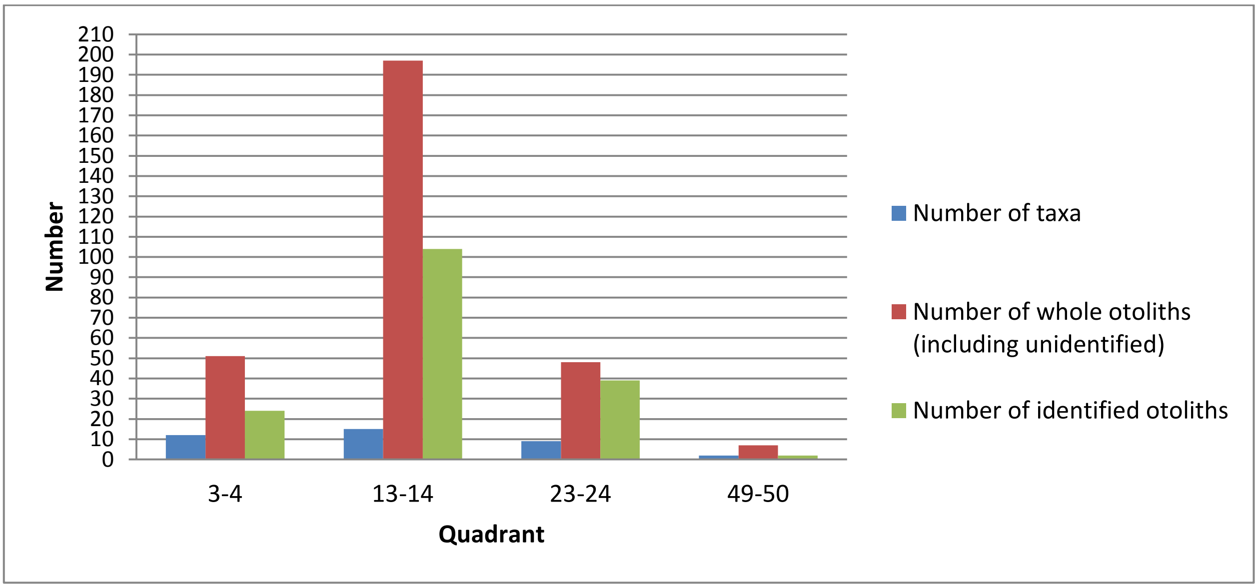


Figure 5.47. The number of otolith taxa and specimens

Quadrant 5-6

Despite its downstream location, Q5-6 contained relatively few otoliths.[64] Unlike the large quantities of mineralized and carbonized material from this quadrant, only 35 whole and 16 otolith fragments were recovered, making it the second smallest quadrant for otolith finds. The low number of otoliths may be due to the varying preservation conditions in the sewer or simply a reflection of this small and light material shifting downstream.

[64] This quadrant is not featured in figs. 5.46-5.47 because only 1 otolith was identified using the AFORO database.

Quadrant 13-14

Q13-14 had the largest number of otoliths as well as the greatest amount of taxonomic diversity (Fig. 5.48). The assemblage is dominated by fish from the Sparidae family as well as pandora and damsel fish. Considering the results of Q3-4 and Q5-6, it is possible that the large number of otoliths in this quadrant is simply the result of chance movement of the sewer material. However, it contains almost twice the number of otoliths as Q3-4 and therefore almost four times the number of fish. Q13-14 is located only six quadrants away from upper floor latrine shaft B7 and it is possible that the inhabitants of the potentially large apartment at *Ins. Or*. II.7 were consuming more fish than the other residents of the insula (Fig. 4.7). The presence of roof drainage shaft B8, three quadrants north of Q13-14 may have helped to push the otoliths farther down the sewer.

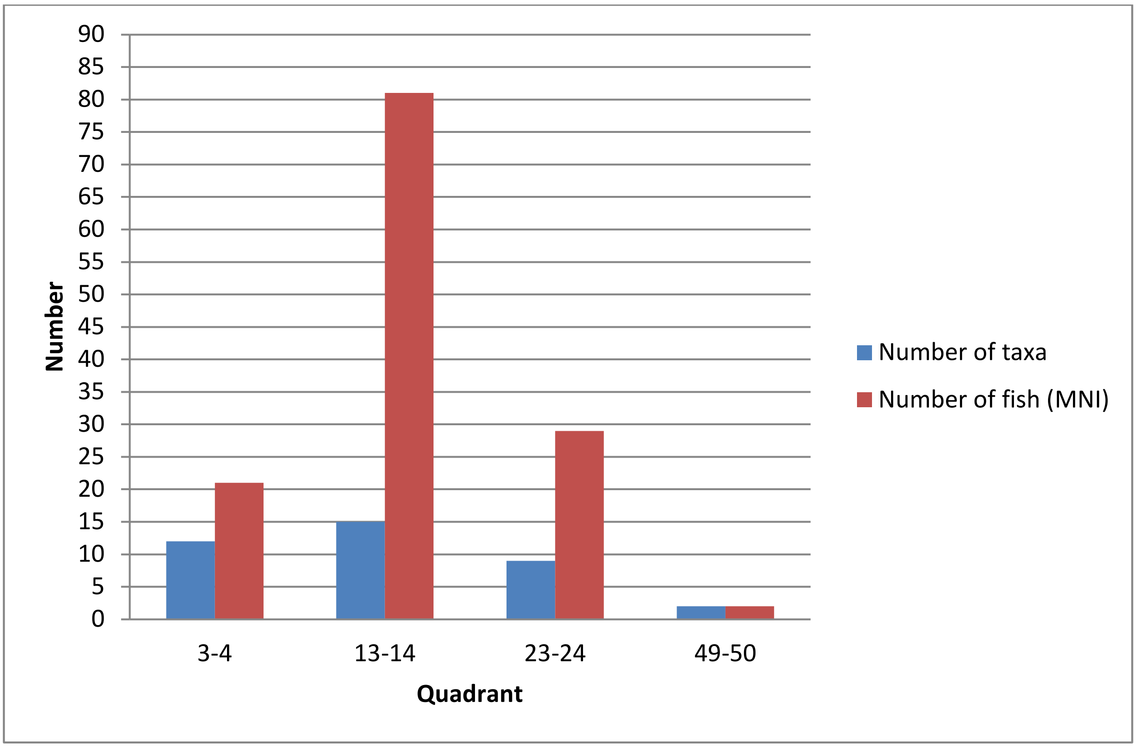


Figure 5.48. Number of taxa compared to the number of fish (based on MNI)

Quadrant 23-24

The quadrant produced an MNI of 29 fish but only nine taxa, suggesting a high level of consumption but with little variety. Similar to Q13-14, the assemblage was dominated by fish from the Sparide family. The otoliths in this quadrant were extremely well preserved, enabling the author to identify 81% of the specimens. This number is far higher than the overall average of 56% (Fig. 5.49).

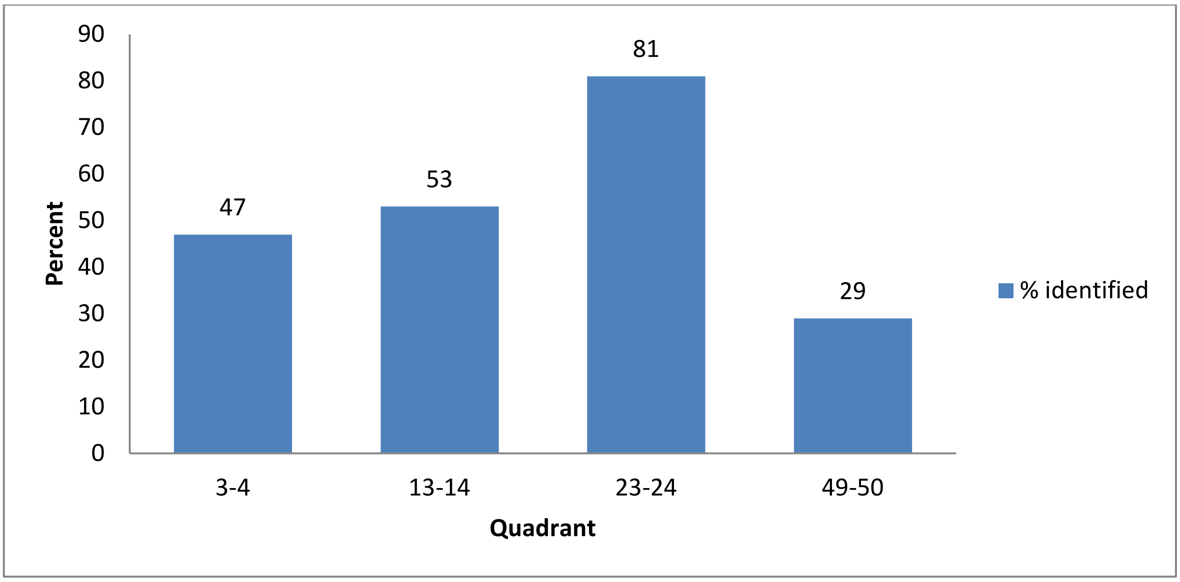


Figure 5.49. The percentage of otoliths identified relative to the whole number of otoliths in each quadrant

Quadrant 49-50

This quadrant contained only seven otoliths in total. Two were identifiable, each from different taxa. The steady decrease in the number of otoliths from this quadrant to Q23-24 reflects the general pattern of low quantity and variety of material in the northern quadrants of the sewer.

5.12.2 Overall trends in the fish otoliths

Sea breams were both the most common and taxonomically diverse family of fish recovered from the sewer. In addition to those that could only be identified to family, the sea bream otoliths are represented by five species and one genus (Table 5.19). Combined, the Sparidae otoliths produced an MNI of 84 fish which comprised 63% of the total MNI. The second largest family, with an MNI of only 17 are the Pomacentridae or damselfish and are represented solely by the species *Chromis chromis*. The remaining nine families had MNIs of less than ten.

Table 5.19. Identified otoliths by family

Family	**Identified otoliths**
Carangidae	cf. *Trachurus mediterraneus*
	Trachurus sp.
	Trachurus trachurus
Centracanthidae	*Spicara* sp
Engraulidae	*Engraulis encrasicholus*
Gadidae	Gadidae
	Trisopterus luscus
	Trisopterus sp.
Labridae	cf. *Xyrichthys novacula*
Merlucciidae	*Merluccius merluccius*
Pleuronectiformes**	Pleuronectiform
Pomacentridae	*Chromis chromis*
Sciaenidae	cf. Scianidae
Scopthalmidae	Scopthalmidae
Sparidae	*Boops boops*
	Diplodus sp.
	Pagellus bogaraveo
	Pagellus erythrinus
	Pagellus pagrus
	Pagellus sp.
	Sparidae
	cf. Sparidae
	Spondyliosoma cantharus
Trachinidae	*Trachinus draco*

** The Pleuronectiforms are an order

5.12.3 Ubiquity of the fish otoliths

The otoliths had moderate to low ubiquity scores. The scores for the quadrants are similar to those found in the carbonized and mineralized material with 48% found in a single quadrant (Fig. 5.50). Only the Sparidae were found in all four study quadrants.

The ubiquity scores based on sample number were unexpectedly low (Fig. 5.51). Although just over half of the 23 identified taxa were found in multiple samples, no taxon was present in more than six of the twelve analysed samples. The Sparidae again were the most ubiquitous and they were the only taxa found in half the samples. The ubiquity scores for the stratigraphic layers follow a similar pattern with the majority of the otoliths found only in three of the seven strata (Fig. 5.52). As expected, it was US38, the largest and longest stratum, that contained the most otoliths. The localized strata, US41, 42 and 52, combined, produced only four identifiable specimens. Nevertheless, the excellent state of preservation of the otoliths, within five of the six studied quadrants and three of the seven strata, spanning the length of the sewer, argues against a hypothesis of differing preservation rates. When these moderate to low ubiquity scores are combined with the ubiquity scores from the fish bones, the results seem to suggest that only certain species (those with high ubiquity scores) were consumed on a regular basis by those living in *Ins. Or*. II. The limited presence of many of the species was probably due to cost restrictions, seasonality and availability (See section 8.4).

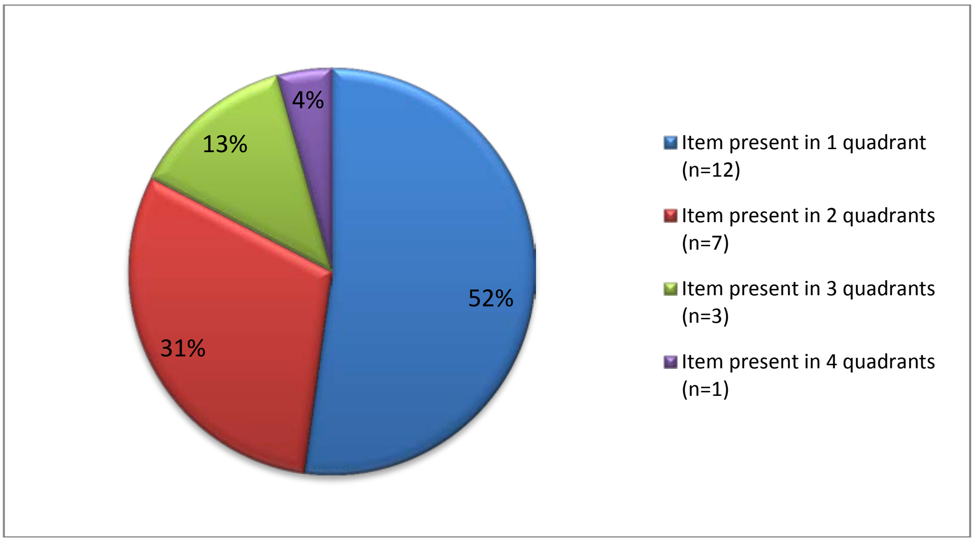


Figure 5.50. Otolith ubiquity by quadrant

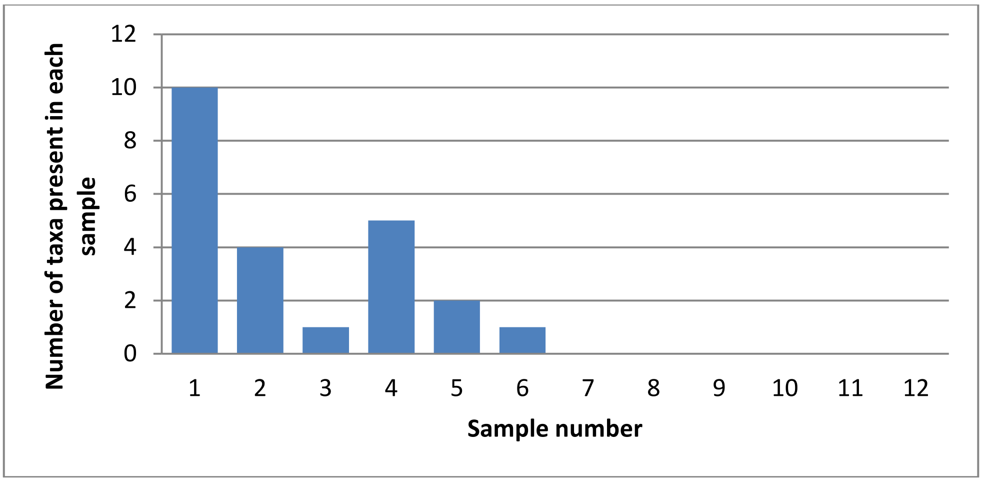


Figure 5.51. Otolith ubiquity by sample

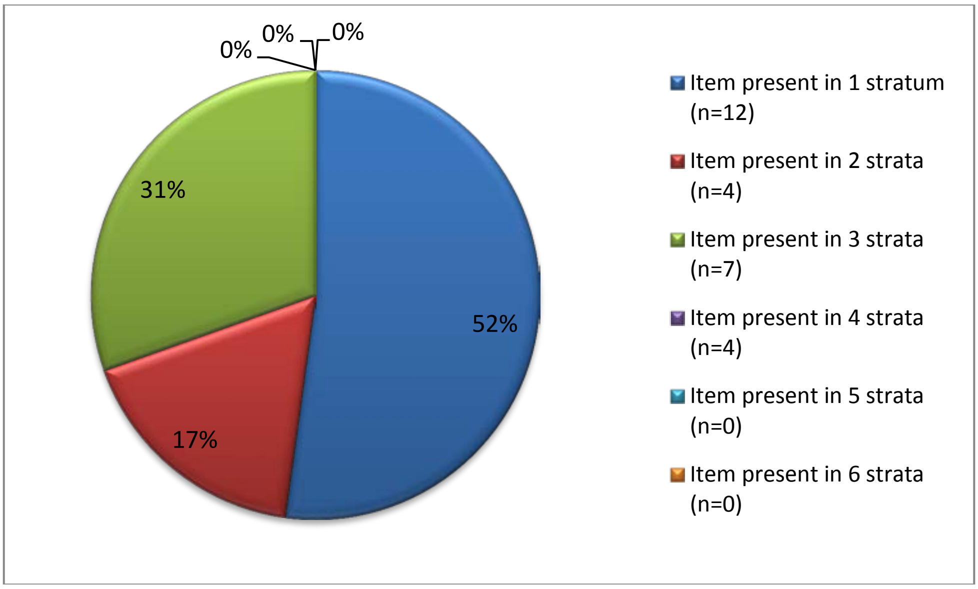


Figure 5.52. Otolith ubiquity by stratigraphic layer

5.13 Comparison of the fish bones and otoliths

The identifications from the otoliths and fish bones from six strata and five quadrants produced a total of 45 taxa. There are 14 taxa unique to the otoliths, 23 unique to the fish bones and nine taxa that are found both as otoliths and fish bones (Tables 5.18 and 5.20). The nine overlapping taxa were those that could either be identified only to family or were particularly ubiquitous in the sewer. The low number of overlapping taxa demonstrates the benefits of using both data sets in conjunction with one another. Sea breams are notoriously difficult to identify to species using the bones and subsequently only three sea breams species could be identified in this way. Five Sparidae species were identified using the otoliths. It should be noted that all the taxa identified through the fish bones are present in the AFORO database and therefore the absence of their otoliths in the sewer is a true absence and not the result of inaccurate database results. A full analysis of the taphonomic processes leading to the preservation of both bones and otoliths can be found in section 6.1.4.

Table 5.20. Number of taxa identified by the otoliths and fish bones

Number of otolith taxa	23
Number of taxa unique to the otoliths	14
Number of taxa from the fish bones	32
Number of taxa unique to the fish bones	23
Taxa found as both otoliths and fish bones	9
Total number of fish taxa	45

5.14 Mineralized invertebrates

The mineralized invertebrates from Q3-4, US38 were identified by Mark Robinson (Table 5.21). Dipterous pupae and puparia, especially the pupae of the trickling filter fly, were by far the most common type of invertebrate found (**Fig. 5.53**). These were followed by woodlice and millipedes respectively (**Fig. 5.54**). As invertebrates do not feature as a main component of this thesis, only a finds list is provided here. No analysis has been performed as the identified material is only from a single sample, Q3-4, US38.

Table 5.21. Mineralized invertebrates

Taxonomic Name	**Common Name**
Diplopoda (undetermined)	Millipede
Diptera (undetermined) (puparia)	Fly
Fannia sp. (puparium)	Latrine fly
Isopoda (undetermined)	Woodlice
Psychoda alternata Say. (pupae)	Trickling filter fly
Rhizophagidae (undetermined)	Beetle
cf. Sphaeroceridae (puparia)	Sewage fly
Thoracochaeta sp. (puparia)	Seaweed fly

5.15 Conclusions concerning the Herculaneum assemblage

The sewer contains a vast array of botanical and faunal remains and some overall statements can be made about the assemblage. Firstly, the SACs have demonstrated that a sufficient amount of material has been examined to begin an assessment of the nutritional composition of the diet of those living above the sewer. This does not mean that all the taxa have been found, simply that it would require a significant amount of additional sampling to locate and identify new species.

The density ratios for the botanical material indicate a horizontal downwards shift in material with specific areas of buildup along the length of the sewer, particularly at Q5-6 and Q23-24. The comparisons of the mineralized and carbonized assemblages suggest that the larger but lighter carbonized remains moved farther along the sewer than the mineralized material. This difference in movment is probably due to the fact that the majority of the mineralized material first entered the sewer as unmineralized seeds trapped inside human faecal matter. Consequently, even after mineralization, the seeds were not directly on the surface and could not easily move downstream even when water was added. The majority of the carbonized material, on the other hand, entered the sewer as loose material produced during cooking and heating. Since the material was not encased, and carbonized material floats, the burnt remains were free to move down the tunnel, especially when there was a sufficient amount of water.

The fish and shellfish material underwent the least amount of movement no doubt due to their size and weight. The minimal amount of all types of bioarchaeological material recovered from Q49-50 and Q37-38 indicates that, although moving slowly, all the material did experience a shift towards the southern end of the tunnel. Thus we cannot associate the material from a particular quadrant with the latrine shaft or apartment above and the Cardo V assemblage must be considered a single context.

The identified taxa have displayed a remarkable level of consistency in terms of diversity, abundance and ubiquity. While all the forms of bioarchaeological material recovered from the sewer displayed a wide range of taxonomic diversity, the overall ubiquity and abundance levels were moderate to low. Items with high ubiquity levels were often found in multiple quadrants and strata and therefore were dispersed throughout the tunnel. These results suggest that preservation conditions within the sewer were consistent across its entire length. Mineralization was able to take place at all points along the length of the tunnel. If conditions had been vastly different at the northern or southern end, then we would expect to find significant differences in the ubiquity and abundance levels, particularly when looking at the quadrants.

The confirmation of stable preservation conditions means that differences in ubiquity, abundance and density scores represent true differences in the consumption and use/deposition of material; that the differences are not due entirely to the effects of taphonomy. Consequently, we can use these results to better understand the diets of those living in *Ins. Or.* II. By analysing quadrants, strata and samples, individually and together, it has been possible to obtain a view of the composition of the sewer contents across space and time. Those taxa with high ubiquity and abundance scores in the quadrants and strata were probably the most widely consumed goods. Taxa found in fewer quadrants, strata or samples were probably consumed less frequently while those with extremely low scores represent rare or unintentionally consumed items. There are a very limited number of taxa within each bioarchaeological category with high ubiquity and abundance levels which suggests that the diet of those living in *Ins. Or.* II consisted of a few staple foods but supplemented on a frequent basis by numerous other foodstuffs. The consistency within both the ubiquity and abundance scores, across the length and depth of the sewer, suggests that this was the diet for the majority of the inhabitants of *Ins. Or.* II in the decade prior to the eruption. In other words, most people ate the same things and there was little change over time. It is the consistency of the preservation conditions, combined with the ubiquity scores for the non-staple foodstuffs that enable us to detect differences in diet (although not differences between specific apartments), probably due to differences in wealth. As shown in section 5.12.3 the ubiquity scores for the fish taxa were not consistent throughout the quadrants and even taking into account the downward shift in material, the decrease in taxonomic diversity north of Q23-24, indicates that not everyone consumed the same range of fish.

Understanding the nature of the assemblage, both spatially and chronologically, has been crucial in establishing the parameters that will shape the examination of the material presented in the following chapters. The outline of the *Ins. Or.* II diet has only been cursorily presented here. The following chapter examines in detail the impact that preservation methods and formation processes had on shaping this assemblage and consequently our ability to understand diet and nutrition in ancient Herculaneum.

Chapter 6: Preservation and formation of the Cardo V assemblage

The following four chapters will build upon the information already presented in this thesis. The previous chapters focused on background information concerning bioarchaeology, archaeobotany, Herculaneum, and the contents of the Cardo V sewer. The focus will now shift to an in-depth analysis of the Cardo V material, looking in detail at this botanical and faunal assemblage from environmental, social and nutritional perspectives.

The structure of this chapter, the first of the analysis chapters, is similar to that of chapter 3. It begins with a discussion of the preservation processes that enabled the Cardo V material to survive in the archaeological record. There will then be a large section on the formation of the botanical and faunal assemblages, examining the items from the time they entered the insula to the time they were deposited and (in the case of mineralization) became preserved in the sewer. Aspects of plant processing and food consumption practices taking place in *Ins. Or.* II will also be discussed. How were people preparing and cooking their food? Is there evidence for ritual burnt offerings? The chapter will conclude with a comparison between the Cardo V assemblage and archaeobotanical material recovered from Pompeii. Since the sewer contains the only sewage material from Herculaneum, the comparison will serve to highlight differences in patterns of food consumption and assemblage formation as well as identify potential sources of preservation bias.

6.1 Preservation of the botanical material

The processes involved in the preservation of the botanical material recovered from the sewer are relatively straightforward and do not deviate from the usual methods of preservation discussed in chapter 3.

6.1.1 Carbonized material

The carbonized assemblage was created when plants were exposed to heat and fire within the insula. The assemblage follows the patterns found in charred remains from other sites in that it is dominated by staple foods, fruit stones and nut shells (Table 5.4, figs. 6.1-6.2). The one exception is the almost complete absence of cereal grains and this will be discussed in section 6.2.1.2.

6.1.2 Mineralized material

It is clear from the diversity of the assemblage, 84 taxa, that the sewer contained the ideal chemical conditions required for mineralization (Table 5.2, fig. 6.3). The human faecal matter provided the necessary phosphate ions while calcium carbonate was derived from the wide variety of faunal material including seashells and eggshells (Fig. 6.4). Additionally, mammal and fish bones acted as sources of both phosphate and calcium (Green 1979: 281). Small fragments of mortar and lime, which were used in construction and wall plaster respectively, are frequently found in the sewer samples and would have provided additional calcium (Robinson 2006: 214). Water came from cooking, urine, flushing of the upper floor latrine pipes and the three small rooftop rainwater drains.[65]

In association with the chemical requirements, Herculaneum's geographical position combined with the structure of the sewer created a favourable environment for

[65] In his study of latrines in Pompeii, Hobson found that niche toilets on upper floors required flushing to keep the pipes clear (Hobson 2009: 25).

mineralization. The decay of human faecal matter, in addition to Herculaneum's location in the Mediterranean climatic zone, would have ensured a constantly warm to high temperature in the sewer. The downward slope of the channel and multiple entry shafts guaranteed the movement of waste water throughout its entire length. The water carried the phosphate and calcium ions throughout the sewer, facilitating their movement into the cells of the seeds. The continuous burial of the material by the addition of more sewage created the necessary oxygen poor environment (Kenward and Hall 2000: 523). Since there had been no recent cleaning of the sewer before the eruption, the material was kept in a stable environment (Camardo 2007: 181). Its burial during the eruption made certain that it remained in an undisturbed state. Once the sewer was sealed the mineralization process slowed. Although phosphate and calcium were still present, the movement of the water that dissolved and transported the ions would have ceased.

6.1.2.1 Mineralized invertebrates in the Herculaneum sewer

The decaying waste in the sewer created a suitable environment for many invertebrate species to live and reproduce. The mineralization of their pupae and bodies occurred using the same sources of calcium and phosphate required for botanical mineralization. Consequently, the Herculaneum material is extremely similar to mineralized invertebrate assemblages found in latrines from other Roman sites such as Silchester (Robinson 2006: 213).

6.1.3 Waterlogged material

The discovery of waterlogged material in the Cardo V sewer was unexpected, especially as the presence of mineralized material presumably indicates the absence of waterlogging (Figs. 6.5-6.6). In addition, the slope of the sewer was designed specifically to drain water away toward the sea and prevent it from building up. There must have been small pockets that were wetter than others, perhaps due to the flushing of a latrine or dumping of cooking water, just before the eruption. The drying and wetting of material when new water was added probably explains why only robust seeds were found waterlogged and not the more delicate parts of plants. When the sewer was sealed by the pyroclastic flows there was little opportunity for water evaporation and the material in the sewer was still damp when it was excavated in 2007 (Mark Robinson Oct. 1, 2010, pers. comm.). The botanical material in the wetter areas was then subjected to anoxic conditions that hindered both bacterial action and mineralization. Thus, while the waterlogged material from the sewer underwent waterlogged preservation in a typical manner, the actual conditions surrounding the formation of submerged areas were unusual.

6.1.4 Faunal material

The faunal material in the sewer, the bones, seashells and eggshell, survived in an unaltered state due to the chemical conditions within the sewer (Figs. 6.7-6.8). The calcium carbonate and calcium phosphate within this large faunal assemblage contributed to its own preservation by ensuring that the sewer maintained a slightly alkaline pH, preventing biogenic degradation. The circulation of waste water helped facilitate the movement of the calcium carbonate.

6.1.4.1 Fish otoliths and scales

The survival of such a large quantity of well-preserved otoliths is an extremely rare occurrence in Roman archaeology. It is clear that the taphonomic conditions within the sewer were ideal for the preservation of this delicate material (Fig. 6.9). As stated above, the pH of the biological material in the sewer was alkaline. Water and human urine would have been the primary sources of liquid. Pure water has a pH of 7 and it can be presumed that the water entering the sewer had a pH very close to 7. Normal human urine has a pH range of 4.5 to 7.8 with an average value of 6, making it only very mildly acidic (Clarkson *et al*. 2010: 34). The numerous sources of calcium carbonate, including eggshell, seashell and fish bones would have helped to maintain the alkalinity of the material by counteracting any acidity in the urine and acidity produced by the decay of faecal material. However the conditions were still too harsh for the preservation of fish scales as very few were recovered.[66]

6.2 Formation processes

The entire assemblage of the Cardo V sewer, including the organic and non-organic material, represents the refuse generated by those who lived, worked and visited the shops and apartments of *Ins. Or.* II between AD69-79. The large quantities of artefacts, including glass, ceramics, lamps, gems and even building materials, indicate that the sewer was treated not only as a cess pit, but also as a place to discard broken or unwanted items (HCP 2008). While it would be going too far to say that the assemblage represents a perfect snapshot of daily life in Herculaneum, it does, for the most part, consist of objects and foods that were probably used on a daily basis. Consequently, we know that the formation of the assemblage is related to a few specific activities such as food preparation and cooking, and is not the result of either the eruption or a few special events such as religious feasts or festivals. The goal of this section is to work backwards; beginning with the refuse and then, by examining the formation processes of the bioarchaeological assemblages, understand how the material was used and the refuse generated. Once the various uses of

[66] The presence of otoliths but absence of fish scales from the sewer is opposite to the Pompeian AAPP assemblages where fish scales are present but otoliths are absent (Andrew Jones March 23, 2011, pers. comm.). The reasons for this difference remain unknown since one would expect fish scales to be present in the sewer considering the high level of preservation.

the remains are understood, it is possible to begin to look at overarching patterns with regards to subjects such as diet, health and social status (chapters 7 and 8).

6.2.1 Formation of the carbonized assemblage

The carbonized assemblage comprises primarily olive stones, pulses, nut shells, fruit stones, weed seeds and charcoal, although charcoal will not be discussed in this thesis. Firstly, the location and approximate time of carbonization can be discerned from the presence and absence of particular items. The presence of carbonized and mineralized plant remains in the sewer signifies that the carbonized material was charred before the eruption. In Sigurdson and Carey's (2002: 54-55) analysis of the AD79 eruption, carbonized and non-carbonized wood was found in the same stratigraphic layer at Herculaneum. They concluded that the first pyroclastic flow to hit the town was not hot enough to cause the full carbonization of exposed organic material. However, this flow did deposit 1.5 m of ash on the town. The ash would have entered the sewer through both the upstairs and ground floor latrine shafts, covering and protecting the sewer contents from the later, hotter pyroclastic flows that hit Herculaneum (Sigurdson and Carey 2002: 55). If the sewer contents had been carbonized during the eruption a larger percentage of the sewer material would be carbonized and much of the mineralized material would not have survived. However, the sewer did contain large quantities of mineralized material and thus we know that all the charred material found in the sewer was carbonized prior to the eruption.

The formation of the carbonized assemblage was therefore the result of human treatment of the plant material. The assemblage is composed of material that can be divided into four distinct but often overlapping groups, based roughly on Van der Veen's (2007: 978-979) three groups of frequently carbonized species (see section 3.4.2) (Table

6.1). The majority of the olive stones represent intentional fuel use, although some were no doubt accidentally or ritually burnt (see section 8.2). As shown in table 6.1, several of the foodstuffs can be categorized as casual fuel; items or waste products that do not require fire in their preparation and were discarded into the fire because they no longer had any use. [67] All the items in the second group are usually cooked before consumption and are probably the result of accidental burning during food preparation. Lentils and millet are quickly made edible by boiling while wheat and barley can be boiled before being turned into *puls* or porridge (Fig. 6.10). The third group consists of items that were accidentally burnt. In this case it is the weed seeds as they are not a food source, do not require cooking and appear in only small quantities in the samples (see table 5.4) (Fig. 6.11). The fourth group, which does not appear in Van der Veen's list, consists of material burnt during ritual offerings and will be discussed below. Thus the carbonized assemblage was formed by way of a limited number of processes: intentional and casual burning, cooking accidents, accidental burning, and religious activities.

[67] The excavated cess pits in Pompeii frequently contain carbonized material that was intentionally thrown into the latrine. The burnt remnants of a fire would not only reduce the smell but would also burn off the methane that builds-up as a by-product of the microbial decomposition of human waste (Hobson 2009: 15).

Table 6.1. The carbonized material from the Cardo V sewer based on route of formation

Formation process	**Taxa**	**Common name**
Fuel (intentional and casual)	*Olea europaea* L.	Olive
	Bread	Bread
	Corylus avellana L.	Hazelnut
	Ficus carica L.	Fig
	Juglans regia L.	Walnut
	Malus or *Pyrus* sp.	Apple or pear
	Phoenix dactylifera L.	Date
	Pyrus sp.	Pear
	Vitis vinifera L.	Grape
Cooked foodstuffs	Cereal grain	Cereal
	Hordeum sp.	Barley
	Lens culinaris Medik.	Lentil
	Panicum miliaceum L. or *Setaria italic* Beauv.	Common or foxtail millet
	Setaria italica Beauv.	Foxtail millet
	Triticum aestivum L.	Bread wheat
	Triticum dicoccum Schübl.	Emmer wheat
	Triticum monococcum L.	Einkorn wheat
	Triticum sp.	Wheat
Rare/accidental	Weed seeds (for a full taxa list see Table 5.13)	N/A
Ritual	Bread	Bread
	Cupressus sempervirens L.	Cypress
	Ficus carica L.	Fig
	Juglans regia L.	Walnut
	Olea europaea L.	Olive
	Phoenix dactylifera L.	Date
	Pinus pinea L.	Stone pine
	Vitis vinifera L.	Grape

6.2.1.1 Ritual

It is probable that some of the carbonized assemblage was formed when ritual burnt offerings were performed inside the insula and the remnants deposited into the sewer. Distinguishing ritual offerings from table waste can be difficult and it is important to use as many identifying features as possible. In this situation, the most readily identifiable features are quantity, composition and comparability of the assemblage. For example, the quantity of burnt grape pips (n=59) is out of proportion to the number of other burnt fruits such as apple or pear seeds (n=4), suggesting that grapes, on occasion, were intentionally burnt. Moreover, while the carbonized assemblage is composed primarily of foodstuffs, it also contains inedible items such as stone pine bracts and cypress twigs (Figs. 6.12-6.13). Pine cones can be found in Pompeian wall paintings that depict burnt offerings (Robinson 2002: 97). These two factors, however, are not enough to confirm the presence of ritual burnt offerings in the Cardo V assemblage. We must turn to an external source and look at the ritual burnt offering assemblages from Pompeii.

The ritual Pompeii assemblages range in date from the 4th century BC to the 1st century AD and, combined, contain 67 different plant taxa from eight deposits (Table 6.2).[68] The most common types of plant remains from ritual burnt deposits include hazelnut, walnut, stone pine, cereal grains, grapes, olives, figs and broad bean. Burnt fragments of bread are also common finds. The carbonized assemblage from the sewer contains 20 of these 67 taxa in addition to burnt fragments of bread (Fig. 6.14). The overlap with the Pompeii material, including almost all of the most commonly found items listed above, strongly suggests that at least a small portion of the Cardo V carbonized assemblage represents waste generated by ritual burnt offerings.[69] In the absence of a garden, the inhabitants of *Ins. Or.* II had to dispose of the offerings down the latrine shafts. Whether or not the material was deposited directly after the ritual activity or was later deposited as a result of accumulated waste remains unknown.

[68] Although botanical remains recovered during the Porta Nocera excavations contains ritual material, the excavators were not able to distinguish it from food waste generated near the graves and thus it has not been included (Matterne and Derreumaux 2008).

[69] The only commonly found item missing from the Cardo V assemblage is pomegranate, and its absence will be discussed further in section 6.3.1.

Table 6.2. List of taxa from ritual deposits in Pompeii

Taxa*	Number of deposits (out of 8)	Present in Cardo V assemblage	Taxa	Number of deposits (out of 8)	Present in Cardo V assemblage
Anagallis sp.	1		*Piper nigrum* L.	1	✓
Arrhenatherum elatius (L.) P. Beauv var. *bulbosum* (Willd.)	1		*Pisum sativum* L.	3	
Astragalus/Trigonella type	1		*Plantago* sp.	1	
Brassiceae indet.	1		*Polygonum aviculare* agg.	1	
Bromus cf. *secalinus* L.	1		*Prunus dulcis*	1	
Ceratonia siliqua L.	3		*Prunus persica* (L.) Batsch.	1	
Cereal grain	4		*Prunus* sp.	1	
Chenopodium sp.	2	✓	*Punica granatum* L.	4	
Chenopodium/Atriplex sp.	1		*Pyrus communis*	1	
Cicer arietinum L.	3		*Rubus* sp.	1	
cf. *Cicer/Vicia/Pisum* sp.	1		*Rumex acetosella* agg.	1	
Corylus avellana L.	8	✓	*Rumex* sp.	1	
Cucumis cf. *melo* L.	1		cf. *Setaria* sp.	1	✓
Cupressus sempervirens L.	1	✓	*Setaria* cf. *italica* Beauv.	1	✓
Cynareae indet.	1		*Sherardia arvensis* L.	1	✓
Echium vulgare L	1		*Silene gallica*	1	
Ficus carica L.	7	✓	*Silene* sp.	1	
Graminae	1	✓	*Stachys* sp.	1	
Hordeum sp.	3	✓	*Trifolium* sp.	1	
Hordeum sp. wild[70]	1		*T. aestivum/durum* L.	1	
Hordeum vulgare L.	4		*T. monoccocum* or *dicoccum*	2	✓
Juglans regia L.	6	✓	*T. dicoccum* Schübl.	5	✓
Juglans sp.	1		*Triticum* sp.	5	
Leguminosae	1		*Triticum* sp. free threshing	2	✓
Lens culinaris Medik.	3	✓	*Vicia faba* L.	4	
Linum catharticum L.	1		*Vica faba* var. *minuta*	2	
Lithosperumum arvense L.	1		*Vicia sativa* L.	1	
Malva sp.	1		*Vicia* sp.	1	
Olea europaea L.	6		*Vicia/Lathyrus* sp.	1	
Ornithopus sp.	1	✓	*Vigna/Vicia* sp.	1	✓
Panicoid	1	✓	*Vitis vinifera* L.	7	
Panicum miliaceum L.	1		Bread fragments	3	✓
Panicum sp.	1		Fruit fragments	3	✓
Papaver somniferum L.	1	✓	Poppy seed cake	1	
Phoenix dactylifera L.	2		Tarallino (donut shaped pastry)	1	
Pinus pinea L.	5	✓	Nut shell (genertic)	2	

* For common names see Appendix B.

Material from:

House of the Vestals (4th century BC) (Ciaraldi and Richardson 2000; Ciaraldi 2007)
House of Amarantus I.9.12 (4th to mid-2nd century BC) (Robinson, M. 1999)
House of Hercules' wedding (late 2nd century BC) (Ciaraldi and Richardson 2000; Ciaraldi 2007)
House of Amarantus I.9.12 (2nd century BC, 1st century AD) (Robinson, M. 1999, 2002)
House of Hercules' Wedding (End of 2nd century BC - 1st century AD) (Ciaraldi 2007)
Porta Stabia, VIII.7.1-15 (4th- 1st century BC) (Ellis and Devore 2009, 2010; Fairburn 2012)
Shrine VI.1 (1st century AD) (Murphy *et al.* 2013)
House of the Greek Epigrams (AD15-79) (Robinson 2007c)

[70] It is unlikely that wild barley grew in the area and this is probably a misidentification of undeveloped or immature grains.

6.2.1.2 Cereal grains and chaff

There is a notable lack of cereal grains and an almost complete absence of chaff within the Cardo V carbonized assemblage. Only one bread wheat rachis, six grains of wheat and three barley grains have been recovered (Figs. 3.2, 6.1). However, despite the presence of a bakery within *Ins. Or.* II, the rarity of grains and chaff is not entirely unexpected, especially when compared to carbonized assemblages from Pompeii. Stratigraphic layers from the House of the Wedding of Hercules, the House of the Vestals and the House of Amarantus, dated to the 2nd century BC and earlier, all contained chaff. The presence of chaff indicates that cereal processing originally took place within Pompeii. However, chaff has not been found in any archaeological context in Pompeii dating to later than the 2nd half of the 2nd century BC, suggesting that by this time crop processing took place extramurally and only clean grain was imported into the town (Robinson M. 1999: 101; Ciaraldi 2007: 150-154). Processing probably took place at the large nearby villas as many of them, such as the Villa Regina at Boscoreale, have archaeological evidence of threshing floors (Thurmond 2006: 22; Ciaraldi 2007: 61; Bonifacio 2007: 65). Thus the lack of chaff, with regards to crop processing, is not surprising since the sewer was built in the early 1st century AD, long after the switch from intramural to extramural grain preparation had taken place at Pompeii and presumably Herculaneum.[71]

The uses of chaff and the nature of the Cardo V assemblage also indicate that the absence of chaff is a true absence and not the result of heat or exposure bias. Within an urban context chaff is often used as kindling for domestic fires, which burn at temperatures

[71] The only other reason to expect chaff in the samples would be in relation to animal fodder. Since *Ins. Or.* II.8 is a bakery it is probable that donkeys or mules were used to work the mills. The discovery of carbonized fodder in the bakery portion of the House of the Chaste Lovers, along with the skeletons of mules or donkeys suggests that fodder, including barley chaff, was used in bakeries to feed the animals (Ciaraldi 2007: 77-78). Carbonized hay for fodder was also found at the *villa rustica* at Oplontis (Ricciardi and Aprile 1988). However, few of the Cardo V species match taxa from either the House of the Chaste Lovers or Oplontis. It is also possible that the animals at bakery II.8 were fed elsewhere or that the mills were worked by human labour.

low enough to allow chaff preservation (Van der Veen 2007: 977-79). If chaff was used as a fuel within the insula, more than one fragment would have survived in a charred state. Additionally, the ubiquity of charcoal in the sewer indicates that hearth and heating waste was thrown into the sewer and any burnt chaff would presumably have also ended up in the deposit.

The scarcity of wheat and barley grains is due to the method of bread production. Grains are crushed during milling and therefore they are unlikely to survive intact. Additionally, the millstones in II.8 are located in a separate room from the oven so that even grains that were dropped or lost during the milling stage would not be near the fire. Botanical samples taken from four bakeries in Pompeii contained almost exclusively the remnants of pomace fuel and very few cereal grains, suggesting that it was uncommon to burn dropped grains (Monteix 2009: 331).

Finally, the small quantities of carbonized wheat (n=6) in the Cardo V samples compared to the far larger quantities of both mineralized and carbonized millet (n=289) and lentil (n= 17) also suggests that wheat was primarily used for bread production while millet and lentil were being prepared in the apartments. Millet and lentil are usually kept whole when boiled, making them more likely to preserve than the milled wheat grains. Home cooking, compared to the enclosed space of a bakery oven, also means that they are closer to an open flame during preparation and therefore have a higher chance of being accidentally dropped into the flames.[72] If wheat and barley were also being prepared and cooked at home, one would expect to find larger quantities of them in the samples.[73]

[72] Evidence for cooking within the apartments is discussed in section 8.2.4.
[73] Pliny (*HN* 18.54-55) states that bread can be made out of millet. If millet was used for flour in Herculaneum it is not readily observable in the archaeological record as the millets would also be crushed during milling and would not survive.

6.2.2 Formation of the mineralized assemblage

The formation of the mineralized assemblage was the result of human consumption and deposition activities taking place inside the apartments of *Ins. Or.* II. However, unlike the carbonized assemblage, the particular use or activity associated with each plant is more difficult to determine as much of the method and degree of interaction with an item is left to personal choice. A grape seed, for example, can be swallowed whole or spat out. Regardless of this choice, the resultant mineralized remain will usually be a whole grape pip. Subsequently, the formation of the mineralized assemblage has been divided into the three broad and largely overlapping categories described in section 3.4.3 (Table 6.3). Unless otherwise noted, a mineralized seed could fall into any of the three categories; human waste, unconsumed food waste and cooking waste.[74]

The majority of the mineralized assemblage was probably consumed and entered the sewer as human waste. Items such as fig pips, grape seeds and celery seeds pass through the human digestive tract intact (Don O'Meara Oct. 6, 2013, pers. comm.). Most of the seeds in the assemblage are smaller than 4 mm and can safely be swallowed whole (Fig. 6.15).[75] Since some were probably swallowed unintentionally, the weed seeds can also be placed in this category.

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[74] These three categories are related to foodstuffs and consumed items. There are some mineralized remains, such as the fragments of box and cypress and all the ruderal species (see table 8.2) that entered the sewer accidentally, perhaps when the floor was swept. See section 5.8.8 for the box and cypress and section 8.3.3 for the ruderal species.

[75] The date seed is perhaps the one exception as a whole date seed would be unpleasant to swallow whole.

Table 6.3. Formation processes of the mineralized assemblage

Taxa	Common name	Human waste	Unconsumed food waste	Cooking waste
cf. *Anethum graveolens* L.	Dill	✔		✔
Apium graveolens (Mills.) Pers.	Celery	✔		✔
Brassica sp.	Cabbages (or mustards)	✔		✔
cf. *Celtis australis* L.	Mediterranean hackberry	✔		✔
Ceratonia siliqua L.	Carob			✔
Cereal grain	Cereal			✔
Coriandrum sativum L.	Coriander	✔		✔
Corylus avellana L.	Hazelnut		✔	
Cucumis melo or *sativus* L.	Muskmelon or cucumber	✔	✔	
Daucus carota L.	Wild carrot	✔		✔
Ficus carica L.	Fig	✔		
Foeniculum vulgare Mill.	Fennel	✔		✔
Lens culinaris Medik.	Lentil	✔		✔
Linum usitatissimum L.	Flax/linseed	✔		✔
Malus or *Pyrus* sp.	Apple or pear	✔	✔	
Malus sp.	Apple	✔	✔	
Malva sp.	Mallow	✔		✔
Medicago sp.	Medick	✔		
Mentha sp.	Mint	✔		✔
Morus nigra L.	Black mulberry	✔		
Olea europaea L.	Olive		✔	
Panicum miliaceum L.	Common millet	✔		✔
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	✔		✔
Papaver somniferum L.	Poppy	✔		✔
Phoenix dactylifera L.	Date		✔	
cf. *Pinus pinea* L.	Stone pine		✔	
Piper nigrum L.	Black pepper	✔		✔
Prunus avium or *cerasus* L.	Wild or dwarf cherry	✔	✔	
Prunus domestica L.	Wild plum		✔	
Prunus sp.	Cherry		✔	
Rubus fruticosus (agg)	Blackberry	✔		
Setaria italica Beauv.	Foxtail millet			✔
cf. *Sorghum* sp.	Sorghum	✔		✔
Triticum cf. *dicoccum* Schübl.	Emmer wheat			✔
Vicia faba L.	Broad bean	✔		✔
Vicia or *Lathyrus* sp.	Vetch or pea	✔		✔
Vicia sp.	Vetch	✔		✔
Vitis vinifera L.	Grape	✔	✔	
Weed and ruderal plants (for full taxa list see Table 5.13)	N/A	✔		

A small portion of the material probably entered the sewer as unconsumed food waste. Pear and apple seeds are much larger than fig or grape seeds and are therefore much easier to avoid (Fig. 3.8). However, the decision to swallow or avoid consuming pear and apple seeds is a matter of personal choice and many of the seeds in this category could also have entered the sewer as human waste.

Finally, there are the items that are the result of cooking waste. The presence in both the carbonized and mineralized assemblages of typically cooked foods such as cereals and pulses, suggests that some were lost during the cooking process while others were lost prior to exposure to heat (Fig. 6.10). Items in this category also include seasonings such as dill, fennel, poppy and coriander which could have been lost or dropped during food preparation (Fig. 6.16). Although they do not require cooking they are usually associated with cooked or baked dishes in the Roman literature (Apicius *passim*; Pliny *HN* 19.173). Some of the seasonings were no doubt consumed and swallowed whole and thus they are also placed in the human waste category.

6.2.2.1 Formation of the mineralized invertebrate assemblage

Identical to the mineralized botanical assemblage, the actual formation of the insect assemblage took place inside the sewer once there was a sufficient build up of the necessary physical and chemical elements. Insects, particularly the trickling filter fly (*Psychoda alternata)*, entered the sewer through the latrine shafts and began to lay their eggs amongst the faecal matter. A proportion of the pupae and puparia died and became mineralized (Fig. 3.10). The exoskeleton of some of the insects, especially the woodlice (*Isopoda*), also mineralized after death (Fig. 5.54).

6.2.3 Formation of the faunal assemblage

Shells

The faunal assemblage, for the most part, represents unconsumed food waste and the formation of the assemblage is straightforward. Since the inhabitants of *Ins. Or.* II treated the sewer as place for general waste disposal, cooking waste such as eggshells, seashells and the animal bones were simply thrown down the latrine shafts after food preparation.[76] The delicate and now fragmentary nature of much of this material makes it difficult to provide any more detail. For example, we cannot tell from the eggshells if eggs were fried or boiled, nor can we tell from the scallop shells if they were cooked in or out of the shell (Fig. 6.8).

Fish

The formation of the fish assemblage, due to its very high level of preservation can provide a more nuanced picture of consumption. Through a careful analysis of the remains, it is possible to distinguish different methods of eating fish. The presence of both the otoliths and fish bones within the Cardo V sewer enables us to roughly differentiate between fish that were eaten whole, in pieces or as fish sauce.

Fish that were consumed whole are those that are represented by the otoliths or by the otoliths and the bones (See table 5.18). The passage of the bones and otoliths through the human digestive system is observable in the flattening of several vertebrae due to chewing and the smoothing of some of the otoliths due to stomach acid (Figs. 6.17-6.18).[77] Unsurprisingly, all of the taxa represented by the otoliths are small fish, often less than 20

[76] It is likely that a small number of the sea urchin spines were accidentally swallowed as some show severe signs of erosion due to stomach acid.

[77] While it is possible that some of the otoliths had smoothed edges due to degradation in the sewer, degradation due to digestion is the more likely cause (Jones 1986: 55). The otoliths would have spent far more time in the sewer than they did passing through the human digestive tract and if there had been acidic conditions in the sewer then the otoliths would probably have broken down entirely (Jones 1990: 143).

cm in length (Froese and Pauly 2013). This list includes the many varieties of sea bream as well as the damsel fish, greater weever and anchovies (see Table 8.3). Today, these species of fish are still consumed whole in the Bay of Naples.

Fish that are larger than 20 cm and represented exclusively by skeletal remains were probably eaten as fresh or salted pieces of fish.[78] Since there is such excellent otolith preservation, it is likely that in many cases the absence of an otolith means the absence of the head of the fish. This category includes taxa such as eels, seabass, garfish, wrasse and mullet.[79]

Finally, the quantities of anchovy, sardine, blotched picarel and mackerel bones suggests fish sauce consumption by the inhabitants of *Ins. Or.* II. Not only were these four species the most commonly used varieties in the production of fish sauce in the Roman world[80], but they are the only small fish, under 20 cm, from the sewer with a proportionally larger number of bones than otoliths, or in some cases, as with the blotched picarel, represented only by the bones. Thus, while on occasion anchovies and varieties of picarel were consumed fresh, they were most often eaten in the form of fish sauce.

6.3 Taphonomic comparison of the Cardo V botanical assemblage to material from Pompeii

The Herculaneum sewer contains primarily mineralized and carbonized material. Due to the taphonomic biases inherent in these two sources, they cannot directly be compared to each other but they can be compared to mineralized and carbonized assemblages from

[78] At the moment, distinguishing fresh from salted fish from the faunal remains alone is not possible and it is probable that some of the fish recovered only as bones were originally salted.

[79] The bones of the eels and garfish recovered from the sewer were from undersized specimens and as these taxa already have small otoliths the absence of eel and garfish otoliths in the sewer may have been due to preservation issues.

[80] The mosaics from the House of Aulus Umbricius Scarus in Pompeii, the primary producer of fish sauce in the region, specifically mention the use of mackerel in his *garum* (*CIL* IV 2576, 9406; Curtis 1984: 561; Cooley and Cooley 2004: 166). An assemblage comprised solely of picarel (*Spicara smaris*) was recovered from the garum shop (I.12.8) in Pompeii (Carannante 2008-2009: 44). In Portugal, at the fish salting factories of Quinta do Marim, Travessa de Frei Gaspar and Troia, sardines and anchovies dominated the faunal remains (Desse-Berset and Desse 2000: 86-91).

similar contexts. The absence of excavated cesspits in Herculaneum means that the sewer is the only source of mineralized material from the town. Although mineralization can only occur under a narrow range of conditions, there is still room for variation in conditions and therefore degree and amount of preservation. Are mineralized finds such figs, apples and pomegranates, commonly found at other Roman sites, absent? Does the sewer contain a large proportion of rare finds due to better than average preservation conditions? The same is true for the carbonized material, as again, the sewer is also the only source of properly sampled and processed carbonized material from Herculaneum. Since both the Pompeii and Herculaneum carbonized assemblages would have undergone cycles of wetting, when urine or kitchen water was added, and drying, during periods of inactivity and later when the material became buried by additional deposits, it is important to determine the degree to which this process may have affected the Cardo V material.

The geographical proximity of Pompeii makes it an ideal site for comparable data, enabling us to assess the level of preservation within the Cardo V sewer. Pompeii's cesspits and drains were used in a similar fashion to the Cardo V sewer, as both a toilet and refuse dump, and, due to the eruption, they have been subject to comparable preservation conditions. This comparison is crucial in order to determine what is genuinely missing from the archaeological record and what is the product of preservation bias. For example, is the absence of items such as sesame seeds due to the moderate socioeconomic standing of the inhabitants of *Ins. Or.* II or is it due to differences in preservation?

The body of data from domestic and commercial contexts from Pompeii is also now sufficiently large to allow for a meaningful comparison with the Cardo V assemblage. Since the late 1990s (when sampling became a standard part of Pompeian excavations), soil has been analysed from a wide range of context types, including drains, cess pits, graves, ritual pits, post holes and floor surfaces. In addition to providing crucial data on preservation conditions, in recent years, a significant amount of mineralized material, in addition to the standard carbonized finds, have been processed, identified and published (Robinson 1999; Ciaraldi 2007; Murphy *et al.* 2013). While the early botanical finds, compiled and published by Borgongino (2006) are useful, the majority were carbonized during the eruption and thus were not subject to the same formation process as material from sealed pre-eruption contexts. Taxa lists from all recent Pompeii excavations and the associated Cardo V material can be found in Appendix B.[81]

6.3.1 Carbonized assemblages compared

The carbonized assemblage from all current Pompeii excavations consists of 131 taxa with an average of 38 taxa per excavation. Species with the highest frequency and quantity include grape, olive, hazelnut, fig, wild grasses, cereals and vetches. Walnut, stone pine, pomegranate, wheat, millet and legumes are also common. Although the Herculaneum material is slightly below average in the range of species, all 27 taxa from the the Cardo V sewer can be found in the Pompeii assemblages. The 27 taxa also include the most frequent items listed above. As regards preservation, the assemblage does not seem to differ significantly from the Pompeii material.

The Pompeii material represents finds from a variety of contexts, and so it is not surprising that the Herculaneum material, as a single context, contains fewer taxa. Notable foodstuffs absent from the Cardo V assemblage include pomegranate, chickpea, broad bean, hulled barley, peas and chestnuts. Some of the weed seeds are also missing, such as the grass species hedgehog dogtail (*Cynosurus echinatus* L.). However, many of the

[81] Taxa lists come from: The House of Amarantus I.9.12 (Robinson, M. 1999); House of Hercules' Wedding and the House of the Vestals (Ciaraldi 2007), House of the Greek Epigrams (Robinson 2007c); Vesonii tomb, Porta Nocera (Matterne and Derreumaux 2008); Insula VI.I (AAPP) (Murphy *et al.* 2013); Pompeii Pistrina project (Monteix 2009, 2010b; Monteix *et al.* 2011); PARP:PS (Fairburn 2012); Research on the Forum of Pompeii project (Kockel and Flecker 2008; for excavation details see Appendix E). Although other finds lists exist, for example Meyer (1988), only material from properly processed and sampled urban contexts were used.

missing foodstuffs, including the black pepper and plums, can be found in the Cardo V mineralized assemblage. Preservation bias is probably responsible for the absence of pomegranate, chickpea and pea as all these items were found carbonized on the upper floor of a house on the nearby *Decumanus Maximus* and therefore were consumed in Herculaneum (Borgongino 2006: 204). The fact that many of the missing carbonized items were also present in the mineralized assemblage indicates that they were consumed in Herculaneum but simply not burnt.

There does however, appear to be one significant difference between the Pompeii and Herculaneum assemblages. At Pompeii, the greatest taxonomic diversity (71.5%) comes from the fruits (n=21) and weed seeds (n=72). Only 53% of the carbonized taxa from the sewer fall into these categories with six fruit and nine weed taxa. This difference is probably not due to taphonomic influences, but instead it is the result of a multitude of factors including context type, context date and depositional practices. Many of the Pompeii contexts come from garden soils and pit fills where material represents secondary deposition and these assemblages probably reflect a range of activities aside from just food preparation. Additionally, early contexts, prior to the mid-2nd century BC, show evidence for crop processing and many of the weed seed taxa probably came into Pompeii with the cereals and pulses. Finally, it is possible that those living in *Ins. Or.* II simply did not burn fruit cores or stones as often, either as a method of waste disposal or for ritual purposes. The complete absence of chestnut, and especially the durable shell of almond from the sewer is unexpected and perhaps the shells were simply never burnt or are present in extremely low quantities in the unexamined quadrants. Nevertheless, few common items are missing and the Cardo V material can be considered a ‘standard’ assemblage for a domestic/commercial context within an urban environment in the Vesuvian region.

6.3.2 Mineralized assemblages compared

As with most mineralized assemblages, the range of Pompeian contexts is limited to cess pits and drains (Ciaraldi 2007: 132). Consequently, a comparison between the Pompeii and Cardo V material does not suffer from the same context bias inherent in the carbonized assemblages. In theory, the preservation conditions should be almost identical. However, there are slight differences between the mineralized material from Pompeii and the Cardo V assemblage. Whether or not these differences are due to taphonomic factors or consumption/socioeconomic influences is difficult to determine.

The mineralized assemblages from six Pompeii excavations consist of 132 taxa.[82] The most common items include fig pips, grapes, lentils, broomcorn millet, wild grasses and bird's foot. There are 84 taxa in the Cardo V assemblage, with only 53 directly overlapping with the Pompeian taxa while some overlap only at the genus level. Out of the 25 Cardo V taxa not present in the Pompeian mineralized assemblages, 14 of those taxa are present in the Pompeii carbonized assemblages (Table 6.4). The 14 taxa are primarily legumes, weed seeds and fruits including broad bean, knotgrass and carob. The remaining 11 taxa are unique to Herculaneum.

These unique taxa consist of weed seeds and seasonings. The weed seeds are often simply different species of a genus or family extant in the Pompeii assemblages. For example, *Ranunculus parviflorus* is present in the Cardo V assemblage while *Ranunculus sardous* was found at the House of the Wedding of Hercules and the House of the Vestals at Pompeii (Ciaraldi 2007: 104, 129). Similarly, *Carduus* sp. was recovered from the sewer and although no plants of the genus *Carduus* were found at Pompeii, other genera, such as *Anthemis,* from the family Asteraceae were identified (Ciaraldi 2007: 125).

[82] The same six as in n. 81 except for the Vesonii tomb and the House of the Greek Epigrams. Providing an average number of taxa would not be helpful as, depending on the type of context, the number ranged from four to 97.

Table 6.4 Mineralized Cardo V taxa not present in mineralized Pompeii assemblages

Mineralized plants from Herculaneum not present in the Pompeii assemblages	**Common name**
Species unique to the Cardo V assemblage	
Apium graveolens (Mills.) Pers.	Wild celery
cf. *Anethum graveolens* L.	Dill
cf. *Celtis australis* L.	Mediterranean hackberry
Linum usitatissimum L.	Flax/linseed
Morus nigra L.	Black mulberry
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup
cf. *Sorghum* sp.	Sorghum
Genus unique to Cardo V assemblage	
Aphanes sp.	Parsley-piert
Carduus sp.	Thistle
cf. *Centauria* sp.	Knapweed
Chara sp.	Green algae
Cardo V taxa present in the Pompeii carbonized assemblages	
Ceratonia siliqua L.	Carob
Chenopodium album L.	Fat-hen
Cucumis melo L. or *sativus* L.	Melon or cucumber
Polygonum aviculare (agg) L.	Knotgrass
Ranunculus sp.	Buttercup
Resida sp.	Mignonette
Sambucus sp. (present as a species in Pompeii assemblages)	Elder
Scrophulariaceae	Figwort family
Silene sp.	Campion
Stellaria media (L.) Vill.	Common chickweed
Triticum cf. *dicoccum* Schübl.	Emmer wheat
Vicia faba L.	Broad bean
Vicia or *Lathyrus* sp.	Vetch or pea
Vicia sp.	Vetch

Consequently, the weed assemblages are not radically different and represent slightly different ecological habitats and anthropomorphic activities rather than large differences in preservation. In addition to the common holly from Insula VI.I, there are 10 items from Pompeii which Ciaraldi (2007: 102, 125-126) has labelled as ornamental plants such as musk-mallow and buckthorn, suggesting at least some of the Pompeii weed assemblage is derived from garden plants. Only cypress, box, violet and mallow are represented in the Herculaneum assemblage. Since there are no gardens located directly in *Ins. Or.* II, this absence is not unusual. There are an additional six species from Pompeii that live on disturbed ground (Tutin 1964-1980; Robinson 2011: 282).[83] However, all six were found only at the House of the Vestals and/or the House of the Wedding of Hercules. Their absence from other Pompeian sites suggests that these plants were not growing throughout the city and thus are rare inclusions in the archaeobotanical record.[84] The Pompeii material also contains two species of poisonous weed seeds: corn cockle (*Agrostemma githago*) and European black nightshade (*Solanum nigrum*). Both were no doubt unintentional inclusions as only three seeds of corn cockle were found during the AAPP excavations and 11 nightshade seeds were found at the House of the Vestals (Ciaraldi 2007: 130; Murphy *et al.* 2013).

The seasonings attest to the scale of the Cardo V mineralized assemblage in relation to the Pompeii assemblages. The Pompeii assemblages lack celery, dill and flax. The quantity of mineralized material present in the sewer may explain the recovery of these items and it is not necessarily due to a superior level of preservation. It is probable that future analysis of mineralized remains from Pompeii will also produce celery, dill and flax seeds. The identification of a wider range of cereals and legumes including sorghum, broad bean and vetch may be due to the author's familiarity with mineralized material. In Pompeii, the only mineralized legume is lentil. As mineralized remains, cereals and legumes are difficult to identify and may simply have been missed.

Finally, there are notable absences in the Cardo V assemblage. Although black pepper was found, there are no seeds of citrus or sesame.[85] These absences may reflect the moderate to low socioeconomic standing of the majority of the inhabitants of *Ins. Or.* II.

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[83] *Urtica urens, Valerianella dentate, Ranunculus sardous, Mercurialis annua, Galeopsis tetrahit* and *Euphorbia peplis.*
[84] It is also possible that some have been misidentified.
[85] Although it is important to acknowledge the possibilities that these items have not yet been found in the sewer, were missed during identification or have been misidentified by other archaeobotanists.

Both items would have been expensive in Italy during the 1st century AD, especially sesame as it was imported either from Egypt or India (*DE* [86]; Cappers 2006: 125). Lastly, a small number of the more common weed seeds are missing such as *Echium vulgare*, although this may be due to differences in the level of identification.[87]

In sum, composition of the carbonized and mineralized assemblages from the Cardo V sewer are similar enough to the Pompeian data sets to conclude that, for the most part, taxonomic differences are not due to taphonomic factors but to differing plant use. The Cardo V assemblage reflects a commercial and residential multi-storey unit inhabited primarily by people of middle to lower socioeconomic status in the mid-1st century AD. The Pompeii assemblages, which span four centuries, largely reflect middle to upper class inhabitants living in houses with planted garden space.

6.4 Biases in the bioarchaeological assemblage from the Cardo V sewer

The biases inherent in the Cardo V assemblage do not deviate from those usually present in other bioarchaeological assemblages (see section 3.3). The carbonized assemblage is biased towards the portions of plants that will not turn to ash during burning while the mineralized assemblage is biased towards seeds that remain intact during preparation and consumption. For example, the mineralized assemblage is dominated by fig pips because there are thousands per fruit and they are very readily mineralized. As the similarities with the Pompeian assemblages have shown, the Cardo V material does not seem to suffer from any significant preservation biases, including cycles of wetting and drying. Moreover, the close taphonomic relationship between the Cardo V material and the Pompeii material also

[86] In the Price Edict a citrus costs 24 denarii while a pound of lamb is only 12.
[87] See n.85. Rosemary, oregano and bay were missing from the Herculaneum seasonings and were preserved in Pompeii only as leaves. However, the preservation of identifiable leaves in mineralized deposits is extremely rare and thus the identifications are perhaps questionable (Ciaraldi 2007:125).

helps us to identify and eliminate several potential taphonomic biases. For example, heat and duration of exposure can impact the types of items that become carbonized. Since the majority of the carbonized material from Pompeii was derived from kitchen waste, the similarity between the two data sets suggests that the material in Herculaneum was burnt using cooking and heating fires. These fires did not burn at temperatures hot enough to result in a significant loss of taxonomic diversity and therefore temperature does not need to be considered a serious source of bias. The recovery of rarely preserved items, such as olive seeds, not present in the Pompeian assemblages, suggests that the quality of mineralized preservation was slightly better than at Pompeii and thus the somewhat selective process of mineralization should not be considered a source of bias either.

Modern processing methods also did not bias the assemblage. The soil in the Herculaneum sewer was very loose, which meant that recovery rates were high. Bucket flotation was done by hand to ensure the survival and recovery of the delicate mineralized material. The residue material was also sorted down to 1mm so even the smaller seeds such as poppy were retained. In addition, the carbonized material was not subject to repeated wetting and drying. These careful processing methods also ensured the full recovery of small fish bones and otoliths.

The single remaining source of bias lies with the archaeobotanist. Access to a good reference collection, confidence of identification and familiarity with the material can all impact the final finds list. Differences in the identification level can create a false sense of discrepancy, making some samples appear more diverse than others if they have more items identified to species rather than simply to genus or family. When using the Pompeii data, every attempt has been made to take these biases into account and limit their impact during the analysis. For example, when looking at weeds of disturbed ground or crops, only items identified to species were used since genus is often too broad a category to ensure correct habitat association. Thus, the biases inherent in a data set created by six different archaeobotanists have been acknowledged and taken into account. By comparing the Cardo V data to that from Pompeii, I have attempted to reduce any biases arising from my own identification work, thereby ensuring that the following analyses are as accurate as possible.

"Among scholars, food is studied chiefly by anthropologists, and for its non-food uses and symbolic significance. Only in the contemporary developing world does food stand centre-stage as indisputably a bio-cultural phenomenon, a subject fit for biological scientists and social scientists alike. So it could be for students of antiquity." (Garnsey 1999: 4)

Chapter 7: Ancient sources, nutrition and the *Insula Orientalis* II diet

It is clear from the surviving ancient texts that the Romans viewed food not only as a source of sustenance and material for social and cultural communication, but as a good that could be studied, manipulated and altered. Authors such as Pliny (*HN* 14.8-150, 15.47-52), Columella (*Rust.* 5.10.19, 12.5-55) and Cato (*Agr.* 156-157) discuss at length new varieties of apples and grapes, methods of food preservation and the health benefits of cabbage. The modern western world views food in much the same way, as both subsistence and as a subject of scientific and nutritional analysis. What is the optimal amount of red meat in the diet? What is the nutritional impact of high yield wheat cultivars? What is the impact of food processing such as frying or boiling on nutritional content? Our knowledge of food sciences has advanced to the point where a re-examination of the ancient sources concerning subjects such as food processing and preservation, will shed new light on nutrition in the ancient world. While the ancients may not have understood the impact of their actions, they did record a wide variety of consumable goods, food preservation methods and recipes (Pliny *HN* 15.62-7, 19.171; Cato *Agr.* 76; Apicius *passim*). This chapter explores the relationship between the ancient texts, the Cardo V assemblage and modern food sciences in the hopes of providing a more nuanced view of health and nutrition in ancient Herculaneum.

The first section of the chapter will compare the statements of the ancient authors to the foodstuffs from the sewer. Are there any major discrepancies between the consumption patterns highlighted in chapter 6 and the claims of the ancient authors? Since these texts are subject to social and temporal biases, it is crucial to establish their validity. This section will be followed by a nutritional analysis of the Cardo V foodstuffs; the goal being to assess the nutritional status of the individuals living in *Ins. Or.* II as best we can. Are they eating a variety of foods that would have provided them with the full range of essential macronutrients, vitamins and minerals? Would they be chronically or severely deficient in an essential nutrient such as vitamin C? The chapter will then focus on an analysis of the *Ins. Or.* II diet from a modern nutritional perspective, exploring topics such as soil quality, food preservation methods and cooking practices. As much of this information can only be gathered from the ancient sources, they will also feature heavily in this section. Finally, the results will be compared to the data concerning health and nutrition derived from the Pompeii and Herculaneum skeletons.

7.1 The Herculaneum diet according to the ancient sources

What do the ancient sources say people of lower to middle socioeconomic status ate? In order to provide an educated answer we must mine the ancient texts for hints and clues since none of them directly address the question (for a description of the ancient texts and authors see section 1.3.1). An additional challenge is matching the ancient name or description of a food to the modern species (Wilkins 2005: 27-28). The ancient sources do not always differentiate between similar species, for example Mediterranean horse mackerel (*Trachurus mediterraneus*) and horse mackerel (*Trachurus trachurus*) (Pliny *HN* 32.89; Oppian *Hal.* 3.398-400). Nevertheless, a rough outline of the Herculaneum diet can be obtained from these texts.

For several centuries, the Campanian region was important both politically and culturally and thus Italy and Campania feature heavily in descriptions and discussions of food. Beginning with Cato (*Agr.* 8) in the 2nd century BC, a range of authors mention foods grown in or imported to Campania or southern Italy directly (Columella *Rust.* 2.10.18, 8.8.8; Pliny *HN* 18.76-77; Galen *Alim. Fac.* 6.524). Pliny is our best source, mentioning Campanian varieties of food or local consumption practices no fewer than eight times. He describes varieties of Campanian grape, fig and cherry and claims that millet grows well in the region (Pliny *HN* 14.10, 15.71, 15.102-4, 18.99-102). When consumption practices are described without geographical context we can turn to the chronology of the sources to assess their validity. Some dishes or recipes are continuously described throughout the centuries and it is probable that they formed a regular part of the diet. Cato (2nd century BC), Pliny (1st century AD) and Galen (2nd century AD) all state that bread wheat is the preferred grain for making bread while emmer is usually made into porridge (Cato *Agr.* 76; Pliny *HN* 18.83, Galen *Alim. Fac.* 6.501-10). Finally, we must look at the context of the item within the text. Simply because a plant or animal is described and is technically edible does not mean that it was considered a food source. Is the item mentioned in the context of consumption or cultivation? Is it considered a famine food or a food with an exclusively medicinal purpose? Edible items falling into these final two categories will not be considered as they would not have formed part of the regular diet.

7.1.1 Plants

There is little doubt that cereals formed the staple of the Herculaneum diet. According to Pliny (*HN* 18.99-102, 18.109) emmer wheat and millet (both common and foxtail) grew well in Campania and there is no reason to doubt that claim. Both Pliny (*HN* 18.71-81) and Galen (*Alim. Fac.* 6.501-10) declare that barley is no longer considered an acceptable foodstuff for humans and Pliny claims that einkorn grows outside of Italy (Purcell 2003: 332). Thus the primary grains in the diet were probably millet, emmer and bread wheat. Barley was used as animal fodder.

Legumes were also an important part of the diet. According to Pliny (*HN* 18.117) the highest honour amongst the legumes belonged to the broad bean. Lentils were often consumed although it is stated that they will give you flatulence (Pliny *HN* 22.142-5). Martial (1.103) says that chickpeas were extremely inexpensive in Rome, costing only one *as* for a serving. Other known legumes included peas, lupins and vetch (Spurr 1986: 113-114; Dalby 2003: 194; Thurmond 2006: 167). Lupins and vetch were considered famine foods and fodder crops and it is unlikely that they were eaten in Campania in any considerable quantity (Pliny *HN* 22.151-7; Jashemski *et al.* 2002: 169). Since legumes were thought to be an essential food source for the poor and an optional food for the rich (Dalby 2003: 167), they were probably widely eaten by those living in *Ins. Or.* II.

A range of nuts were cultivated in the Campanian region and throughout the Italian peninsula. If your farm was situated near an urban center, Cato (*Agr.* 8) recommends growing hazelnut and walnut trees. According to Pliny (*HN* 15.88-9), in Campania, hazelnuts were roasted. Other available nuts included chestnuts, almonds and pine nuts (Pliny *HN* 15.35-6, 15.90-2, Apicius 5.2.2). Based on the large quantities of these carbonized nuts recovered from Herculaneum during the early excavations, all were no doubt eaten in the town (Borgongino 2006: 65, 107, 114, 130-131).[88]

The variety of fruits available for consumption in Italy increased dramatically from the 2nd century BC to AD79 and those living in Herculaneum in the mid-1st century AD had a large amount of choice. This increase in variety is often noted in the sources. In Cato's (*Agr.* 7.3-4) time there were five varieties of pear but by the 1st century AD, Columella (*Rust.* 5.10.18) claims that the varieties are now too numerous to count. New introductions to Italy since the 2nd century BC included peach and pomegranates (Pliny *HN* 15.40, 44; Thurmond 2006: 174-5). Plums and cherries were brought under cultivation

[88] The only nut not found in large quantities was hazelnut, although entire jars of them were recovered from Pompeii (Borgongino 2006: 112).

during this time (Zohary *et al.* 2012: 143-144) and Pliny (*HN* 15.41-43, 102-4, 19.67) states that a new type of cucumber had just been produced in Campania. The expansion of fruit species and cultivars was due in large part to the Romans' extensive understanding of grafting techniques (Cato *Agr.* 40-42; Virgil *Georg.* 2.69-82; Pliny *HN* 15.38; Lowe 2010: 467). The Vesuvian region is mentioned as having its own variety or particularly good cultivar of several fruits including a Herculaneum fig, a Plinian cherry, a Falernian pear and an Aminaea grapevine that grew well on the slopes of Vesuvius (Pliny *HN* 14.22, 15.53, 15.71, 15.102-4). Other commonly available fruit included apples, mulberries, blackberries, olives, quinces and carob (Columella *Rust.* 15.10.19; Pliny *HN* 15.97; Thurmond 2006: 174-5). Lemon is not described by the sources as an edible food until the 2nd century AD and it is probable that prior to this time citrus was used as an ornamental or aromatic plant (Dalby 2003: 88). Thus those living in Herculaneum had access to a wide variety of fruits, and probably ate all but the most expensive, such as peach, on a regular basis.

Compared to the fruits and cereals, there is less clarity in the sources in descriptions of vegetables. Consequently, our estimation of vegetable consumption in Herculaneum must be somewhat more hypothetical. The available vegetables fall into two categories, root and leafy vegetables. The most common root vegetables probably included onion (shallots), garlic, leeks (chives), parsnip[89] and radishes[90] (Pliny *HN* 19.101-11; Thurmond 2006: 169). Since these were all good storage foods, they were extremely important for the winter diet of the lower classes (Pliny *HN* 19.87; Thurmond 2006: 170). Turnips and navews (rutabaga) are described by both Pliny (*HN* 18.126-31) and Columella (*Rust.* 2.10)

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[89] According to Columella (*Rust.* 12.7.1) it was the flowers and stalks of parsnips that were consumed, not the bulb that is usually eaten today.

[90] Pliny (*HN* 19.82) says that radish stems are the most valuable part of the plant, although the bulb was eaten as well.

but they were generally considered a food for country folk and a useful source of animal fodder.

There was more variety amongst the leafy vegetables. Cabbage was probably the most widely consumed vegetable as Pliny (*HN* 19.40) mentions Cumae and Pompeian cabbages, known for their tenderness. Kale, rocket and lettuce were probably popular as they appear in a variety of recipes and are praised for their nutritional qualities (Columella *Rust.* 11.3, 19.36-43; Apicius 1.27). Endive, purslane and cress were eaten as well. Many other leafy vegetables are mentioned by the ancient sources but often with limited uses or only for medicinal purposes (Thurmond 2006: 172). Pliny (*HN* 19.133-4, 19.185) states that dock was only eaten with pearl-barley while beets and chard were to be consumed only by people with strong digestive systems. Mallow and nettles had medicinal uses and Pliny (*HN* 20.220-1) recommends avoiding orach. However, simply because an author suggests that something be avoided does not mean that it was, and it is possible that foods such as chervil, chard and nettle were consumed in Herculaneum.

Mushrooms were also eaten in Roman Italy (Pliny *HN* 16.31). Depending on the type, the mushroom could be a common food, a luxury food or a poison (Seneca *Ep.* 95.25; Horace *Sat.* 2.4.20-21; Brothwell and Brothwell 1998: 91). There are many anecdotes about people being poisoned by mushrooms, including the Emperor Claudius (Pliny *HN* 22.92-96; Martial 1.20; Juvenal 5.147). Consequently, people living in Campania probably ate a variety of mushrooms that they knew were safe.

Finally, the Romans used a wide range of available herbs and spices to preserve and flavour food and drinks. According to Miller (1969: 111-118), 84 seasonings have been identified in the classical texts and there are 45 spices, seeds and dry herbs listed in Apicius. Several of these plants grew in Italy and could easily be grown on nearby farms or in kitchen gardens and sold in urban centres. In many cases the flesh, leaves and the seeds were used as flavourings. Such herbs include celery, mustard, cabbage, rocket, dill, fennel, coriander, mint, rue, lovage, cumin, savory, oregano, anise and poppy seeds (Cato, *Agr.* 79, 84; Galen *Alim. Fac.* 6.641; Pliny *HN* 19.156-9, 19.165-8, 19.175, 20.147, 20.185; Varro *Rust.* 18; Dalby 2003: 243). The ancient authors discuss and use, especially in the case of Apicius, many imported seasonings including ginger, black pepper, asafoetida, caraway, saffron and sesame, but it is doubtful that most of those living in *Ins. Or.* II could afford them (Apicius 1.1, 1.32, 2.1, 4.4.2, 7.6.10; Pliny *HN* 12.26-29, 19.41-45, 21.31; Dalby 2003: 29; Cappers 2006: 125; Van der Veen 2011: 169). Moreoever, not all the seasonings mentioned in the sources would have been available in Italy in the 1st century AD and certainly not to those of moderate means. Immediately, we can exclude turmeric as it had not yet reached Italy, as well as cardamom and cinnamon since they were used as aromatics and not seasonings (Van der Veen 2011: 54-55, 62).[91] We can also probably exclude those that, although they are common seasonings today, were considered more suitable for perfumes and medicines. Rosemary, sage and laurel (bay) all fall into this category (Pliny *HN* 15.127; Dalby 2003: 48, 284-290).

7.1.2 Animals

The range of animals and animal products described in the ancient texts is extensive, and once again, the anecdotal and symbolic must be separated from the affordable and practical foodstuffs. Apicius (2.2.6, 7.4.3) has recipes using peacock and wild boar and while technically available in Italy in the 1st century AD (Horace, Satires 2.2.23-28), it is doubtful that either were eaten by the majority of people living in Herculaneum. Aside from such obvious examples, separating the probable from the improbable is made

[91]For silphium see section 1.3.1.

somewhat easier by the logistics of food storage, spoilage and transportation in the ancient world.

Dairy products are the best example of these logistical concerns. Sheep, goat and cow milk, and to a lesser extent mare and donkey's milk were used by the Romans (Pliny *HN* 28.131). However, fresh milk will spoil quickly and those living in Herculaneum probably did not drink fresh milk. Instead their dairy products came in the form of cheese, yogurt and curds (Columella *Rust.* 7.8, 12.8, 12.43).[92] Cattle were not widely bred in the Campanian region and most cheeses were probably made from goat and sheep milk (MacKinnon 2004: 78, 90-91; Thurmond 2006: 191).

Animal meat was mostly restricted to domesticated species, although in theory people could catch wild animals such as rabbits or small birds themselves (Columella *Rust.* 8.7-9; Varro, *Rust.* 3.12.6-7; Apicius 2.2.6; Thurmond 2006: 210). More exotic or rare meats such as venison, ostrich and flamingo were too expensive (Pliny *HN* 10.133; Dalby 2003: 114, 244). Pork, therefore, was the main source of meat as it could easily be salted and stored for long periods of time. Chicken, sheep and goat were also available.[93] The cuts of meat and types of meat dishes consumed are more difficult to determine. Columella (*Rust.* 12.55) does not discuss the sale of fresh pork and instead describes at length the salting of pork, suggesting that salted meat was the most common form available. Meat could also be made into sausages or minced or boiled (Horace *Sat.* 2.4.60-65).

Eggs were considered to be an aphrodisiac (Ovid *Ars. Am.* 2.423) yet at the same time, according to Horace (*Sat.* 2.2.45), they were a plain food often consumed by the lower classes. Chicken eggs would be the most common form, although goose eggs are also mentioned as a foodstuff (Galen *Alim. Fac.* 6.706).

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[92] Butter, although known, was not very popular in southern Italy because it would not keep well without refrigeration (Pliny *HN* 28.133-5; Dalby 2003: 65; Thurmond 2006: 191).

[93] Horse, although it is edible, was only consumed by the Romans in times of emergency or famine (Dalby 2003: 180).

Several ancient sources discuss fish and shellfish in much more detail than domesticated animals. The range of available species and products was considerably more varied and the differing characteristics and symbolic meanings associated with these various species lent itself to greater analysis. Nevertheless, the sources do present some unique challenges when attempting to reconstruct seafood consumption in Herculaneum. Fish and their habits were considered something of a curiosity and an author can discuss a fish at length without ever stating whether or not it was consumed by humans.[94] Since fish sauce and salted fish were traded around the Mediterranean, authors such as Pliny (*HN* 9.68) describe the best locations to eat or catch a particular species without mentioning if it could be found or was eaten in other regions of the Empire. In reconstructing the types of fish and shellfish consumed in Campania, we must assume that if a species was mentioned as a food item within the Mediterranean, it was probably consumed in Herculaneum, taking into account financial and ecological considerations.

Since those living in *Ins. Or.* II were of moderate to lower socioeconomic status, they could probably afford fish species ascribed to the poor. Galen (*Alim. Fac.* 6.728) claims that dog fish were cut up and pickled for ordinary people. *Apua* is described by Pliny (*HN* 31.95) as small fry that are not useful for anything other than the production of *allec* (the dregs of *garum*). Oppian (*Hal.* 1.762-97) states that there are plenty of small fry in existence and it is clear that many of the smallest edible fish species, including anchovies, sardines and herrings were considered a single, inexpensive type. Picarel was said by Martial (3.77, 12.32) to be a food for the poor while he recounts how he was served sea bream at a dinner while the wealthy host was served turbot (3.60). Other species that are mentioned but not especially praised (except sometimes for their size) include tuna,

[94] Pliny (*HN* 9.74-8) spends a considerable amount of time describing the ecological characteristics of skates and the dangers that they present to humans when trying to hunt them. However, he does not state that once they are caught they are used as a food source. Instead we must look to Galen (*Alim. Fac.* 6.729) to find evidence of their consumption.

shark, ray, mackerel, wrasse, weavers, grey mullet, hake and flatfish (Horace *Sat.* 2.8.30; Thurmond 2006: 222).

Finally, some fish were noted for their price and quality. Juvenal (6.40, 11.37) says that red mullet was too expensive for a married man on a moderate income while Pliny (*HN* 9.61) states that sea bass is the best of the edible fish. Herculaneum's location, directly on the Bay of Naples, means that those living in *Ins. Or.* II probably ate all but these expensive species of fish.

Shellfish are discussed in the sources more sporadically than fish. Species are often only described in detail if they have an unusual use or habit. Murex, for example, are noted for their purple dye while Lucrine oysters are noted for being intentionally cultivated in the Lucrine lake and thus are considered a delicacy (Pliny *HN* 9.125, 9.168-9, 32.59; Martial 3.60). Cuttlefish and squid are mentioned for their ability to produce ink (Pliny *HN* 9.84). Alternatively, the tendency of the ancient sources to group taxonomically diverse shellfish types together makes it difficult to discern the consumption of individual taxa within Herculaneum. For example, even though there are several species of mussels, wedge shells and limpets present in the Mediterranean, they are always referred to by the generic name of mussel, wedge shell or limpet. Occasionally, particular 'types' but not species are noted for their excellent quality (Horace *Sat.* 2.4.25-29; Pliny *HN* 9.101). Horace (*Sat.* 2.4.30-35) mentions particularly good shellfish varieties from the Bay of Naples area including a Lucrine mussel, a Baian cockle and sea-urchins from Misenum. Other shellfish are simply noted for being a foodstuff or an item caught by fishermen including sea urchin, scallops, razor clams, clams and cockles (Pliny *HN* 9.100-101, Galen *Alim .Fac.* 6.733-5). At least some of the species from each variety of shellfish were probably eaten at Herculaneum since it was situated on the coast.

7.2 Comparison of diet between the ancient sources and the Cardo V floral and faunal remains

According to the ancient sources, the Herculaneum diet was extremely diverse. The town had easy access to food from its fertile hinterland, from the Bay of Naples and imports arriving into the nearby port of Puteoli. The Campanian region was noted for several of its own varieties of fruits and vegetables and its high quality goods such as oysters and wine. However, this is the picture painted by elite authors, most of whom were often describing food on a Mediterranean- or Italian-wide scale. How closely does the diet of those living in their small shops and apartments in *Ins. Or.* II, based on the sources, match the actual bioarchaeological record?

7.2.1 Plants

Taking into account issues of preservation, the two sources of information on diet are very similar. Millet and emmer wheat are the most common cereals recovered from the sewer, followed by small quantities of bread wheat and barley. The slightly larger quantities of emmer compared to bread wheat (see tables 5.2 and 5.4) suggest that, as the sources claim, emmer was used for porridge and bread wheat was used for bread (Cato *Agr.* 76; Pliny *HN* 18.83; Galen *Alim. Fac.* 6.501-10). The popularity of certain legumes also matches the written sources as lentil and broad bean dominate the Cardo V assemblage. The absence of chickpea and pea is probably due to taphonomic factors while the small quantities of vetch and bitter vetch most likely reflect weed seed contamination rather than consumption. The range of consumed nuts is slightly smaller than the sources would suggest with only walnut, hazelnut and stone pine recovered from the sewer. For the absence of almond and chestnut see section 6.3.1.

The fruit finds from the sewer match exactly what one would expect to find based on the sources. Fruits described as widespread or common such as apple, pear, fig and grape dominate the assemblage while the most expensive items, including peach and pomegranate, are missing. The only unusual absences are sorbes and quinces, especially since Pliny (*HN* 15.37) describes a Naples quince. However, they are mentioned as being very sour by the ancient sources. Moreover, they are not often found during Pompeian excavations, which suggests that in reality they were not a very popular foodstuff (Pliny *HN* 15.38, 15.85; Varro, *Rust.* 1.68; Ciaraldi 2007: 119, 132).

The range of vegetables consumed in Herculaneum is more difficult to determine as plant flesh and tissue have not survived. None of the root vegetables, mushrooms or leafy vegetables can be seen in the Cardo V deposit and we only have evidence for plants whose seeds were also used as a seasoning. We know that cabbage, mustard, celery and carrot were consumed in Herculaneum and the rest must remain speculative. The situation is similar with regards to seasonings, as only flavourings where the seed was used will survive. However, even that is not always the case. Cumin and anise seeds were used in Roman times, but archaeological evidence for these plants has only been recovered from desiccated sites in Egypt and waterlogged northern and central European deposits (Kuijper and Turner 1992: 195; Van der Veen 2001: 180; Bakels and Jacomet 2003: 543; Van der Veen and Tabinor 2007: 113; Livarda 2011: 144). Nevertheless, except for these two items, it appears that the sources are again accurate in their descriptions of the commonality and cost of herbs and spices. Barring the black pepper, only local and easily grown culinary herbs are found in the sewer such as dill, coriander, fennel and poppy. The recovery of caraway and sesame seeds from Pompeii indicates that other expensive imported seasonings were available in the area, and it is not surprising that they are absent from the Cardo V sewer bearing in mind the socioeconomic status of the inhabitants (Ciaraldi 2007: 102; Fairburn 2012).

7.2.2 Animals

Considering issues of preservation and identification, the relationship between the ancient texts and the recovered animal products are closely matched. Boneless pieces of meat and dairy products degrade entirely and unfortunately, the animal bones from the sewer have not yet been studied, and thus little can be said about them. However, the preservation of the eggs, fish and shellfish remains was excellent and so a full comparison is possible. As shown in section 5.9, the eggshell assemblage was composed almost exclusively of chicken egg and this is in line with the statements of Horace (*Sat.* 2.2.45) that chicken eggs were a cheap and common item.

The fish assemblage is dominated by what the Romans considered to be fish for the poor. There are sharks, rays, sardines, anchovies, pilchard and numerous types of sea bream. Most of the fish genus or families mentioned by the sources are also present including mackerel, wrasse, weavers, grey mullet, hake and flatfish. The presence of sea bass and moray were unexpected since both are stated to be expensive fish (Pliny *HN* 9.61, 9.170; Juvenal 5.103-6). However, as section will 8.4 point out, Herculaneum's proximity to the Bay of Naples meant that fish were probably cheaper there than many other places in the Empire. Therefore, the only missing fish, discussed extensively by the sources, is tuna (Marzano 2013: 66-77). However, tuna was often salted or turned into fish sauce where none or few bones are present (Pliny *HN* 9.47-48; Martial 13.103). Consequently, even if it was consumed, it is unlikely that any remains would survive in the sewer. It is also possible that it was too expensive for those living in *Ins. Or.* II.

Unlike the plants and fish, where the most commonly discussed foods are those most frequently found in the sewer, the most ubiquitous Cardo V shellfish are absent from the written sources or barely mentioned. The sources focus on oysters and murex, and while these items were recovered from the sewer, the majority of the shellfish material consisted of wedge shells, limpets, cockles and scallops. Only Galen (*SMT* 12.362) and Athenaeus (*Deipn.* 85e-86b) discuss wedge shells while Pliny (*HN* 9.101) makes a single reference to scallops. In his general section on shellfish, Pliny (*HN* 9.101-42) states that they are suitable for consumption, but his discussion focuses more on other products such as pearls and purple dye. It is clear that while shellfish were an important part of the diet in Herculaneum, they were not considered by the ancient authors to be a valuable or significant foodstuff and therefore were not worthy of discussion. Thus while the sources are a helpful resource in understanding ancient diet, the discrepancy in the actual shellfish remains highlights the importance of using both the written texts and the physical remains in conjunction with one another.

In conclusion, the descriptions of common, everyday food stuffs in Italy, and even throughout the Mediterranean, corresponds quite closely to the finds from the Cardo V sewer. The ancient texts should therefore be considered a valid and reliable source, although not to be used to the exclusion of the bioarchaeological material. The proximity between the sources and the sewer material indicates that when environmental remains are not available, as in the case of dairy products, the ancient sources can be utilized to fill in the gaps. The only considerable departure between the sources and the remains, except for the shellfish, is in the consumption of expensive or luxury goods. People of middle to lower socioeconomic standing in Herculaneum were eating more expensive foods than one would expect based on the statements of the ancient authors. In theory, they should not be able to afford black pepper and sea bass. Whether the difference is due to an over exaggeration of value and prices by the authors or to the considerable wealth of Herculaneum remains to be answered.

7.3 Nutritional assessment of the *Insula Orientalis* II diet

7.3.1 Background information

It is only in the past 200 years that human nutrition has been understood from a physiological and biological perspective (Stipanuk 2006: 4-8). The topic can be discussed on a molecular and even atomic level, but for the purposes of this thesis only a cursory overview will be provided.

The human diet, like that of most omnivores, is diverse. The human body cannot generate all the energy and nutrients it needs for proper functioning and instead these elements must be obtained from a range of foodstuffs. There are nine essential amino acids, 14 vitamins, 15 minerals and two fatty acids which the body cannot produce itself (Table 7.1).

Table 7.1. Essential nutrients

Amino acids	**Vitamins**	**Fatty acids**	**Minerals**	**Other**
Isoleucine	C (Ascorbic acid)	Linoleic	Calcium (Ca)	Water
Histidine	A	α-Linolenic	Phosphorous (P)	Carbohydrates
Leucine	D		Magnesium (Mg)	Protein
Lysine	K		Iron (Fe)	Fats
Methionine	E		Sodium (Na)	
Phenylalanine	B_1 (Thiamin)		Potassium (K)	
Threonine	B_2 (Riboflavin)		Chloride (Cl)	
Tryptophan	B_3 (Niacin)		Zinc (Zn)	
Valine	B_6		Copper (Cu)	
	B_{12}		Manganese (Mn)	
	Panthothenic acid		Iodine (I)	
	Folate		Selenium (Se)	
	Biotin		Molybdenum (Mo)	
	Choline		Chromium (Cr)	
			Fluoride[95] (F)	

Stipanuk 2006: 7; USDA DRI tables

Carbohydates, fats, and proteins provide the necessary building blocks for growth and energy. Amino acids are required for the creation of protein molecules while fatty acids are essential for cell function and cell membrane structure (Webb 2006: 124-128;

[95] Fluoride is not considered an essential nutrient. However, it is extremely important in the protection of tooth enamel and thus is included by the USDA.

Geissler and Powers 2011: 154). Vitamins and minerals are necessary for a range of biological activities including metabolism, gene expression and blood clotting. Although deficiencies in some of these nutrients can cause severe health problems, deficiencies in particular nutrients are more common and less harmful than others. Iron deficiency is the most frequent shortage amongst modern populations while the rates of copper deficiency are almost negligible (Geissler and Powers 2011: 250, 261).

Dietary reference intake (DRI) tables indicate the required daily amount of a particular nutrient or vitamin for optimal health and the prevention of chronic disease (USDA 2013a).[96] The nutritional assessment of a diet evaluates the foods consumed and their nutrient value in relation to health and deficiency.

7.3.2 Methodology and limitations

It has been well documented in modern scholarly publications that any attempt at a nutritional reconstruction of ancient diet is a risky undertaking (Wing and Brown 1979: 8; Dennell 1979: 121-127). The archaeological record is not complete and therefore we cannot know with certainty every item people consumed and in what quantities. While valuable, the ancient sources, as described above, provide only secondary evidence for consumption practices. To assess a diet based on their statements requires too much guesswork. Nevertheless, statements are continuously and repeatedly published about ancient nutritional status and health often based on estimates of only bread, wine and olive oil consumption (Jasny 1950: 228-9; Foxhall and Forbes 1982; Sippel 1987: 50-51; Garnsey 1999: 19; Curtis 2008: 373). Since the 1960s and 70s, significant progress in the fields of food science, human nutrition and bioarchaeology have generated a wealth of data that has yet to be fully utilized by scholars of the ancient world (Friedman 1991; Garnsey

[96] Full DRI tables are available on the FDA website. http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/5_Summary%20Table%20Tables%201-4.pdf .

1999: 4; Stipanuk 2006: 8; Winter and Davis 2006). The simple outlook on ancient nutrition must be updated if we are to achieve a more accurate and nuanced picture of diet and health in the ancient world.

In the following section I will attempt to assess the nutritional status of those living in *Ins. Or.* II. I acknowledge that this is a risky undertaking yet I have made every attempt, through the incorporation of modern food and nutritional science as well as the ancient sources, to minimize the amount of bias. This exercise is not only designed to provide nutritional information, but to demonstrate how advances in modern nutritional data can be used to investigate as yet unexplored avenues of research in archaeology and ancient diet.

7.3.3 Nutritional criteria

The high level of preservation in the sewer, as well as its function as a cess pit, means that we have a fairly good estimation of the range of items being consumed in *Ins. Or.* II. There are some obvious items missing, including all dairy products, boneless portions of meat and the leafy parts of vegetables. The ancient authors have helped to fill in the gaps, mentioning and describing many of the foodstuffs that do not survive. Nevertheless, we do not have definitive evidence that these missing items were consumed and so they have not been included in the assessment. Only the foodstuffs present in the sewer have been assessed under the assumption that if these items provided a sufficient amount of vitamins and minerals, then all the missing items would simply be providing additional (but not absolutely necessary) nutrients. To minimize bias, we will work only with what we know.

Some criteria and assumptions must be established. Firstly, we need to establish the physical characteristics of the people we are assessing. Depending upon sex, age, and especially in the case of pregnant or lactating women, nutrient requirements will vary. In this study, the nutrient requirements are based on a man and a woman, each between the ages of 19-30, since people of this age represent the point at which optimal genetic potential can be achieved.[97] The 'average' man is 177 cm tall and weighs 70 kg while the woman is 163 cm tall and weighs 57 kg (A Report 2005: 34-36). They have an active but not physically labour intensive lifestyle.[98] Unlike modern western populations, the Romans did not know about specific nutrients and we need to assume that people ate roughly the same diets. For example, while a woman may have consumed more while lactating, she would not have consciously been aware that she needed more calcium or phosphate and therefore consumed more dairy (Geissler and Powers 2011: 250).

The second set of criteria involves the food itself. Since the majority of the items consumed in *Ins. Or.* II were grown, raised or caught in the Vesuvian area, it is probable that many of the foodstuffs were consumed fresh. Nutritional values have been calculated for the food finds from the Cardo V sewer. Data and references for precise nutrient quantities can be found in Appendix C. The majority of the values were obtained from the USDA Food Nutrient Database (USDA 2013b). It was not always possible to match the Herculaneum items to an entry in the USDA database exactly. Subsequently, when no precise species comparison was available, the nutrient values for a range of species within that genus were recorded. The food type column indicates whether nutrient values were established for raw, cooked or dried foods.[99] The values are calculated for a 2 g sample for the seasonings and a 100 g sample for all other food unless otherwise stated. These nutritient values were then compared to the DRIs to assess the quantity of each nutrient in the diet.

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[97] Full DRI tables can be found in Appendix C.

[98] Although people in ancient Herculaneum no doubt participated in more labour intensive activities than most people living in the western world today, the people living in *Ins. Or.* II appear to be primarily shop owners or craftsmen and are not engaged in extremely labour intensive activities such as farming or fishing.

[99] It should be kept in mind that the nutrient quantities will vary considerably when comparing raw/dry and cooked foods. These differences have been taken into account in the following analyses and the cooked examples have been used whenever that was the most probable manner of consumption, as for example, with cereals.

7.3.4 Macronutrients

Macronutrients are the basic components of the human diet (Table 7.2). They are divided into five categories; carbohydrates, proteins, fats, essential fatty acids and fiber. The Cardo V foodstuffs would have provided people with a range of available options in each category and it is unlikely that people had any difficulty in obtaining a sufficient amount of macronutrients and calories. The primary source of carbohydrates would have been the cereals and pulses. Since people were probably eating whole grain bread and porridges, the cereals, along with figs, would have provided excellent sources of dietary fiber. Olives, olive oil and nuts were valuable sources of fats and polyunsaturated fatty acids. It is often assumed that people in the ancient world ate a heavily carbohydrate based diet with only a few sources of protein (Sippel 1987: 50-53; Curtis 2008: 373). However, the Herculaneum diet contained numerous sources of protein including fish, shellfish, nuts, eggs and legumes. Considering the ubiquity of these sources (see sections 5.9-12), it is unlikely that people were protein deficient. Since essential amino acids are derived from protein, it is also unlikely that people had any amino acid deficiencies.

Table 7.2. Macronutrient functions and sources

Macronutrient	Function	Sources from Herculaneum and the Cardo V sewer
Carbohydrates	Metabolic fuel	Millets, dried dates, wheat, dried figs, lentils, broad bean
Total fiber	Aids in gastro-intestinal function, increases nutrient absorption, protects against colon cancer	Dried figs, wheat, hazelnuts, dried dates, walnuts, broad bean
Fat	Energy, absorption of fat soluble vitamins, maintenance of cell membranes	Nuts, eels, olives, sardines
Polyunsaturated fatty acids	Cell function, cell membrane function	Nuts, eels, sardine, mackerel
Protein	Energy, source of essential amino acids	Pine nuts, clams, fish, walnuts, wheat, legumes

Webb 2006: 124-128, Stipanuk 2006: 21-22; Giessler and Powers 2011: 112-176

7.3.5 Vitamins and minerals

Simply because people were eating enough calories or enough protein does not necessarily mean that they were consuming sufficient quantities of vitamins and minerals. Even today, large percentages of the population in developing and developed countries are deficient or marginally deficient in certain nutrients (Giessler and Powers 2011: 199). Many people in the UK are slightly magnesium deficient while over half of the world's population are zinc and iron deficient (Webb 2006: 99-101; Salter 2012: 260).[100] Each essential vitamin and mineral will be discussed below in order to assess the likelihood that those living in *Ins. Or.* II were deficient in a particular nutrient (Tables 7.3 and 7.4).

7.3.5.1 Fat-soluble vitamins

Vitamin A

People were probably not vitamin A deficient. Thirteen of the Cardo V foodstuffs had vitamin A levels higher than 300μg per 100g sample, with each serving providing over 1/4 of the daily required amount. The range of foodstuffs with moderate to high levels of vitamin A was diverse, including many of the fish and shellfish species as well as cherries, plums and blackberries. If some of these items were not in season or too expensive then there were several other options.

Vitamin D

The best source of vitamin D comes from UV-B rays generated by sunlight. Considering Herculaneum's geographical location, obtaining sufficient amounts of vitamin D should not have been difficult. Nevertheless, there were several excellent dietary sources of vitamin D that would have helped make up for the smaller amount of sunlight available in

[100] It should be kept in mind that mild deficiencies in certain nutrients will not cause any symptoms or disease and the condition is not fatal. The deficiency can however result in a compromised immune system, leaving the individual more vulnerable to illness and infection.

the winter. Eels contain extremely high levels of vitamin D while the oily fish species, including sardines, mackerels and herrings all contain moderate amounts. Eggs are also a good source, with one egg providing twice the required daily intake.

Vitamin E

The Cardo V material does not contain many foodstuffs with large quantities of vitamin E. Only four foods would have made significant contributions towards the daily requirements: hazelnuts, pine nuts, eels and land snails. Nevertheless, vitamin E is found in small quantities in almost all of the other foodstuffs and deficiency only arises after months of low level vitamin E consumption (Geissler and Powers 2011: 238). It is possible that people were slightly vitamin E deficient but it is unlikely to have had any adverse effects. The consumption of the many types of leafy green vegetables mentioned by the ancient sources would have prevented deficiency (see section 7.1.1).

Vitamin K

Pine nuts were the only excellent source of vitamin K recovered from the sewer. There are an additional seven foodstuffs where one serving would have provided approximately 10% of the daily requirement. Although the number of items is small, they were probably commonly consumed foods including wheat, dried figs, grapes, hazelnuts and blackberries. Green vegetables such as kale and cabbage are also excellent sources but we do not know if and how much of these foods they consumed (USDA 2013b). However, naturally occurring intestinal bacteria also produce vitamin K, making deficiency very rare (Geissler and Powers 2011: 241).

7.3.5.2 Water soluble vitamins

Vitamin B_1 (Thiamin)

The people living in *Ins. Or* II were not thiamin deficient. Their diet had many good sources including eight foodstuffs where one serving would have provided at least 1/3 of the required daily intake. These items included staple foods such as wheat and millet. In addition, almost all the other foodstuffs contained moderate to small amounts of this vitamin.

Vitamin B_2 (Riboflavin)

Riboflavin is an unusual vitamin. Firstly, while deficiency is common, the body is very good at using its available sources and thus there are no adverse effects. Secondly, studies have found that people with mild riboflavin deficiency living in areas where malaria is endemic are relatively resistant and have a lower parasite burden than those achieving the daily recommended intake (Geissler and Powers 2011: 204). Within the Cardo V assemblage, only lentils and cuttlefish have high levels of riboflavin. However, another 12 foodstuffs have been 0.4-0.2 mg, where each item provided been 15-30% of the daily required intake. Therefore, people in Herculaneum were probably not riboflavin deficient, although if they were it may have helped to protect them against malaria.

Vitamin B_3 (Niacin)

Consuming enough niacin was not difficult in ancient Herculaneum and pellagra was probably extremely rare. Both white and oily fish species, including sardines, mackerel, garfish and in particular, anchovies, are very good sources of niacin. Wheat and barley are also good sources with a 100 g portion of wheat bread (two modern slices) providing 25% of the daily intake. In total there are 15 foodstuffs that contain at least 3.2 mg, with each 100 g serving equal to 20% of the daily required amount.

Vitamin B_6

Worldwide, vitamin B_6 deficiency is rare as it is found in many foods and can be synthesized by the intestinal flora (Geissler and Powers 2011: 208-209). Similar to niacin, there were many good sources of vitamin B_6 in the *Ins. Or.* II diet so deficiency is unlikely. The best source is garfish, followed by hazelnuts, walnuts, cherries, mullet and wheat. There are 11 foodstuffs containing 0.3 mg or more, providing at least 20% of the daily recommended intake.

Vitamin B_{12}

Vitamin B_{12} deficiency only occurs amongst strict vegans and thus was probably not a problem in Herculaneum (Geissler and Powers 2011: 215). The recommended daily intake is 2.4 µg/d and nine of the fish and shellfish species, including cooked clams, mussels and sardines provide much more than that amount.

Folate

Folate deficiency is not uncommon and 8-10% of people in developed countries have low levels of folate in their diets (Geissler and Powers 2011: 212). In Herculaneum, there were several moderate to low sources of folate including legumes, nuts and wheat. Obtaining a sufficient amount of folate depended on the quantity of foods consumed. However, since 100 g of cooked lentils provide over 1/4 of the daily requirement, it is probable that deficiencies, if they existed, were mild.

Vitamin C

It is very unlikely that scurvy was a problem in Herculaneum, although intake levels may have been low. While many of the Cardo V foods contain small amounts of vitamin C, there are very few that have nutritionally significant amounts. Melons, black mulberries, clams and blackberries are the best sources, where a 100 g serving provides at least 20% of the daily requirement. Again, it is the quantity that would have differentiated between getting enough vitamin C to avoid scurvy (7-10 mg/d), to allow for proper wound healing (20 mg/d) and to achieve optimal health (40 mg/d).[101]

Biotin

Biotin is so common in foodstuffs (in addition to being made by the intestinal flora) that it is not even calculated by the USDA in their nutrient evaluation of foodstuffs and it is assumed that people receive a sufficient amount in their diets to avoid deficiency (Geissler and Powers 2011: 221). Deficiency in Herculaneum is extremely unlikely.

Pantothenic acid

Similar to biotin, pantothenic acid is found in most foods and is also synthesized by the intestinal flora (Geissler and Powers 2011: 221). Deficiency in healthy individuals is almost impossible. The highest sources of pantothenic acid in the Herculaneum diet included hazelnuts and mackerel. The majority of the fish, fruits, cereals and legumes also contained moderate to low amounts of this vitamin.

Choline

In addition to being found in foods such as eggs and liver, choline can also be synthesized in the body from the amino acid methionine. While scientists are still uncertain if the amounts created within the body are high enough for optimal health, choline deficiency is not a wide spread problem (Talbott and Hughes 2007: 154-155). The *Ins. Or.* II diet included a wide variety of foodstuffs with high to moderate amounts of choline, thus ensuring a sufficient supply regardless of season or financial considerations. Eggs were by far the best source, followed by several species of fish, shellfish, nuts and legumes.

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[101] According to the NHS (UK) (http://www.nhs.uk/Conditions/vitamins-minerals/Pages/Vitamin-C.aspx), an individual only needs 40mg/d day while the DRIs for the United States state that a person needs between 75-90mg/d.

Table 7.3. Vitamin functions, deficiencies and sources. The top sources of each vitamin are presented first, followed by the best sources recovered from the Cardo V sewer.

Vitamin	**Function**	**Deficiency disease**	**Good sources**
Vitamin A (Retinol)	Gene expression, tissue differentiation, vision	Xerophthalmia – causes blindness, increased susceptibility to infection	Liver, full-fat dairy products, oily fish, kidneys, and dark green, yellow, red, orange fruits and vegetables HERC: European eel, cherries, plums, clams, cuttlefish, pickled olives, eggs, shark, blackberry, mackerel
Vitamin D (Cholecalciferol)	Calcium homeostasis, regulation of cell differentiation and proliferation	Rickets (children), Osteomalacia (adults)	Oily fish, fish liver oils, eggs, full-fat milk products, liver HERC: eels, oily fish – sardine, mackerel, flatfish, grey mullet, eggs
Vitamin E (α-tocopherol)	Antioxidant, cell signalling, gene expression, inhibition of cell proliferation and platelet aggregation	None	Fish, nuts and seeds, vegetable oils, beans, green leafy vegetables HERC: mint, hazelnut, pine nuts, eel, snails, pickled olives, eggs
Vitamin K (Phylloquinone)	Blood clotting, regulation of apoptosis	Haemorrhagic disease	Nuts, seeds, and nut and seed oils HERC: pine nuts, blackberries, dried figs, grape, hazelnut, mulberry, wheat
Vitamin B_1 (Thiamin)	Coenzyme, electrical conduction in nerve cells	Beriberi, Wernicke-Korsakoff syndrome	Pork, meat, fish, wheat, nuts, beans HERC: barley, hazelnuts, foxtail millet, wheat, pine nuts, walnuts
Vitamin B_2 (Riboflavin)	Metabolism, mitochondrial function, setting circadian rhythms	None	Milk, eggs, liver, meat, fish, leafy vegetables HERC: cuttlefish, lentil, clam, mackerel, eels, barley, sardine, wheat
Vitamin B_3 (Niacin)	Part of coenzyme responsible for oxidation and reduction reactions	Pellagra	Meat (esp. liver and heart), fish, nuts, some fruit and vegetables HERC: oily fish – anchovy, mackerel, garfish, bread wheat

Vitamin	Function	Deficiency disease	Good sources
Vitamin B_6 (Pyridoxine)	Metabolism, steroid hormones, regulation of gene expression	Extremely rare	Meat, fish, milk, nuts, beans, vegetables HERC: garfish, hazelnut, walnut, wheat, grey mullet
Vitamin B_{12} (Cobalamins)	Metabolism	Only occurs amongst strict vegans	Liver, fish, meat (not found in plants) HERC: cooked clams, cooked mussels, sardines, eels
Folic acid (Folate, folacin)	Necessary for many carbon reactions	Megaloblastic anaemia, neural tube defects in newborns Mild deficiency causes depression, insomnia, forgetfulness, irritability, sometimes cognitive impairment and dementia	Liver, green leafy vegetables, beans, nuts, milk, some fruits HERC: lentil, hazelnut, broadbean, walnut, wheat
Biotin	Cell proliferation	None	In most foods
Pantothenic acid	Metabolism, biosynthesis of fatty acids	None	In most foods HERC: mussels, hazelnuts, mackerel, garfish, small amounts in all fruit
Vitamin C (Ascorbic acid)	Hydroxylation reactions, reducing agent, anti-oxidant	Scurvy	Fruits and vegetables HERC: black mulberry, clams, blackberry, mussels, cherries, plums
Choline	Liver function, cardiovascular health, brain development, cell structure integrity, cell membrane signaling, neurotransmitter formation, lipid transport	Liver dysfunction	Eggs, milk, beef, liver HERC: eggs, sharks, eels, clams, sardines, scallops

Stipanuk 2006: 703; Talbott and Hughes, 2007: 154-155; Geissler and Powers 2011: 199-245; USDA nutrient database, 2013b

7.3.5.3 Minerals

Calcium

Sufficient levels of calcium can be difficult to obtain and maintain. It is required in large quantities, yet significant amounts of calcium are lost every day during urination (Geissler and Powers 2011: 249). The people living in *Ins. Or.* II had access to numerous sources of calcium and their consumption practices meant that they probably received adequate amounts. The small fish, including sardines, anchovies and mackerels have the largest quantities of calcium, and as shown in section 6.2.3, the consumption of the bones of these fish would have further increased calcium intake. Other good sources include dried figs, oysters and hazelnuts.

Chromium

Chromium deficiency does not occur in people and therefore it is not measured in nutritional charts and it is not included in the USDA database (Expert group 2002: 3).

Copper

Copper is another element where deficiency is extremely rare in healthy individuals. It is found in many foods and has a high absorption rate within the gut (Geissler and Powers 2011: 261). There are nine foods from the Cardo V sewer, including all three nut species, where a 100 g serving provides more than the daily copper requirement. Other good to excellent sources include bogue, clams, land snails, hake, dried figs and wheat.

Iodine

Iodine is not measured by the USDA and therefore it is difficult to estimate intake. Nevertheless, the best dietary sources of iodine come from marine fish, shellfish, sea salt and seaweed. Based on the ubiquity of fish and shellfish remains from the sewer, it is safe to assume that iodine deficiency was not a common occurrence in Herculaneum.

Iron

Iron deficiency anemia is the most common deficiency in the world, present in over 2 billion people (Geissler and Powers 2011: 250). Mild anemia does not have any adverse effects, and considering the range of protein choices available to those living in *Ins. Or.* II, severe anemia was unlikely to occur. The *Ins. Or.* II diet was rich in iron with 22 foodstuffs providing at least 2 mg, or 1/4 of the daily required intake. Staple foods such as wheat and lentils, in addition to the many fish and shellfish species all have nutritionally significant iron levels. However, as will be shown in detail in section 7.4.2, due to the (probably) limited quantities of red meat in the diet and the method of bread production in Roman Italy, it is probable that mild anemia was common in Herculaneum.

Magnesium

Although magnesium deficiency is relatively common today in the UK due to unhealthy dietary choices (too much refined sugar and grains), it is unlikely to have been common in ancient Herculaneum (Webb 2006: 99-101). Moderate to high levels of magnesium are found in a range of foodstuffs from the sewer, including staple foods such as wheat and common millet. Pine nuts and snails are the best sources, providing over half of the daily recommended intake. These foods are followed closely by hazelnuts and walnuts.

Manganese

Manganese deficiency only appears in those with diseases that disrupt intestinal absorption (Webb 2006: 101). Almost all of the foodstuffs from the sewer contain manganese, with seven foodstuffs, including wheat and nuts, containing 50% to over 100% of the daily recommended intake. Manganese levels are also moderate to high in many of the legumes, fruits and shellfish.

Molybdenum

Deficiencies do not occur in this nutrient as it is found in almost all foodstuffs and it is not recorded by the USDA.

Phosphorous

Phosphorous is present in large to moderate quantities in all the Cardo V foodstuffs except for the fruit and seasonings. Since it is such a common component of foods, deficiency is extremely rare and most of the phosphorous in the Herculaneum diet probably came from cereals and fish. There are seven foods, including emmer, bread wheat and sea bream where a 100 g serving provides at least 50% or more of the daily required intake.

Selenium

Selenium can be obtained from plant and animal sources, although the amount of selenium in a plant depends significant on the quantity of selenium in the soil. The Vesuvian region has not been identified as an area with selenium deficient soil and thus a sufficient amount would have been consumed (Geissler and Powers 2011: 259-261). Moreover, mussels, clams, sardines and cuttlefish all contain high levels, as do anchovies, mackerel, sharks and rays.

Zinc

The typical omnivorous diet should provide enough zinc to avoid deficiency. The *Ins. Or.* II diet was clearly omnivorous although the potential for high levels of phytate in the diet, which hinders zinc absorption, may have led to mild deficiencies (Geissler and Powers 2011: 257) (see section 7.4). Nevertheless, there are 16 foodstuffs with at least 2 mg or more, providing almost 20% of the daily recommended intake. Included in this list are pine nuts, wheat, barley, mussels, anchovies and cuttlefish.

Potassium

Despite potassium requirements being the highest of all the minerals, deficiencies do not occur as it is found in almost all foodstuffs. Excellent sources of potassium from the Cardo V material can be found in a range of food groups and thus it would not have been difficult to consume a sufficient amount of potassium throughout the year.

Sodium

Compared to the modern western diet, the *Ins. Or.* II diet would have been low in sodium. Nevertheless, in addition to the direct consumption of salt, seafood, fish sauce (see section 6.2.3) and salted goods would have provided sufficient amounts to avoid any kind of deficiency. In addition to pickled olives, a 100 g serving of clams, oysters, scallops or cuttlefish would have all provided over 20% of the daily sodium intake.

Chloride

Chloride is usually consumed with sodium in the form of salt (NaCl, sodium chloride), so sufficient sodium intake should result in sufficient chloride intake. Due to its association with sodium, chloride is not measured by the USDA.

Fluoride

Although not considered essential, fluoride does prevent tooth decay (Stipanuk 2006: 1127). Since the ground water in Herculaneum had a naturally high fluoride content, the majority of the fluoride would have come from the drinking water (Petrone *et al.* 2011). It could also be found in nine of the foodstuffs including grapes, apples, pears, cherries and black pepper.

Table 7.4. Mineral functions, deficiencies and sources. The top sources of each mineral are presented first, followed by the best sources recovered from the Cardo V sewer.

Mineral	Function	Deficiency disease	Good sources
Calcium	Bone formation, blood clotting	Osteoporosis	Milk and dairy products HERC: sardines, oysters, dried figs, anchovies, mackerel, hazelnuts, walnuts
Chromium	Carbohydrate and lipid metabolism, helps control blood glucose levels	Impaired glucose tolerance	Meat, nuts, cereal grains, brewer's yeast, spices HERC: Eel, mackerel, dogfish
Copper	Reduction-Oxidation reactions	None	Shellfish, liver, kidney, nuts, whole grain cereals HERC: goatfish, horse mackerel, hazelnut, walnut, pine nut, mussels
Fluoride	Mineralization of bones and teeth, protection against dental caries	None	Drinking water HERC: Water, grapes
Iodine	Essential component of thyroid hormones thyroxine and triiodothyronine – crucial regulators in metabolic rate and physical and mental development	Mild - Goitre Severe - mental retardation or cretinism If mother is deficient - mental retardation, hearing and speech defects	Marine fish, shellfish, sea salt, seaweed HERC: dogfish, eel, garfish
Iron	Binding haemoglobin in red blood cells, immune function	Anemia	Meat, cereals, vegetables, beans, pulses, fruits HERC: horse mackerel, mussels, pine nuts, hazelnuts, lentils, wheat
Magnesium	Component of several enzymes required for metabolism and cell function	Muscle weakness, spasms, personality changes, nausea, vomiting and anorexia	Leafy vegetables, whole grains, nuts, seafood, legumes HERC: nuts, snails, wheat, common millet, mackerel

Mineral	Function	Deficiency disease	Good sources
Manganese	Enzyme function	None	Most foods HERC: pine nuts, mussels, nuts, barley, wheat
Molybdenum	Enyzme co-factor	None	Most foods
Phosphorus	Bone formation, energy metabolism	None	Dairy, cereals, vegetables, meat, fish HERC: sea bream, pine nuts, wheat, sardine, eel
Selenium	Component of several proteins, cancer protection	Keshan disease	Cereals, meat, fish HERC: mussels, clams, sardine, cuttlefish, wheat
Zinc	Metabolism, enzyme co-factor, synthesis of DNA and RNA, antioxidant	Dermatitis, diarrhoea, impaired immunity, stunted growth	Meat, whole grains, shellfish HERC: pine nuts, mussels, anchovy, cuttlefish, wheat
Potassium	Cellular function	None	Fruits and vegetables HERC: mackerel, date, goatfish, dried figs, hazelnuts
Sodium	Muscle and nerve function, blood pressure maintenance	Hyponatraemia[102]	Salted fish and meat, shellfish HERC: pickled olives, fish and shellfish
Chloride	Muscle and nerve function, blood pressure maintenance	No associated disease (although a deficiency in chloride will likely correspond to a deficiency in sodium)	Salted fish and meat, shellfish (usually consumed with sodium since salt is composed of sodium chloride HERC: pickled olives, fish and shellfish

Webb 2006: 99-104; Stimpanuk 2006: 952-955; Geissler and Powers 2011: 246- 269

[102] Although this condition usually only occurs as a result of another activity or illness, for example, the over consumption of water or kidney failure.

7.4 Preservation, processing and cooking

Herculaneum is situated in a warm climate where food will spoil quickly. The recovery of fermented fish sauce along with dried figs, pears and plums from Herculaneum and Pompeii attests to the practice of preserving foodstuffs (Borgongino 2006: 88, 127, 137; Carannante 2008-2009). Preservation not only extended a food item's shelf life, but helped maintain dietary diversity throughout the winter. Moreover, not all food could be consumed raw (nor was that desired) and the Romans prepared and cooked their food in several ways (Apicius 8.8.8-13; Pliny *HN* 19.171; Galen *Alim. Fac.* 6.720-4). All these processing activities have a significant impact on the nutrient density of a food.

Unlike the often symbolic descriptions of foodstuffs in the ancient texts, discussions of food preservation methods are practical and straightforward. Distinct from several of today's preservation methods such as artificially created chemical preservatives and irradiation, there were a limited number of techniques available to people in the Bay of Naples (Tull 1983: 169-170). Drying, salting, pickling, fermentation, smoking and refrigeration (by keeping food in a cool dry place) were all used to store and preserve foodstuffs (Wing and Brown 1979:10; Thurmond 2006: 5-10). While textual descriptions of cooking may not be as straightforward as preservation techniques, the methods of preparation used by those living in Herculaneum were also limited. In association with the ancient sources, the recovery of pots, frying pans and baking trays from the Vesuvian region indicates that food was fried, grilled, boiled and baked (Apicius 8.8.8-13; Pliny *HN* 19.171; Galen *Alim. Fac.* 6.720-4; Tassinari 1993; Grocock and Grainger 2006:73-82).

The surviving textual and archaeological evidence allow us to assess which was the most common method or methods used on each foodstuff and subsequently, using modern nutritional science, we can examine the positive and negative nutritional impacts of these activities. For example, although B vitamins and protein are lost during the boiling of meat, this activity kills harmful bacteria (Wing and Brown 1979: 64-65; Muller and Tobin 1980: 253). Plant based foods can have antinutrients such as phytate and tannins. Phytate is a molecule found in cereals that hinders the absorption of iron, zinc and calcium and is removed during the milling process (Slavin *et al.* 2001: 53; Hotz and Gibson 2007: 1098). Tannins, which also decrease iron absorption, are found in broad beans and can be removed through, soaking, malting or germination (Stahl 1989: 176; Hotz and Gibson 2007: 1098).

7.4.1 Patterns of consumption

Prior to discussing the impact of processing and cooking techniques on nutrient density, we must first understand Roman consumption practices, particularly as they relate to those living in *Ins. Or.* II. In what form did people consume their different foods? Raw? Boiled? Salted?

Cereals, which formed the staple of the diet, were eaten in *Ins. Or.* II as bread and porridge (see section 6.2.1.2). Bread in Roman Italy was probably dense and heavy as Pliny (*HN* 18.68) seems to imply that not much yeast or leaven was used to make the bread rise. Leaven could be made by saving a portion of dough for the following day or soaking bran in unfermented white wine (Pliny *HN* 18.102-4). However, neither method would have produced a very fluffy loaf and there is no mention of the creation of sourdough. The consumption of legumes was more diverse. They could be boiled and eaten on their own, used in soups, added to porridge or made into flour and added to wheat flour to make bread (Galen *Alim. Fac.* 6.527-8; Pliny *HN* 18.117). Nuts could be eaten fresh or dried (Pliny *HN* 15.88-9, 23.147-9).

Fruit was the most diverse food group in the Roman world, allowing for the creation of numerous by-products and preservatives. Most fruits were eaten fresh or dried, especially figs and dates (Columella *Rust.* 12.15.1-5; Pliny *HN* 15.60; Ath. *Deipn.* D80e-82e;). Large quantities of (now carbonized) dried figs have been found throughout Herculaneum, including 2.9kg from the upper floor of a house on the *decumanus maximus* (Borgongino 2006; 88). In addition to grapes, fruits such as apples and pears were fermented into wine (Pliny *HN* 14.103). Dried figs could be made into bread while apples and pears could be made into jams and olives into oil (Columella *Rust.* 12.15.3-5, 12.42; Pliny *HN* 15.6, 15.58, 15.71). Syrups could be made from figs and blackberries while grape juice could be boiled down into must (Pliny *HN* 14.102, 14.83, 18.318, 24.117-120).

Little could be done to truly alter vegetables and seasonings. Leaves and seeds such as mustard could be pounded to make a paste and others such as cabbage could be boiled (Pliny *HN* 18.144; Cato *Agr.* 156-7; Columella *Rust.* 12.57).

Eggs, fish and shellfish were cooked using a range of methods or turned into edible by-products. The ancient sources attest to the consumption of raw, hard boiled, soft boiled and fried eggs (Apicius 7.17; Galen *Alim. Fac.* 6.705-9). Shellfish could be eaten raw or cooked by boiling or grilling (Galen *Alim. Fac.* 6.733-5). In addition to salted fish and fish sauce, fish were prepared by grilling, frying or baking (Galen *Alim. Fac.* 6.720-8; Ath. *Deipn.* D148e, D309e-f; Pliny *HN* 31.95). A small number of burnt fish bones were recovered from the Cardo V sewer.

7.4.2 Processing and cooking

There are five processing and four cooking techniques discussed by the ancient sources that would have had an impact on the quantity of nutrients in foodstuffs. As the following section will show, there was often a trade-off between increasing nutrient availability and the reduction of particular vitamins and minerals.[103]

[103] Nutrient differences for a selection of the Cardo V material can be found in Appendix C.

Soaking, milling and baking

These three processing methods were used principally on cereals and legumes. Pliny (*HN* 18.72-6) states that barley was soaked before being pounded into porridge. The ancients knew that soaking legumes made cooking easier and removed harmful toxins (Pliny *HN* 22.142-5). There is no mention of sprouting cereals or legumes, which would have increased digestibility and nutrient availability. Nevertheless, soaking of the grains and flour results in very little nutrient loss while decreasing the amount of phytate (Hotz and Gibson 2007: 1098; Duhan *et al.* 1989: 450-451).

The process of milling or pounding removes the bran and germ from the endosperm of a cereal grain. Both activities, whether to make flour or porridge, increase the calorific content of the final product by eliminating much of the insoluble dietary fiber and phytate. However, these processes do result in nutrient losses since the highest concentration of nutrients is in the bran (Slavin *et al.* 2001: 53). The amount lost depends on the extraction rate. An extraction rate of 75% or less is classified as white flour, where the flour has been finely sieved and most of the bran removed. Wholemeal wheat has an extraction rate of 100% as all the bran and germ are retained (Slavin *et al.* 2001: 53). The most significant losses occur in the B vitamins and folate, although levels of fat and protein decrease as well (Table 7.5). Pliny (*HN* 18.86-90) describes four grades of flour, *siligo, flos, cibarium* and *furfur* and thus extraction rates varied. *Cibarium* was probably the most common grade of flour for making bread (Moritz 1958: 170-172; Thurmond 2006: 55). Since Pliny lists them in order of descending quality, *cibarium* must have had a high extraction rate and been close to wholemeal flour.[104] As will be shown in section 8.3.1, it is unlikely that the flour consumed by those living in *Ins. Or.* II. was highly refined and it probably contained a significant amount of bran. Pliny (*HN* 18.105-7, 18.117) also claims that flour was often

[104] The ancients considered whiter flour to be of a higher quality (Pliny *HN* 18.105).

adulterated with broad bean flour to increase the weight. Ironically, this adulterant actually improved the nutritional quality of the bread. Cereals are low in protein and the amino acid lysine while legumes are high in lysine and have a greater protein content than cereals (Muller and Tobin 1980: 142, 149; Bhatia 1983: 458). Thus nutritionally they complement each other and it is best if they are consumed together. Although we do not know if they were consumed simultaneously in *Ins. Or.* II, both wheat and legumes were eaten and the residents would have received the nutritional benefits.

Table 7.5. The loss of nutrients during milling of wheat (100g) based on different extraction rates

Nutrient	**Extraction rate (%)**			
	100	85	80	70
Energy (kcal)	327	339	340.5	340.5
Protein (g)	13.6	13.6	13.2	12.8
Fat (g)	2.5	1.7	1.4	1.2
Fiber (g)	2.2	0.3	0.1	Trace
Calcium (mg)	28	19	15	13
Vitamin B_1 (mg)	0.4	0.35	0.25	0.08
Vitamin B_2 (mg)	5	2	1.6	1.1
Vitamin B_3 (mg)	0.16	0.08	0.08	0.05
Pantothenic acid (mg)	1.5	1.1	0.9	0.7
Vitamin B_6 (mg)	0.4	0.18	0.11	0.06
Biotin (μg)	5.0	-	1.4	1.1
Folate (μg)	35	18	13	-

Bender 1978: 141; Muller 1980: 240

Similar to milling, baking was both a harmful and beneficial process. Turning flour into bread increases the bioavailability of thiamin, folate and vitamin B6 but results in the decrease of several B vitamins and amino acids (Hotz and Gibson 2007: 1097). The bakeries at *Ins. Or.* II.1 and 8 and the eight finds of carbonized bread from Herculaneum indicate that bread was a constant part of the diet (Borgongino 2006: 143-144). However, the lack of much yeast in Roman bread would have ensured that large quantities of phytate remained, potentially resulting in mild zinc deficiency and anemia due to the poor absorption of iron (Giessler and Powers 2011: 251). Nevertheless, baking flour made from cereals was actually less nutritionally harmful than boiling grains to make porridge. Pliny provides recipes for making *alica* and *puls*, a more traditional form of *alica.* As stated in section 7.2.1, porridge was also consumed at *Ins. Or.* II and probably prepared by the residents themselves. Emmer wheat is pounded in a mortar and then sieved to remove the bran. Again Pliny (*HN* 18.109-117) lists three different grades, so the amount of bran varied. The porridge is then boiled to make the grains edible. The loss of B vitamins from boiling is around 40% while losses due to baking are only between 15-25%. During baking, only the outside of the loaf reaches very high temperatures and the inside remains cool enough to retain most of the nutrients (Muller and Tobin 1980: 255-256).

Thermal processing

Thermal processing involves the use of dry or moist heat to prepare food. Using any one of these methods, including boiling, frying and grilling, will alter the nutrient density of a foodstuff (Table 7.6). The heating process increases the bioavailability of thiamin, vitamin B_6 and folate but at the same time results in the loss of vitamins C and $B_{2.}$ (Hotz and Gibson 2007: 1097).

Boiling was a common method of food preparation according to the ancient sources. Meat, shellfish, vegetables and even fruit were boiled. Galen (*Alim. Fac.* 6.604, 6.733-5) attests to the boiling of pears and states that all shellfish except oysters were boiled. The nutritional impact of boiling depends heavily upon the amount of water used and cooking time; the more water and the longer the cooking time the greater the nutrient loss (Muller and Tobin 1980: 253). The survival of otoliths and chewed fish bones in the sewer indicate that when fish were fried or boiled in *Ins. Or.* II it was not for very long as lengthier cooking times would have softened the otoliths and bones to the point where they would not have survived (Rebecca Nicholson May 19, 2012, pers. comm.). Consequently, the nutrient losses were probably minimal. However, in all foods there is a moderate to significant loss of almost all the essential vitamins and minerals (Table 7.6). In vegetables, the water soluble vitamins are particularly vulnerable (Tull 1983: 176-77). According to Pliny (*HN* 19.171), mustard leaves were boiled just like all other vegetables, attesting to the frequency of this practice. In meat, protein can be lost. Steaming, due to its minimal use of water, is a far less destructive process (Hotz and Gibson 2007: 1097), but it does not seem to be described by any of the ancient authors. Nevertheless, boiling was an important way to eliminate harmful bacteria and parasites, especially from meat and shellfish. A limited number of the shellfish fragments from the sewer did show signs of burning. Boiling could also make salted goods more palatable by removing the majority of the salt.

Grilling and frying were primarily used in the preparation of meat and fish. Galen claims that hake, drums and horse mackerel could all be fried while in Athenaeus, gurnard is considered best when grilled over an open fire (Galen *Alim. Fac.* 6.720-8; Ath. *Deipn.* D309e-f). Similar to baking, frying only causes the outside of the food to reach very high temperatures. Subsequently, nutrient losses are fewer and it is only the heat sensitive vitamins C and B_1 that are usually lost in substantial amounts (see Table 7.6).

Fermentation and germination

Fermentation was used to make some of the staples of the Roman diet. Grapes and other fruits were fermented to make wine while dairy was fermented to make cheese and fish to make *garum.* A piece of carbonized cheese has reportedly been recovered from Herculaneum, although the identification is questionable (Capasso 2002: 122). Grapes, or wine, were also fermented to make vinegar, which was an important preservative, antibacterial and antifungal (Columella *Rust.*12.5). Although it does not necessarily enhance the nutrient availability of foods, fermentation did allow nutrient dense foods such as dairy products, to be converted into goods that would not spoil as quickly (Thurmond

2006: 6). Moreoever, there is little nutrient loss associated with fermentation and it acts as an excellent source of beneficial bacteria for the digestive track.

Germination and malting do not seem to have been popular activities in Roman Italy. The malting of barley to make beer was popular in the northern provinces, but Pliny (*HN* 14.149) claims that beer was not brewed in Italy.

Table 7.6 Impact of food processing and cooking on nutrients

Process	Positive impact	Negative impact	Food
Soaking	Passive diffusion of phytate out of the flour		Cereals
	In chickpeas, removes toxin causing lathyrism		Legumes
Milling	Increases calorific content	Reduction in selenium and pantothenic acid	Cereals
	Increases digestion and absorption by removing insoluble dietary fiber and phytate	Decrease in quantity of protein, fat, fibre, folate, B vitamins, minerals	
	Protein quantity remains same	Refined flour with low extraction rate - significant nutrient loss	
Baking	Minerals remain stable	Considerable loss of antioxidents, but can create new ones	Cereals
	Less vitamin loss than with boiling	Loss of vitamin C and folate	
	Increase absorption of niacin	Loss of lysine (up to 15%) and thiamin (15-30%)	
Thermal processing – boiling, frying, grilling	Increase bioavability of thiamin, B6, niacin, folate, carotenoids	Loss of vitamin A, C, thiamin, riboflavin, and minerals	All foods
	Causes phytate degradation	Significant vitamin losses	Cereals
		Losses of thiamin, riboflavin, niacin and protein with all cooking techniques, if water is added more protein lost	Meat
Boiling		Medium losses (~50%): Vitamins – A, D, E, B_3, B_6, biotin, pantothenic acid Amino acids – lysine, threonine	All foods
		Large losses (>75%) of: Vitamins – C, B_1, B_2, B_{12}, K, folate Amino acids – isoleucine, leucine, methionine, phenylalanine, tryptophan, valine Essential fatty acids	
		Significant losses of A and C, will also loose thiamin, riboflavin, niacin	Vegetables
		Significant losses of water soluble vitamins	
		Protein loss	Meat

Process	Positive impact	Negative impact	Food
Frying/grilling	Absorption of vitamin E from cooking oil during frying	Loss of heat sensitive nutrients vitamin C and B_1	All foods
		Losses of B_1, B_2, B_3, pantothenic acid – around 20% 20-30% loss of lysine in white fish	Meat Fish
Fermentation	Grains – can break down phytate Improves protein quality and digestibility and vitamin B content		Cereals
	Increase in amounts of B_2, B_3, B_6		Cereals and legumes
	Increase in acidity prevents bacterial growth		All foods
Germination/malting	Decrease in amount of phytate, especially in millet		Cereals and legumes
	Reduction of tannins and other polyphenols, leading to better iron absorption		Legumes
Chopping		40% loss of vitamin C	Vegetables

Bender 1978: *passim*; Wing and Brown 1979: 64-65; Muller and Tobin 1980: 235-265; Tull 1983: 181-224; Slavin *et al.* 2001; Thurmond 2006; Hotz and Gibson 2007; Geissler and Powers 2011: 32-35.

7.4.3 Preservation

As stated above, preserving foodstuffs was important for the maintenance of health during the winter. According to the ancient sources, the Romans used six forms of preservation as well as air tight storage (Table 7.7). Refrigeration, in the modern sense, was not available, but several ancient authors constantly state that preserved foods should be stored in a cool dry place such as a pit or a loft (Cato *Agr.* 7.2; Columella *Rust.* 12.45-46; Varro *Rust.* 1.54.2; Thurmond 2006: 175-76). As shown in section 2.5, large quantities of food were often kept on upper floors in Herculaneum.

Desiccation was the most common form of preservation, used on every type of foodstuff except for fish and eggs.[105] It is a straightforward process that does not require any special equipment. Columella (*Rust.* 2.10.16) and Cato (*Agr.* 116) attest to the drying of millets and lentils respectively before storage to prevent spoilage. Since the cereal caryposes and pulse seeds would still be intact at this point, as shown by the large stores of clean grain recovered from Herculaneum, there would be little nutrient loss (Wing and Brown 1979: 64-5; Thurmond 2006: 15; Borgongino 2006: 101-103) (see fig. 2.24). In fruit, the heat sensitive vitamins C and B_1 are lost (Thurmond 2006: 174). However, the removal of water from the fruit means that the remaining macro and micronutrients are concentrated and thus the overall nutrient levels compared to the identical amount of fresh fruit are considerably higher. Figure 7.1 highlighs the nutrient changes between 100g of fresh and dried figs. All of the minerals and all but three of the vitamins increase when the figs are dried. Although they were not aware of the reason, Cato's (*Agr.* 56) claim that fig rations should increase in the winter indicates that the Romans knew dried fruit was an important source of energy and nutrients.

[105] Fish could be dried in the sun, but it seems that the Roman preferred to preserve fish through salting or smoking.

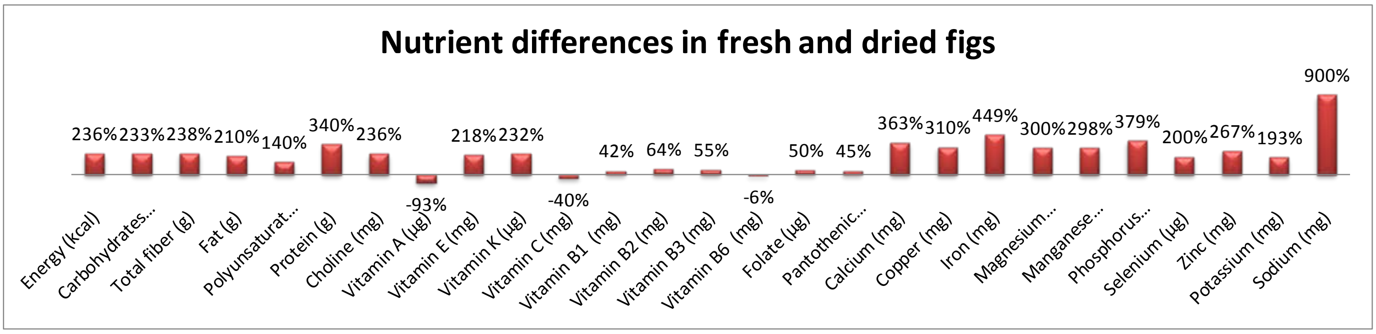

Figure 7.1. The nutrient increases and decreases that occur when 100g of fresh figs are dried

Pickling, through the use of brine and vinegar was another widespread form of preservation. Columella (*Rust.* 12.6.1-2) provides a detailed recipe for the production of three different types of brine with varying concentrations of salt. The high salt content and decreased pH prevented bacterial growth (Thurmond 2006: 182). Several sources attest to the practice of sprinkling vinegar over lentils to prevent mold growth while olives were pickled in order to make them edible (Pliny *HN* 15.16; Columella *Rust.* 12.49-50). A wider variety of foods were pickled in Roman times than is common in the modern western world including garlic, lettuce, fruits and herbs (Apicius 3.18; Pliny *HN* 19.128). Subsequently, there has been little research on the nutritional impact of pickling although it is known that the pH and length of storage time will alter the nutrient concentration since nutrients will slowly leach out of the food.

Salting and smoking were used by the Romans to preserve animal products such as fish and meat (Varro *Rust.* 2.4.18; Columella *Rust.* 12.55; Pliny *HN* 31.93-95).[106] The effect is somewhat similar to drying in that water is removed and the nutrient concentration increases (Thurmond 2006: 213). However, unlike dessication, fewer nutrients are lost during these processes and there is no effect on the protein levels (Table 7.7). Iodine is the only nutrient lost in significant quantities in fish while thiamin levels are reduced in meat

[106] The difference between salting and pickling is that pickled foods are submerged in a liquid while salted goods are usually kept dry.

(Bender 1978: 127, 133; Wing and Brown 1979: 64-65). Subsequently, high protein, nutrient dense foods could be transported large distances and stored for long periods of time. Salted goods, such as the *garum* produced at the *garum* shop I.12.8 in Pompeii, were no doubt a crucial source of protein for those who could not afford fresh meat.

Fermentation has been discussed in the previous section.

All the methods of preservation are designed to slow spoilage and decay, not stop it. While nutrients are slowly lost the longer an item is stored, losses occur differently in different foodstuffs (Table 7.14). Vitamin C and B_1 are the most unstable nutrients (Bender 1978: 101, 126). Vitamin C will leach out of legumes, leafy vegetables, root vegetables and fruit during storage while thiamin is lost from cereals and meat. Cereals, if they are unprocessed, will remain edible for long periods of time with very little nutrient loss. In eggs, the level of folic acid and B_6 decrease during storage.

It is clear that the Romans knew how to preserve a wide variety of foodstuffs. Although the bioarchaeological evidence from the sewer is limited to bread, porridge, fish and fruit, there is little doubt that many of the foodstuffs that ended up in the Cardo V sewer had originally been been processed and preserved in Herculaneum using these described methods. Archaeologically we can see that milling, baking, desiccation and salting took place as evidenced by the millstones, ovens, dried figs and fish sauce amphorae found in Herculaneum. Consequently, people living in *Ins. Or.* II probably had year-round access to a range of foodstuffs that was diverse enough to provide them with a constant supply of all the essential nutrients.

Table 7.7 Nutrient benefits or losses due to preservation

Preservation method	Grains	Legumes	Vegetables	Fruit	Nuts	Eggs	Fish	Meat and dairy
Desiccation (drying)	The removal of water increases the nutrient concentration, so nutrient levels are higher in a dried foodstuff compared to an identical volume of the item when fresh							
			Nutrient losses comparable to fruit drying	Sun drying- extensive loss of vitamin C, thiamine and β carotene	Slows oil rancidity		No effect on the protein content, in white fish it can result in a 50% loss of vitamin B_1, and a 65% loss in B_2	No effect on the protein content
Salting/ smoking							Little nutrient loss, no effect on protein content, 30-40% loss of iodine	Salting - no nutrient loss, vitamins and amino acids good until spoilage starts Smoking - little effect on nutrients, 20% loss of thiamin in pork
Pickling								26% loss of thiamine
Fermentation	Little nutrient loss							
Refrigeration	Vitamin losses are minimal (for all foods), most common vitamins lost include vitamin C in fruits and vegetables and vitamin B in animal products							
								Small to moderate losses of vitamins B_1, B_2 and pantothenic acid
Storage	Little nutrient loss, small loss of thiamin	Losses of vitamin C	Leafy vegetables - start to loose vitamin C when they wilt Root vegetables – vitamin C lost more slowly	Hard fruit – slowly loose C		Folic acid and B6 decrease during storage	No nutrient loss before spoilage	Quantity of thiamin loss depends on the type of meat

Bender 1978 *passim*; Wing and Brown 1979: 64-65; Muller and Tobin 1980: 230-233, 263-264; Tull 1983: 166; Thurmond 2006

7.5 Herculaneum, Campania and nutrient quality

An apple grown in Campania in AD79 would not be the same as an apple grown in Campania in 2014 or in Oxfordshire or Michigan. The precise nutritional composition of each apple will be slightly different due to cultivar type, soil conditions and farming method. What was an apple from AD79 Campania like? Why is this question important and how does it inform us about nutrition and health in ancient Herculaneum? The question is important because ancient diet is increasingly becoming detached from our own even though we still eat many of the same foods. Humans have been manipulating plants and animals for millennia, but it is only recently, with the advent of practices such as genetic engineering and pesticide use in the 20th century, that foodstuffs and their nutrient profiles have been dramatically altered and on a global scale. Therefore, it is important to understand what was different about food in ancient Herculaneum and the potential impact that these differences would have had on people's daily lives and overall health. The following section will highlight soil quality, phytochemical content and cultivar variety as it applies to the *Ins. Or.* II diet by looking at the geological, genetic and micronutrient evidence. Although items such as cereals may have been imported from abroad, for the purposes of this discussion it will be assumed that all plant foods (except black pepper, sorghum and dates) were produced in Campania.

7.5.1 Soil fertility

The Campanian region, because it hosts a large human population, important farm and horticultural land as well as an active volcano, has been well studied with regards to geology and soil science (Ramunni *et al.* 1987; Cicchella *et al.* 2005; Lulli 2007). Due to the AD79 eruption of Vesuvius, the Roman paleosol is well preserved and we are able to obtain a rough estimate of its fertility. Firstly, volcanic soils are known for being extremely fertile due to their elevated mineral levels, deep rooting zones and high water content (Shoji *et al.* 1994: 210). Foss (1988) examined Campanian soil from pre-eruption contexts that were exposed during archaeological excavations while Vogel and Märker (2011: 549) studied cores taken from the south side of Pompeii down to the Sarno river. The cores demonstrated that the Roman soil had a higher nutrient content and pH than modern Pompeian soils. The soil in the Sarno floodplain had been approximately 30-60 cm thick. Although this seems shallow, the strata below the Roman paleosols was loose and permeable so roots could still extend downwards (Vogel and Märker 2011: 557). Pliny (*HN* 18.110-111) noted this feature when he said that the surface of the Vesuvian soil is sandy but the soil beneath is spongy and porous. Additionally, the soil had excellent water-holding capacity as pumice fragments from the previous eruptions aided water retention. The ability to retain water was vital as the region is dry during the growing season. Foss (1988: 131-133; Foss *et al.* 2002: 78) concluded that the soil had excellent agricultural potential. These conclusions are supported by the ancient sources who praise Camapania for its fertility. Both Pliny (*HN*, 18.110 -111) and Strabo (*Geog.* 5.4.8) claim that crops were sown year round. Plants obtain their minerals from the soil, so the high mineral content of the Campania soil would have been transferred to the plants (Sillanpää 1982: XIII, 139-149; Salter *et al.* 2012: 258). The high yields due to soil fertility combined with the high nutrient densities of the plants meant that those living in *Ins. Or.* II had easy and probably inexpensive access to excellent quality plant foods. Moreover, meat from animals that grazed or were fed from foods grown on this soil would also have a high nutrient content.

7.5.2 Phytochemicals and disease prevention

Phytochemicals such as polyphenols, carotenoids and flavonoids, are compounds found in plants that are beneficial but not essential to human survival. Recent research has demonstrated that these compounds help protect against chronic and age-related diseases such as cancer and neurodegenerative disorders (Manach et al. 2004: 272; Holst and Williamson, 2008: 73-74; Salter *et al.* 2012: 32).[107] It is perhaps taking the Herculaneum diet to the extreme, but if we want to understand health in the ancient world, it is crucial to understand what was being done, whether consciously or unconsciously, to maintain good health and a strong immune system. We cannot know how much fruit and vegetables people in *Ins. Or.* II consumed, but we do know that they ate a wide variety of them. Wine, grapes, apples, blackberries and cherries are all high in polyphenols while nuts and grains are high in phytoestrogens (Salter *et al.* 2012: 110-127, 227-229). These compounds, along with several others, act as antioxidants, anti-inflammatories and anti-carcinogens (Stipanuk 2006: 27). As will be shown in the next section, the life span of those living in Herculaneum was long enough for people to suffer from chronic and age related diseases (Lazer 2009: 219) and it is probable that the many phytochemicals obtained from this varied diet played a role in reaching old age.

7.5.3 Cultivars – Ancient and modern

Barring harsh climatic conditions or insect infestations, plants grown on fertile soil should produce high yields. However, during the 20th century, global food demands rose and people increased yields by using fertilizers and selective breeding (Davis 2009: 15). Fruit and vegetable cultivars were created that would produce higher yields. During the "green revolution" of the 1960s and 1970s new dwarf cereal crop cultivars were created that

[107] For a description and overview of phytochemicals see Benbrook (2005).

responded better to fertilizer and agrochemicals, thereby producing more food (Çakmak *et al.* 2004: 1047; Fan *et al.* 2008: 316). However, the impact of these breeding activities is only now beginning to be fully understood. The creation of higher yield crops has caused a dilution effect, whereby a plant will produce more volume, but with fewer micronutrients. Subsequently, the amounts of zinc, copper, magnesium and iron in wheat are significantly lower than they would have been in antiquity (Fan *et al.* 2008: 321). Moreover, long term studies have now found there to be a 5-40% decrease in the amount of minerals, vitamins and protein of several fruits and especially vegetables (Winter and Davis 2006: 121; Davis 2009: 18). Pliny's (HN 15.47-52) extensive list of apple species indicates that the Romans knew how to create new cultivars and propagate them through grafting and selective breeding. However, they did not have the detailed knowledge of genetics to breed as selectively as today. While yields were lower in antiquity, the micronutrient content of the food consumed in Herculaneum would have probably been considerably higher, especially considering the volcanic soil. While research on the nutrient densities of organic versus conventional[108] farmed food continues, it is possible that future results will also demonstrate that the organic food produced in ancient Campania was more nutrient dense than the conventionally farmed food produced today (Woese *et al.* 1997; Worthington 2001; Asami 2003; Winter and Davis 2006). It has already been shown that organically grown foods produce more polyphenols and thus more antioxidants than conventionally grown foods (Benbrook 2005: 28-32).

[108] Conventional farming refers to the use of synthetic pesticides and herbicides, which are not allowed in organic farming (Asami *et al.* 2003: 1237).

7.6 Comparisons with the skeletal data

The human skeletons from Pompeii and Herculaneum have been thoroughly studied. Since 1982, approximately 350 skeletons have been excavated from the beach and nearby beach front chambers at Herculaneum. Hundreds of skeletons have been found during the centuries of excavations at Pompeii, but unfortunately most have been disarticulated and stored according to bone type, and thus it is difficult to estimate the total number (Lazer 2009: 100). Bisel (1987, 1988, 1991, Bisel and Bisel 2002), Capasso (2001, 2007; Capasso and Cappaso 1999) Petrone (Petrone and Fedele 2002; Petrone et al. 2011) and Torino (Torino and Fornaciari 2000) combined have analysed 216 of the Herculaneum skeletons while Lazer (2009) has been the principal scholar on approximately 260 Pompeii skeletons. Comparing the skeletal data from Pompeii and Herculaneum with the food remains from the Cardo V sewer is necessary in order to check the accuracy of the nutritional assessment presented above. Both sources of evidence contain biases that are minimized by comparing the two. The foodstuffs provide information about precise types of foods consumed but nothing about quantity or frequency in the diet. The skeletal results, on the other hand, provide rough estimates of food quantities and health for particular individuals, but do not provide information on the species of cereals, legumes or fish. Moreover, a recent article by Craig *et al*. (2013: 345) has highlighted the importance of using the physical food remains as a way to check the accuracy of scientific tests such as stable isotope analysis.

Morphological and chemical analyses have been performed on skeletons from both sites in order to establish basic levels of health for individuals and the overall populations. The Herculaneum skeletons have been studied using direct measurements, magnetic resonance imaging (MRI), electron microscopy and trace element analysis to examine longevity, stature, dental health, trauma, diet and nutrition (Capasso *et al.* 2001: 1065-

1067; Scaravilli, 2001; Bisel and Bisel 2002: 451; Petrone *et al.* 2002b; Petrone and Fedel 2002). Unfortunately, the multiple anthropologists who worked on the bones did not always use the same methodology or publish their raw data and there are often significant discrepancies in the results even when the same skeletons were analysed. The different results are discussed and reconciled in detail by Lazer (2009: 62-64, 153-220).[109] The Pompeii material has also been studied using direct measurements but due to the disarticulation of the skeletons, other forms of anaylsis have not been performed. (Lazer 2009: 106-107). Nine Herculaneum and 22 Pompeian skeletons have undergone isotopic analyses (Nitsch 2012: 136; Craig *et al.* 2013: 346).[110]

Despite these differing results, some common themes concerning diet and nutrition have arisen. Multiple trace mineral analyses of the Herculaneum bones have all indicated high levels of strontium and magnesium and low levels of zinc, suggesting a diet high in carbohydrates and nuts with protein derived primarily from marine and vegetable sources (Bisel 1988: 64-65; Bisel and Bisel 2002: 458; Capasso *et al.* 2001: 1065-1067, Petrone *et al.* 2002b: 79-80). Stable isotope analysis of the Herculaneum skeletons has shown that marine foods consistuted approximately 0-15% of the total dietary protein (Craig *et al.* 2013: 350). The isotopic data from the Pompeian skeletons has produced similar results, although as Nitsch (2012: 136, 225-234) points out, there are many confounding factors, such as carbon routing and the consumption of fresh water fish, that may falsely suppress the results. The high incidence of dental caries in the Pompeii skeletons confirms that fermentable carbohydrates were a significant part of the diet (Lazer 2009: 172). The lower

[109] In the following section Lazer will be referenced along with other authors as she often provides a corrected account of the results.

[110] There is still considerable debate surrounding the interpretation of isotope results (Milner *et al.* 2004; Richards and Shulting 2006; Nitsch 2012: 122-123). While isotope work has been done on skeletons from other Italian sites (Prowse *et al.* 2005; Craig *et al.* 2009; Killgrove and Tykot 2013), at the moment, the isotope work from the Vesuvian region has been more focused on achieving accurate results, particularly with regards to fish consumption, than an understanding of overall diet (Nitsch 2012: 99, 225-243; Craig *et al.* 2013: 345). Consequently, trace element analysis and morphological studies are still our best sources of evidence for overall health and diet, although that is likely to change with additional isotopic work.

incidence of caries in the Herculaneum skeletons is probably due to the high fluoride content of the ground water (Torino and Fornaciari 2000: 61; Petrone *et al.* 2002b: 76; Bisel and Bisel 2002: 455). Attrition (wearing down of the teeth) on skeletons from both sites reveals that people were constantly chewing abrasive substances in their food, in this case, grit from the milling process (Bisel 1988: 63; Lazer 2009: 170). All of these findings are in line with the results of the Cardo V analysis of diet.

Similar to the results of the nutritional assessment presented here, a high level of health and nutrition can be seen in the skeletons. Stature is the result of genetic influences, nutrition and environmental stressors such as disease (Lazer 2009: 167). The Trotter and Gleser formula (1958) has been frequently used to assess the height of the Herculaneum and Pompeii skeletons. Although there are complications with using this formula, overall, the results have shown that people living in both Pompeii and Herculaneum were slightly taller than modern Neapolitans. The average height of men in Herculaneum was 166.45 cm and 153.45 cm for women (Capasso *et al.* 2001: 924-927; Bisel and Bisel 2002: 455; Lazer 2009: 179-184). Modern Neapolitan men and women are 164 cm and 152.6 cm tall respectively (D'Amore *et al.* 1964). These heights indicate that people were not exposed to many environmental stressors during the growing period, particularly during adolescence, and that people consistantly had access to an adequate amount of food and nutrients, especially protein (Lazer 2009: 184).

Age and healing capacity are two interrelated indicators of nutrition and health. While genetics does play a role, achieving old age indicates that people are consuming nutrients at a level that decreases their susceptibility to disease and infection. In other words, they did not suffer from constant deficiencies that would have compromised or strained their immune systems. Despite the fact that the age distribution tables generated by Bisel and Bisel (2002: 454), Capasso (2001: 959) and Petrone *et al.* (2002a: 71) differ slightly due to methodological differences, all three scholars agree that the skeletons represent an accurate cross section of the Herculaneum population (Lazer 2009: 163). Capasso and Capasso (1999) used the skeletons to estimate the demographic structure of Herculaneum based on a population of 5000 people. Between 21.6%-31.39% of their Herculaneum sample was at least 40 years old and if they are correct, then in AD79, 1155 people, or 23.1% of the Herculaneum population had been healthy enough to reach the age of 40 or older. At Pompeii, Lazer found skeletons of men suffering from diffuse idiopathic skeletal hyperostosis (DISH) and women from hyperostosis frontalis interna (HFI). Both of these are age related conditions, not appearing in men until the age of 50 and in women until they are post-menopausal, indicating that people did in fact live long enough to suffer from age-related illnesses (Lazer 2009: 153-156). When infant mortality and the absence of modern medicine are taken into account, Lazer (2009: 165, 219) suggests that Pompeians had life spans comparable to modern western populations.

The ability to recover from trauma or infection testifies to the strength of an individual’s immune system. The evidence from Pompeii and Herculaneum indicates that people had very strong immune systems and thus, sufficient access to high quality nutrients (Lazer 2009: 167, 201). Only one of the bone fractures from Pompeii showed signs of secondary infection and all fractures showed signs of healing (Lazer 2009: 196). In the Pompeii skeletons, lesions in the orbital roof of the eye socket due to porotic hyperostosis, a side effect of nutritional deficiencies or anemia, also showed signs of healing. The anemia may have been the result of iron being diverted to other parts of the body to fight infection (Lazer 2009: 197-200). In addition to iron, essential nutrients such as vitamin A and omega-3 fatty acids help regulate and protect the immune system and deficiency in these nutrients will compromise the body’s ability to prevent and fight off illness (Stipanuk 2006: 23; Geissler and Powers 2010: 272). It is clear that many people in Pompeii and

Herculaneum were able to fight off disease and reach old age. The consistently good sources of nutrients and phytonutrients in their diets no doubt played a significant role in ensuring the maintenance of long term health.

The ancient world did not have the levels of hygiene and sanitation of modern developed countries and despite eating a nutritious diet, the people of Herculaneum still suffered from mild deficiencies and chronic health problems. Examinations of the teeth from both Pompeii and Herculaneum indicate that dental hygiene was poor and dental caries and abscesses were common (Petrone *et al.* 2002b; Lazer 2009: 171-176). Bisel and Bisel (2002: 455) found there to be 0.73 abscesses per mouth for men and 0.66 for women and that 37.4% of 139 individuals had lost at least one tooth before death (Lazer 2009: 173). Linear enamel hypoplasia can result from nutritional stress, infection or trauma to the tooth. Capasso (2001: 1035-1037) found that 96.1% of his 51-person sample had evidence for hypoplasia although Bisel (2002: 455) identified it in only 50% of her 139 Herculaneum skeletons. Despite the different results, it suggests that childhood illness was common, as is expected for the ancient world. Lazer (2009: 219) found that some of the damage to the teeth and jaw was a result of systemic infection or soft tissue pathologies. While the high fluoride content of the water may have protected people’s teeth, recent research by Petrone *et al.* (2011) has shown that much of Herculaneum’s population suffered from fluorosis (fluoride toxicity). In his examination of 76 skeletons, he found that 73.5% of people over 15 years old showed evidence of intense calcification of the ligaments, tendons and cartilage. The over consumption of fluoride can result in calcium deficiency and other mineral abnormalities. Combined with the minimal amount of red meat in the diet, this may have resulted in widespread anemia (Petrone *et al.* 2002b: 80).

In sum, the skeletal data from Pompeii and Herculaneum match very closely with the results of the nutritional analysis based on the Cardo V food remains. The conclusion of a high carbohydrate, high seafood and vegetable protein diet corroborates with the diversity of cereals, pulses and seafood species recovered from the sewer. Despite the large quantities of recovered shellfish and fish, the species consumed were small, and many clams or sardines, for example, would have to be eaten in order to make a 15% contribution to protein intake. Attrition shows that bread was a popular form of cereal consumption in Herculaneum and helps explain why so few cereal grains were found in the sewer. The high level of nutrition based on the food remains is supported by absence of any of the deficiency diseases observable in skeletons such as rickets. Many deficiency diseases and especially mild deficiencies will not leave evidence on the bones. However, it is clear from the ability to survive childhood illness, trauma and infection that people were eating a varied diet that provided them with enough nutrients to support a robust immune system. Their tall stature and long life spans indicate that nutritional levels were constantly high and the healed porotic hyperostosis suggests that if there were periods of deficiency, they were short. As the foodstuffs indicate, mild anemia was probably common and other than complications arising from fluorisis, it is unlikely that people were severely deficient in any of the essential nutrients. The levels of growth, health, healing and nutrition in ancient Herculaneum were excellent and often comparable to modern western populations.

7.7 Summary

Together, the ancient sources, the Cardo V material, the skeletons and modern food science have enabled us to examine and assess the quality of the *Ins. Or*. II diet in considerable detail. Discussions of ancient nutrition and diet will always be hypothetical, but by using as many sources of evidence as possible, we have dramatically increased the likelihood that our hypothesis of a healthy diet is correct. The ancient sources praised the Campanian region for its fertility, abundance and the good quality foods it produced and so we have been led to believe that the diet there must have been good, at least for the rich. The Cardo V remains have revealed that this image of a varied and healthy diet is not only correct but extends to the middle to lower classes. Food was preserved and cooked in ways that often resulted in greater nutrient gains than losses. Preservation enable people to eat a diverse diet year round while cooking eliminated harmful toxins and bacteria. Modern food technology has enabled us to increase food yields and shelf life, but it has also shown us that the cereal, fruit and vegetable cultivars eaten in ancient Herculaneum were more nutrient dense than our own. Although health and sanitation were far from modern standards, and people frequently suffered from childhood illness and poor oral hygiene, the Herculaneum skeletons indicate that these nutrient dense diets enabled them to live relatively long and healthy lives. Life in Herculaneum was good, at least where diet is concerned.

Chapter 8: Beyond diet: Three case studies

8.1 Chapter layout

The bioarchaeological remains found in the Cardo V sewer represent the final stages of interaction between these objects and the inhabitants of *Ins. Or.* II. Chapter 6 discussed these final stages by examining the formation of the assemblage from the time an item entered the *insula* to the time it was deposited in the sewer. However, the taphonomic variety of the material, preserved through mineralization, carbonization and as calcium carbonate, has created the additional opportunity to use the material to enhance our understanding of the creation and acquisition of these goods beyond the confines of *Ins. Or.* II. In other words, to explore the series of processes that occurred in order to bring the items to the *insula*. This chapter will present a series of three case studies, using material from each of the preservation types in order to highlight the “life cycle” of particular remains and the extent to which bioarchaeology can inform us about the ancient world beyond diet and consumption.

8.2 Case study 1: The carbonized remains – Olive stones

Whole and fragmented olive endocarps make up 94.3% of the carbonized assemblage. Burnt olive stones have been found in Pompeii as remnants of table waste and in association with domestic ritual burnt offerings (Robinson 2002: 95-96, 2007c, Murphy *et al.* 2013). As stated in section 6.2.1, it is probable that a small proportion of the Cardo V olives also represent consumption and ritual activities. However, the olive stones are simply too numerous to be associated solely with these activities and it will be argued here that the carbonized olive assemblage primarily represents the use of olive pomace as fuel for cooking and heating (Fig. 8.1).

8.2.1 Olive oil production process

The methods and technologies used to extract olive oil have not changed dramatically since Roman times. Although modern equipment is now frequently employed, there are still areas in the Mediterranean and the Near East where olive oil is extracted using traditional methods (Mouncif *et al*. 1993: 335; Warnock 2007: 21-24). The basic process, now, as it was in AD79, involves three stages: crushing, pressing and separation. Olives are first washed to remove dirt, twigs and leaves. They are then crushed using a *trapetum* type rotary mill, although simpler methods such as mortar and pestle, stone basin and roller, and trampling are also effective (Warnock 2007: 72-75). Once a paste has been obtained it is placed in round woven baskets and the baskets are stacked on the press bed. When enough baskets are in place the paste is compressed using either a lever or screw press (Fig. 8.2). The oil runs out of the baskets, into the shallow groove of the press bed and into a collection tank (Fig. 8.3). The remaining paste is then washed with hot water and pressed again. The hot water helps to separate the oil from the paste. After settling in the tank, the oil is either skimmed off the top or the water is removed by opening a plug at the bottom of the tank (Foxhall 2007:133-138).

8.2.2 Pomace as fuel

Pomace is the material that remains in the baskets after pressing.[111] It is composed of olive flesh, skin, stones (endocarp) and seeds, containing 3.5–12% olive oil and 20–30% water (Karapmar and Worgen 1983: 185). For every 1000 kg of olives pressed, 350-400 kg of pomace is produced (Niaounakis 2011: 414). While both the Roman authors and ethnographic studies have shown that pomace can be used as fertilizer for olive groves and as fodder for livestock, the chief use for pomace in modern olive oil producing regions,

[111] It is also referred to as *jift* (Arabic) or *grignons* (French) in many ethnographic studies while modern scientific articles often refer to it as olive mill cakes (OMC) (Galili *et al.* 1997; Mekki *et al.* 2006). For a detailed list of olive pressing waste terminology see Table 1.5 in Niaounakis and Halvadakis (2006: 20-21).

including Jordan, Israel, Spain and Tunisia, is as a source of fuel (Cato *Agr.* 37.2; Attom and Al–Sharif 1998: 220; Niaounakis and Halvadakis 2006: 15; Cuomo di Caprio 2007: 490).

Turning pomace into a fuel is a simple procedure. After olive pressing, pomace is sun-dried to reduce the high water content. Drying is done either by spreading the pomace flat or by shaping it into bricks or balls. In present day Jordan and Israel, pomace is pressed by hand into 8–12 cm balls and dried on floors or rooftops (Warnock 2007: 48-51). To convert it to fuel at a later date, the pomace can be covered with fresh or salted water to prevent rancidity (Avitsur 1994: 127).

Dried pomace is a viable charcoal alternative. In North Africa and the Near East it is used in domestic contexts for heating and cooking and in industrial contexts as fuel for baking, heating the water required for olive pressing and in kiln firings (Sethom 1964; Matson 1972: 219; Doymaz *et al.* 2004: 214; Warnock 2007: 47-52). It has a calorific value of 5,360 kcal/kg, and although this is lower than wood charcoal (7,350 kcal/kg), when used in a small stove, 4–5 kg of pomace will burn for 12 hours (Warnock 2007:47-51). [112] Pomace provides a more consistent temperature for a longer period of time than charcoal and burns with an odourless and almost smokeless fire, which is a desired characteristic when used indoors for cooking or heating (Brun 2003: 183).

8.2.3 Archaeological and literary evidence for pomace fuel use

Carbonized olive stones, attesting to the use of pomace fuel, have been found at archaeological sites throughout the Mediterranean and the Near East, often in association with areas of pottery and olive oil production (Smith 1998: 192-193; Margaritis and Jones 2008a: 395-398; Lewit 2011: 318-322; Rowan 2015). The sites range in date from the 3rd

[112] The energy content listed in Warnock does not specify if it is for loose or dried pomace. However, the value is probably for dried pomace as loose, wet pomace would be too volatile a substance to burn, especially in a small enclosed stove.

millennium BC to the 7th century AD and demonstrate a continuity of pomace use before, during, and after the Roman period (Rowan 2015) (Fig 8.4). Carbonized olive stones have been found at a wide variety of Roman period sites including a kiln in Leptiminus (Tunisia) and an olive press at La Garde (France) (Brun *et al.* 1989: 113-126; Smith 2001: 435).[113] In Pompeii, the Pompeii *Pistrina* project recovered thousands of olive fragments during the excavation and cleaning of four bakeries (VII.1, 25.46–47, IX.3.19–20, I.12.1–2, IX.12.6–8). The number of fragments ranged from 832 to 2,763 while approximately 4% of the stones were found intact. The high degree of fragmentation, in addition to their location near the ovens, led the excavators to conclude that the olive stones must have been used as fuel for the ovens (Monteix 2009: 330-331; 2010a: 276-277; Monteix *et al.* 2011: 307; Monteix *et al.* 2012: 10; Coubray *et al.* 2013) (Fig. 8.5). After sampling every excavated context, the AAPP considered burnt olive stones to be botanical background noise as they were consistently found in low quantities in almost every sample from Insula VI.1 at Pompeii (Murphy *et al.* 2013: 415). The excavators have suggested that the stones could represent either kitchen waste or domestic fuel although the concentrated deposit of fragments from a pit in the garden of the House of Hercules' Wedding almost certainly represents fuel waste (Ciaraldi 2007: 147).

The ancient literary sources also attest to the use of olive pressings as fuel. Pliny states that pomace is the best fuel for heating olive oil press rooms as its clean burning will not ruin the flavour of the oil (*HN* 15.22). Additionally, Justinian's Digest (32.55) lists olive stones as an alternative source of fuel together with twigs and charcoal. Thus, the archaeological evidence, combined with the literary sources leaves little doubt that pomace was a widely utilized fuel source in antiquity and the Bay of Naples.

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[113] For a full list of Roman period sites see Rowan 2015.

8.2.4 Carbonized olive stones as a source of fuel for cooking and heating in Herculaneum

Since the Herculaneum assemblage represents one of the first recognized instances of the urban domestic use of pomace fuel from the Roman period, it is especially important to establish that the olive stones represent fuel used for heating and cooking and were not carbonized due to other formation processes, namely the eruption, table waste and burnt offerings.[114] The eruption, as stated in section 6.2.1, was not a factor in the carbonization of the Cardo V finds.

The presence of mineralized olive seeds confirms that table olives were consumed at *Ins. Or.* II. However, it is the fragmentary nature of the carbonized assemblage which suggests that most of the burnt olives were not consumed but were crushed during the milling stage of olive oil extraction. Experimental studies done by Margaritis and Jones (2008b), Warnock (2007) and Tyree and Stefanoudaki (1996) have all found that the use of a *trapetum* style rotary mill will cause the majority of the olive stones to crack and fragment (Fig. 8.6). Only 1.35% of the Cardo V olives were whole and one would expect a greater proportion of whole stones if they had been used as food (Fig. 8.7). Most whole stones thrown into the sewer would probably have remained intact since the material was not subjected to post-depositional fragmentation due to trampling. Additionally, the rounded edges of the fragments demonstrate that the olives were crushed prior to their deposition in the sewer and not during recovery, flotation, and sample processing (Neef 1990). If the olives had been fragmented during sample processing, then the edges of the breaks would appear sharp (Fig. 8.1).

It is not just the degree of fragmentation but the quantity of olive stones that distinguishes this assemblage from those associated with ritual burnt offerings. At the

[114] Finds of olive stones from the Avenue Bourguiba and three cisterns at Carthage are from domestic contexts but the earliest of these finds dates to the 5th century AD (Hoffman 1981, 1982; Stewart 1984). The lack of other finds is probably, in part, a reflection of limited detailed archaeobotanical studies on Mediterranean Classical sites.

House of the Greek Epigrams in Pompeii, three burnt offering pits contained a total of 10 olives (Robinson 2007c). Other ritual deposits from Pompeii have produced equally small numbers of carbonized olive stones, including the street-front shrine VI.1 (n=1), the House of the Vestals (n=1), the House of Hercules' Wedding (n=3) and the House of Amarantus (n=1) (Ciaraldi and Richardson 2000: 80; Robinson 2002: 95-96; Ciaraldi 2007: 100, 117-119; Murphy *et al.* 2013, suppl. 1). The sheer quantity of olive fragments from the Herculaneum sewer (n=6,426) appears to be more closely related to the numbers of olive stone fragments found at sites such as Tria Platania (n=13,868), Carthage (Avenue Bourguiba, n=1693) or Leptiminus (Site 250, n=454) rather than ritual garden pits in Pompeii (Stewart 1984: 257; Rife 2001: 301; Smith 2001: 434; Margaritis and Jones 2008a: 395). The number of stones is also too large and ubiquitous to have resulted from accidental burning. Pomace fuel is therefore the most probable explanation for the presence of such a large volume of fragmented olive stones in the Cardo V assemblage.

However, the Vesuvian area had more available woodland than large parts of North Africa and the Near East, and thus charcoal was available. In fact, charcoal was recovered from every Cardo V sample and was ubiquitous in the sewer. At Herculaneum, there is no evidence for olive oil production within the town and pomace would have had to have been imported from the nearby farms. Why then did the inhabitants of Herculaneum use pomace as well as charcoal if charcoal was readily available?

The question can be answered in terms of both the practical benefits and economic advantages. Firstly, the structure and arrangement of the shops and apartments of *Ins. Or.* II would have made pomace the preferred fuel type. As shown in section 2.3.1, the majority of the apartments were small and most of the ground and upper floor rooms had only small windows for light and ventilation (Fig. 8.8). Since pomace burns at a high temperature for longer and with less smoke than charcoal it would have been the ideal fuel source for use in braziers, particularly in the winter when the shutters would be closed to retain the heat (Brun 2003: 183; Warnock 2007: 47–48).

Except for the potentially large apartment at *Ins. Or.* II.7, none of the upper floor apartments had evidence for raised hearths or kitchens (Andrews 2006, 2: 101). However, the ubiquity of foodstuffs in the Cardo V assemblage that usually require cooking before consumption, such as pulses, cereals and fish, strongly suggests that cooking took place even in the smaller apartments. If cooking was done on the floor, possibly with the use of a stone slab supporting a small tripod or brazier, then pomace cakes would have been more manageable and efficient than raw wood or charcoal (Fig. 8.9). Raw wood, even in Roman houses that had hearths, would have been nearly impossible to use as cooking fuel. Too much raw wood is required to create a fire hot enough to even boil water and fit beneath a tripod. Similarly, the bakeries could not have used raw wood due to space limitations in and around the ovens. Since the bakeries at Pompeii were using pomace, it is possible that the bakery at Herculaneum in *Ins. Or*. II.8 also used pomace as fuel for the bread oven. This may explain the higher concentration of olive stones at the southern end of the sewer where the bakery is located (Fig. 8.7).

In addition to the practical benefits of pomace, cost probably played a significant role in ensuring its use in Herculaneum. While there is no way to determine if all the apartments at *Ins. Or.* II used pomace, the ubiquity of the burnt olive stones suggests that pomace use was widespread in the insula regardless of shop or apartment size. It is probable that pomace was actually cheaper than charcoal, especially in winter. Olive oil was produced in the area and while on a significantly smaller scale than areas such as Baetica or Tripolitania, local production was not limited to personal use. Pollen analyses from the Naples harbour have shown that large numbers of olive trees were growing in the region in the first century AD (Allevato *et al.* 2010: 2368.) Amongst the numerous nearby villas, at least three were in operation in AD 79 and contain archaeological evidence of oil production in the form of presses and/or a *trapetum*: San Rocco, Villa Pisanella at Boscoreale and Casa dei Miri at Gragnano (Ruggeiro 1881: 325; Rossiter 1981: 358-359; Brun 2004: 14, 20-21) (Fig. 8.10). The presence of at least two presses at San Rocco and Casa dei Miri suggests that large quantities of olive oil, and therefore, pomace were being produced (Brun 2004: 20-21; Flohr *et al.* 2013). Some of the pomace was probably used to heat the water required during future pressings as well as for fertilizing the olive groves. However, the excess pomace could also easily have been transported into Herculaneum in amphorae but more likely in skins, barrels or even loose in carts (Peña 1998: 166–171; Marlière 2002). Pomace cakes may have been formed and dried at the villas and then sold in the town.

The amount of time and effort required to prepare dried pomace cakes for burning is minimal relative to the effort required to create charcoal. Wood for charcoal is often cut in the winter and then allowed to dry for six months. The charring process then takes 5–7 days for larger logs and the fire must be tended during the entirety of this time (Veal 2009: 143-146). In addition to the labour input, the transportation of the charcoal would have increased the cost. Veal (2009: 71-83, 131-133) looked at 3,911 fragments of charcoal from four different sites around Pompeii,[115] ranging in date from the 3rd century BC to the 1st century AD and found that after the 2nd century BC 60% of the charcoal was made from beech (*Fagus sylvatica*). Beech charcoal is also commonly found in the Cardo V sewer (Dana Challinor April 8, 2014, pers. comm.). Beech grows at elevations greater than 500 m, although ideally between 1200-1600 m. The nearest sources of beech were 15–25 km from Pompeii and consequently even farther from Herculaneum (Veal 2009: 3-7) while the olive oil producing Villa Pisanella was only 2 km from Pompeii and 12 km from

[115] Insula VI.1, VIII.7, V.2.g and VIII.1.

Herculaneum (although there were surely others closer to Herculaneum) thus reducing the shipping costs. The price of charcoal would have also varied by season, being the least expensive in the mid to late summer, just after the charcoal had been created (Veal 2009: 209). Olive oil production takes place in the late autumn and winter, exactly when the charcoal supply would be at its lowest. Thus in the Bay of Naples, it is probable that in the winter pomace was less expensive than charcoal since it was more abundant, while charcoal was cheapest in the summer.

8.2.5 Summary

Regardless of their motivations, whether due to cost or burning quality, it is clear that the inhabitants of *Ins. Or.* II actively chose to use pomace in addition to charcoal. By recognizing the use of the olives as a fuel source, we are better able to understand the life cycles of the olives and subsequently obtain a better understanding of the economic connections that were taking place between the Vesuvian towns and their hinterland. The accumulation of material in the Cardo V sewer suggests that pomace had been used in Herculaneum for at least a decade before the eruption. At Pompeii, the large quantities of olive stones, scattered throughout the bakeries in multiple pre-eruption contexts, also indicate that this was not a single event. There was probably an established relationship between the producers and consumers of pomace in the Vesuvian region. Once obtained, whether traded or purchased, the olive stones inside the cakes were carbonized when the pomace was used as fuel for cooking and/or heating in the apartments. After burning, the ashes, along with the surviving stone fragments, were deposited in the sewer as waste material.

8.3 Case study 2: The mineralized remains - Arable and ruderal weed seeds

Weed seeds represent material from any plant that was not intentionally sown, harvested, gathered or consumed. The weed seed assemblage from the Cardo V sewer falls into two categories, the weeds of arable crops and ruderals. The ruderals are plants that grow on uncultivated soils, usually on disturbed ground. There is a significant amount of overlap between these two categories, as many of the weeds can grow either in crop fields or in uncultivated areas (Pignatti 1982; Stace 2010). Subsequently, reconstructing the life cycles of many of these plants is difficult and their method of entry into the insula can only be hypothesized. The weeds of arable crops will receive the majority of the attention in this section as they provide the largest quantity of information on food production and consumption in Campania.

8.3.1 Arable weed seeds

The nature of the Cardo V assemblage, as a mixed deposit of both human and food processing waste, restricts our ability to fully reconstruct the life cycles of the arable weed seeds (Table 8.1). We do not have a deposit that features a single cereal species, which would have allowed for a clear association between the weeds and the particular crop. Instead, the sewer contains multiple cereal and legume species and therefore a mixture of weed seeds from crop types that were probably obtained using a variety of different harvesting and processing methods. Except for one rachis node, the sewer does not contain any material from the intermediate stages of crop processing, for example chaff. The assemblage represents only the final cleaned and processed products so our understanding of crop growing practices is limited. The limitations apply to the initial life cycle stages and subsequently we can only make broad assumptions based on common pre-industrial crop harvesting and processing practices (Hillman 1981, 1984; Jones 1984).

Although the seeds listed in table 8.1 can grow on both arable and uncultivated land and could have entered the sewer through a multitude of routes (see section 8.3.3), at least some, such as *Papaver* sp. and *Centaurea* sp., were more likely to be the contaminants of crops and consequently began their lives in a field. When the crops were harvested the weeds were collected along with the cereal grains. The cereals were then parched (if necessary), threshed and winnowed. While the chaff of both the crops and the weed plants were lost during these processes, the weed seeds remained mixed with the cereal caryopses (Hillman 1981: 132-133). The next stage in crop processing involves sieving, usually done with coarse and fine sieves. The coarse sieve would have separated out all the seeds and remaining chaff fragments that were larger than the cereal grains. The grain was then sieved through a second mesh to eliminate the very small weed seeds, although some no doubt remained (Cappers and Neef 2012: 78).

Table 8.1. Arable and/or ruderal weed seeds from the Cardo V sewer[116]

Taxon	**Habitats**
Anagallis sp.	Grows with crops or on uncultivated land
Aphanes sp.	Cultivated ground and open habitats
cf. *Avena* sp.	Often grows amongst crops, also in pastures and paddocks
Anthemis arvensis	Arable land, pastures or abandoned land
cf. *Centaurea* sp.	Grows with crops
Chenopodium album	Grows with summer broadcast or row crops, wheat, barley and poppy and on uncultivated land
Lithospermum arvense	Arable land, pastures, uncultivated land, arid, scrubland
cf. *Medicago* sp. or *Melilotus* sp.	Medicago – cultivated fields, roadsides, grassy places Meililotus – cultivated as fodder, occur as casuals
Papaver sp.	Grows with summer and winter broadcast sown crops
Polygonum aviculare (agg.)	Grows with summer broadcast or row crops, also on uncultivated or trampled ground
cf. *Ranunculus parviflorus*	In arable fields, uncultivated land, muddy areas
Sherardia arvensis	Arable fields, scrubland, pastures and arid regions
Silene gallica	Arable fields, pastures, sand
Stellaria media	Grows with crops, can also grow in human settlements
Vicia ervilia	Grows with summer and winter broadcast sown crops, can also be a fodder crop in its own right

Tutin *et al.* 1964-1980; Pignatti 1982; Stace 2010; VegItaly 2013

[116] Some genus, such as *Polygonum* sp. and *Sambucus* sp. have not been included because their range of habitat characteristics are too broad to provide any useful data.

These processing stages were completed outside the town (see section 6.2.1.2) and the clean grain and any remaining weed seeds were then transported into Herculaneum. The majority of the grain was probably brought to the bakeries where it was milled into flour. Some grain was sold unprocessed and used to make porridge and other dishes. Since the weed seeds from the Cardo V assemblage are much smaller than the cereal grains, they were able to survive the milling process intact (Fig. 8.11). The two halves of a millstones were set at the optimal distance for crushing cereals, primarily wheat, and thus many of the weed seeds would have been too small to have been crushed (Moritz 1958: 87-88; Thurmond 2006: 53). In theory, the intact weed seeds should have been sieved or picked out of the flour. However, they were not picked out, suggesting that the flour and subsequently the bread was not of the highest quality. We do not know if all the bakeries in Herculaneum produced this type of moderate quality flour, but some certainly did and it is not difficult to think that some of the less wealthy inhabitants of *Ins. Or.* II had to buy lower quality bread.

After milling, the flour was mixed with salt and water, kneaded into loaves, and baked (Pliny *HN* 18.103-104). The incorporation of the weed seeds into the bread prevented them from becoming carbonized despite being baked in an oven. When the bread was consumed the weed seeds were also eaten and would have subsequently passed through the human digestive tract intact, enabling them to become mineralized once deposited in the sewer.

Consequently, the weed seeds can tell us about milling and flour sieving practices. Thus from the time the weed seeds entered Herculaneum, their path to the sewer is relatively clear and straightforward. The events taking place prior to their entry into the town are far more difficult to reconstruct. Archaeobotanists use weed seed assemblages and an associated range of techniques, including ecology, phytosociology, and Functional

Interpretation of Botanical Surveys (FIBS) to determine ancient crop growing activities (Westoff and van Der Maarel 1973: 626-631; Behre and Jacomet 1991; Jones 1992; Bogaard *et al*. 2001; Bogaard 2004: 5-8; Jones *et al.* 2010). However, as a mixture of different grain types present within a single context, located in a region that has not been extensively studied with regards to its floral composition, none of these methods can be applied to the Cardo V weed seed assemblage without an extensive amount of additional field work that is beyond the scope of this study. Nevertheless, a small quantity of information about the life cycles of the weed seeds, prior to their entry into Herculaneum can be gleaned from the available climatic and soil data.

The calcareous soil was enriched by the volcanic debris of past eruptions and due to its high fertility it is unlikely that manuring or intensive cultivation were necessary in producing adequate yields (Fig. 8.12) (Pliny *HN* 18.109-111; Florus 11.3-6; Strabo *Geog.* 5.4.8; Foss *et al.* 2002: 78; De Pippo *et al*. 2008: 29). Cato (*RR* 37.2) and Pliny (*HN* 18.120) state that crop rotation and green manuring (growing legumes and then ploughing them back into the soil) was a common practice, which would have helped prevent soil nutrient depletion. The Vesuvian region has a characteristically Mediterranean climate, receiving 800-1000 mm of rainfall each year, primarily between October and April (De Pippo *et al.* 2006: 186). The sufficient amount of rainfall would have also made dry farming possible and, as Pliny (*HN* 18.110-111) states, irrigation unnecessary in the Campanian plains.[117] Thus we can tell that the Vesuvian crops and their associated weed seeds were sufficiently watered, grown on enriched soil and were probably not subject to intensive cultivation.

[117]The annual minimum volume of rainfall for dry farming is 200 mm. In addition to rainfall, the groundwater in the Sarno plain was also recharged by aquifers and reservoirs in the limestone (De Pippo *et al.* 2006: 186).

8.3.2 Crop growing locations

It is well documented in the ancient sources that Rome, via Puteoli, was supplied with cereal from Egypt and North Africa (Josephus *Bell. Iud.* 2.383, 386; *Acts* 27-28; Seneca *Epist.* 77.1; Casson 1980). Both the archaeology and the ancient sources also indicate that the Campania region was densely populated and could not feed itself solely from its own hinterland (Strabo *Geog.* 5.4.8; Vogel *et al.* 2012: 378). Despite the fertility of the soil, there is evidence to suggest that landowners in the Vesuvian region found it more profitable to practice horticulture and viticulture than grow crops. Agriculture and viticulture were practiced in the Sarno river basin and at the foot of Vesuvius where it was wettest, while the slopes of the volcano and the surrounding mountain ranges, including the Lattari Mountains, were used for horticulture, viticulture and silviculture (Fig. 8.13) (Ciarallo 2002: 139; De Simone 2009: 192-193; Vogel *et al.* 2012: 378; Veal 2012: 43; Bowman and Wilson 2013: 3-4). The Murecine tablets indicate that some of the grain and pulses that arrived in Puteoli were not shipped on to Rome but in fact were kept to feed the large Campanian population (Rickman 1980a: 262-263; Casson 1980). Two of the tablets, dated to AD37 and AD40 state that over 10,000 and 13,000 *modii* of Alexandrian wheat and pulses were held as collateral for a loan in the Horrea Bassiana in Puteoli (Casson 1980: 28).

It was originally hoped that the weed seeds from the Cardo V assemblage would provide data on the origins of the imported crops and pulses. Unfortunately, the assemblage does not contain any seeds that would enable us to say with certainty where the crops were grown. The inability to distinguish Egyptian, North African and Campanian cereals from the weed assemblage is symptomatic of the larger, although rarely discussed, challenges that archaeobotanists face in determining the origins of the grains that were grown and consumed in the Mediterranean.

Cereals grown and imported in geographically distant parts of the Empire, should, in theory, display a varying range of weed contaminants. Differences in the weed flora or the recovery of weed flora native only to a particular region of Egypt or North Africa would provide concrete evidence that the crops were imported from outside the Vesuvian region. In Roman Britain, there have been multiple cases where the weed seeds from charred grain assemblages have provided evidence for the importation of crops from outside the UK (Helbaek 1964: 162-163; Straker 1984: 327; van Zeist 1991: 116). However, in the Mediterranean, a combination of ecological and anthropomorphic factors has made these crop growing regions botanically almost indistinguishable.

8.3.2.1 Egypt

In Egypt, the majority of the crops were grown along the Nile where the annual flooding of the river irrigated the fields and made the soil rich in nutrients and minerals. Unlike the rest of Egypt, which is primarily desert, the area around the Nile is climatically very similar to the Mediterranean. Therefore, the Nile valley is a suitable habitat for the naturalization of Mediterranean flora and many of the arable weed species found in Italy and the wider Mediterranean Basin can also be found in this area of Egypt (El Hadidi and Kosinová 1971: 364; Kosinová 1974: 283).[118] Due to the region's long history of agriculture, many arable weeds from the Mediterranean had been accidentally introduced into Egypt long before the Roman period. A study by Fahmy (1997) of 61 sites dating from Predynastic times (4500BC) through to the end of the Greco-Roman period (AD395) found that 57 out of the recovered 112 weed seed types had been introduced to Egypt either from the Mediterranean or the Irano-Turanian region. Four of the identified weed species

[118] Some rain-fed agriculture also took place in a narrow strip of land approximately 30 km wide stretching along the coast west of the Nile delta. This region is phytogeographically part of the Mediterranean basin and thus the weed seed flora is similar to that found in arable fields throughout the Mediterranean (El Hadidi and Kosinová 1971).

overlapped directly with the material from the Cardo V sewer as did many weeds identified only to genera.[119] There are several weed seeds found amongst Egyptian crops, particularly the Saharo-Sindian species, that do not grow in Italy (Fahmy 1997: 246), but none of those were found in the Cardo V samples. Therefore, although some grains and their associated weed seeds probably came from Egypt, we cannot distinguish the Egyptian crops from the Campanian crops in the Cardo V botanical assemblage.

8.3.2.2 North Africa (other than Egypt)

When examining crops grown in North Africa, we face a set of floristic challenges similar to the ones from Egypt. The statement, by both modern scholars and ancient authors that the Romans imported grain from North Africa is helpful but vague (Casson 1980: 21; Aldrete and Mattingly 1999: 177). Except for the work done by Rickman (1980a: 108-113, 1980b: 264), little research has taken place to determine precisely where in North Africa the grain was grown, particularly in the areas outside of north-eastern Algeria and the hinterlands of Carthage, Hippo Regius, and Rusicade. Inscriptions from Imperial estates indicate that surplus grain was certainly produced in the Bagradas valley in Africa Proconsularis (modern Tunisia) (Kehoe 1988: 4-7). Macrobotanical finds from farms (*gsur*) in the Libyan Valleys indicate that cereals, in addition to olives, were widely grown there as well, but not in quantities that allowed for export (Van der Veen 1985: 24-25; Van der Veen *et al.* 1996: 254-256). However, evidence for the rest of North Africa remains scant and we must rely on the geographical and climatic characteristics of the region to more narrowly define “North African grain.”

Vegetation maps of North Africa reveal that agricultural production probably took place in a strip of land stretching from the eastern coast of modern Tunisia, across Algeria,

[119] The four overlapping species were *Chenopodium album, Polygonum aviculare, Vicia ervilia* and *Vicia sativa.*

to the north western coast of Morocco including the Atlas Mountains (Fig. 8.14). This region of land encompasses the coastal Mediterranean zone as well as the Mediterranean/Sahara transition zone which acts as a barrier between areas with sufficient rainfall for dry farming and irrigation and the arid interior (White 1983; Vilà *et al.* 1999: 11). These areas of North Africa, similar to the Nile valley, have a Mediterranean climate, making it easy for flora from other parts of the Mediterranean Basin to become naturalized after their initial introduction (Fig. 8.15). In North Africa, most of the naturalized flora has come from the northern shores of the Mediterranean and research has shown that crop fields and areas of human-disturbance were the habitats with the largest number of naturalized species (Vilà *et al.* 1999:14-15). Although they were not originally native, by the Roman period, several foodstuffs, including barley, wheat, lentils and chickpeas had already been introduced into the region (Le Floc'h *et al.* 1990: 109). Many of the weed flora associated with these crops were accidentally introduced and quickly became naturalized. Subsequently, all of the weed seeds found in the Cardo V sewer can also be found in the crop growing regions of North Africa, particularly in Tunisia and Algeria (Bonnet and Barratte 1896; Maire 1955).

As the seeds were smaller than normal, sorghum has only been tentatively identified from the Cardo V sewer (Fig. 8.16). Sorghum is a sub-saharan crop requiring summer irrigation and therefore was not cultivated in the Mediterranean region of North Africa until the late Roman period (4th-5th centuries AD) (Van der Veen 2011: 103). It is recorded from a 3rd-4th century AD site in the North Kharga Oasis in Egypt (Clapham, quoted in Pelling 2007: 227-8) and from the Fazzan in southern Libya (Pelling 2007: 227-240, 249; 2013), where qanat or foggara irrigation allowed summer cultivation. While in theory it could represent imported grain, it is also possible that it represents a contamination of other imported goods from the Red Sea trade routes, the Egyptian Oases, Nubia or the Sahara (Pelling 2007: 229-231; Wilson 2012: 423-425). However, the identification is only tentative and more evidence is required to link Herculaneum to the Red Sea and trans-Saharan trade networks.

8.3.3 Ruderal plants

The ruderal plants are those that did not grow amongst crops, but instead inhabited a wide range of ecological habitats. The ruderals in tables 8.1 and 8.2 represent the multiple types of uncultivated lands that were present both inside and outside Herculaneum. The beachfront, roadways, pastures and forests around Herculaneum are each represented by a small number of species (Pignatti 1982; Stace 2010). Plants such as the nettles and knotgrass probably grew in Herculaneum between cracks in the pavement. All the seeds could have entered the insula through a number of routes including attachment to clothes or furs, on the bottoms of shoes or on the hides or fleeces of animals that had grazed in the nearby pastures. It should be noted that wetland species are very poorly represented in the seed assemblage. The Cyperaceae family, and its associated genus, *Carex*, are the only plants that live primarily in wet areas (Fig. 8.17). The absence of hydrophilic plants suggests that there was very little fresh, stagnant water near Herculaneum.

Table 8.2. Ruderals

Taxon	Habitats
Daucus carota	Uncultivated land, road sides, meadows (can also be consumed as a seasoning but the seeds are very spiny)
Linum sp.	Disturbed ground and grassland, rocks and well-drained calcareous or sandy soil
Ornithopus sp.	Dry, sandy places
Pteridium aquilinum	Woods and grasslands with acid soil
Rumex acetosella agg.	Uncultivated acidic and sandy soil (the leaves can also be consumed as a seasoning
Urtica dioca	Grows on abandoned land, waste piles and forests
Urtica sp.	Abandoned land, disturbed ground

Tutin *et al.* 1964-1980; Pignatti 1982; Stace 2010; VegItaly 2013

8.4 Case study 3: The biogenic material - Fish and otolith remains

Unlike the weed seeds, the life cycles of the fish and shellfish from the Cardo V sewer are comparatively straightforward. The seafood remains were subjected to very little human processing and alteration prior to their entry into the insula. Instead, processing took place in the various apartments of *Ins. Or.* II. Consequently, a large quantity and variety of remains ended up in the sewer and these remains provide important clues to understanding fishing and shellfish collecting practices in Herculaneum and the Bay of Naples. The ubiquity and diversity of the remains attests to the popularity and accessibility of seafood for the majority of the inhabitants of *Ins. Or.* II (see sections 5.10-5.12). In order to be provided with 77 different edible seafood taxa, the fishing industry in the Bay of Naples had to be relatively large and well equipped. Supplemented by ecological data, it is possible to use the artefactual and faunal remains to not only reconstruct the life cycles of these various species, but to also reconstruct some of the features and characteristics regarding the sale of fish and shellfish in Herculaneum.

8.4.1 Literary and archaeological evidence for fishing in the ancient world

The majority of our information about fishing and shellfish collecting in the ancient world comes from pictorial depictions and the ancient sources.[120] The association of fishing and fishermen with particular cultural and economic values in the ancient world limits the degree to which the written sources are helpful in reconstructing fishing practices. Fishermen, like peasant farmers, were regarded by the Romans both as individuals of lower social and socioeconomic standing as well as a pastoral ideal. Fishing for the wealthy was considered a leisure activity and involved the use of a single line and hook or the construction of elaborate fish tanks at their *villa maritima* (Aelian 12.43; Marzano

[120] The sources, as they relate to the consumption of fish have been described in section 7.1.2.

2007: 47-50). Men who did practice fishing as their livelihood were believed to live in abject poverty, subject to the whims and dangers of the sea (Plutarch *Antony* 29.7; Wilkins 1993: 195-194; Purcell 1995: 135-137; López Monteagudo 2010: 182-184). Thus commercial fishing was not of interest to the literary elite and except for a brief description of fishing equipment in Oppian's *Halieutika* (3.73-164), there is no surviving handbook on fishing techniques, equipment and methods as there is for farming and horticulture.

However, numerous pictorial and epigraphic descriptions of fish and the act of fishing have survived in the archaeological record. The majority of the representations of fishing are in the form of mosaics, primarily from North Africa, although fish-themed mosaics can also be found at multiple sites in Spain and Italy (Dunbabin 1978; Reese 2002a: 274-275; López Monteagudo 2010; Bernal Casasola 2010: 84). A mosaic from the *hypogeum* of Hermes from the site of *Hadrumetum* in Sousse, Tunisia, dating from the late 2nd century AD, depicts four pairs of fishermen in four boats working to catch a variety of fish and shellfish (Fig. 8.18). The top pair uses lines and hooks to catch fish while the pair to the left use traps to catch octopus. At the bottom, one of the fishermen prepares to throw a casting net while to the right, two men work together to pull in a seine net full of small fish (López Monteagudo 2010: 161-162). As mosaics are decorative pieces, it was at first believed that many of the depicted techniques were rarely used and highly ineffective (Gallant 1985: 24-25). However, recent excavations in Spain and the Black Sea region have recovered multiple types of fishing equipment, confirming that many of the techniques depicted in the mosaics, including fishing from boats, were in fact effective and widely utilized (Bekker-Nielsen 2004: 85-93; Kron 2008: 205; Bekker-Nielsen and Bernal Casasola 2010).

Fishing in the ancient world could range from the very basic to the very complex in terms of both equipment and manpower. The simplest technique was fishing with a line and hook. Fishing hooks, made out of wood, bone and bronze have been found throughout the Empire and appear to have come in a standard set of sizes (Kron 2008:205; Bernal Casasola 2010) (Fig. 8.19). Single, double and multiple hooks, and even a bronze chained hook have been found in the Campania region, indicating that hook and line fishing was used to catch both small and large species such as sea breams and flatfish as well as octopi and squid (Stefani 2002: 14; Bernal Casasola 2010: 95). Beyond a simple hook and line, fishermen could use longlines to catch multiple fish at the same time, a method particularly useful for schools of medium-sized fish such as mackerel (Marzano 2013: 32).

Multiple types of nets were used in the ancient world. Archaeological finds of nets are rare because they are made out of organic fibers such as hemp or flax (Giner 2010: 66-75).[121] Consequently, Oppian`s *Halieutika* (3.73-163) is a particularly useful source as he describes at least eight different types of nets in detail and the type of fish to catch with each net. Modern ethnographic comparisons are also helpful in understanding Roman net use as many of the techniques have not changed over the centuries. In order to catch smaller fish, such as sardines and anchovies, casting and dipnets can be thrown right from the shore or from shallow water. Seine or drag nets, which are pulled along the floor of the sea from the shore or from boats, are efficient ways of catching multiple species, particularly bottom-dwelling flatfish (Muñiz 2010: 42). Gillnets are effective ways of catching multiple species of approximately the same (Oppian 3.577-605; Sbrana *et al.* 2007).

Finally, there are the more specialized types of equipment, designed to catch a narrower range of species. Traps and weirs are used in rivers and estuaries to catch eels and on rocky reefs or in harbours to catch wrasses and damselfish (Thomas 2010: 153-155). Spears and tridents can be used to catch larger species including eels, flatfish, sharks

[121] A far more common find are the weights used to hold the nets down as they are made out of archaeologically durable material such as stone, clay and lead (Bernal Casasola 2010: 96-117).

and rays (Muñiz 2010: 34-36). Although the metallic ends of spears and tridents survive well in the archaeological record, it is often difficult to determine whether or not they were used primarily for hunting or fishing (Bernal Casasola 2010: 123-124). When appropriate, fishing was done from boats using any one of the above-mentioned methods (Fig. 8.18). Thus the equipment and techniques used for fishing in the Roman world varied depending on the habitat, size and schooling patterns of the various consumable fish species.

8.4.2 Environmental and artefactual evidence for fishing in Herculaneum and Pompeii

Despite the large number of faunal remains recovered from the Cardo V sewer, and the attestation of the ancient sources that Pompeii was a producer of fish sauce, there are relatively few pictorial representations of fish and fishing in the Bay of Naples (Pliny *HN* 31.94). The mosaics from the *triclinia* of the House of the Faun and House VIII.ii.16 display a range of primarily consumable fish and shellfish species (Fig. 8.20). Fish were also occasionally depicted in wall paintings such as the garden nymphaeum at the House of the Centenary, the House of the Vettii and the Villa of Diomede (Reese 2002a: 275). However, unlike many of the North African mosaics, the artistic representations of fish from Pompeii seem to focus exclusively on the fish themselves and are not concerned with the act of catching or collecting fish and shellfish.

The lack of pictorial evidence does not mean that fish and fishing was not an important part of the diet and economy of those living in the Bay of Naples. As is the case with most biodegradable artifacts, it was the eruption of Vesuvius that ensured the survival of certain types of fishing equipment in the Bay of Naples that are rarely found elsewhere in the Roman Empire. Fishing hooks of various sizes as well as lead weights have been recovered from both Herculaneum and multiple *insulae* at Pompeii. Rare and delicate finds include several fragments of carbonized fishing net (Reese 2002a: 275; Bernal

Casasola 2010: 106; Giner 2010: 70). A carbonized long line, still wrapped inside its woven basket, was found in Herculaneum and is the only example of this type of fishing line known from the Roman world (Pappalardo 1990; Bernal Casasola 2010: 121) (Fig. 8.21).

Fish bones and seashells have been recovered from multiple Vesuvian sites. Although early excavations simply noted and subsequently threw out fish and shell finds, material collected during recent excavations has increased the number of faunal remains found in the area. At Pompeii, fish bones have been recovered and identified from the House of Amarantus, House of the Postumii, Garum shop I.12.8 and House II.2 (Nicholson 1997; Locker 1999; Reese 2002a: 274; Carannante 2008-2009; Bernal Casasola *et al.* 2009).[122] Marine molluscs have also been found in multiple buildings in Pompeii and Herculaneum including the House of Menander in Pompeii and the central baths in Herculaneum (Robinson, J. 1999; Reese 2002b; Alissa Whitmore March 14, 2013, pers. comm.). The content of the Cardo V sewer adds significantly to the growing list of assemblages.

8.4.3 Reconstruction of fishing practices in Herculaneum and the Bay of Naples

Understanding the precise processes that brought a fish from the sea to one of the units in *Ins. Or.* II requires an interweaving of the archaeological data with ecological data. The fish remains from the sewer act as the starting point, revealing which species were consumed and which were popular. The fishing equipment sheds light on the methods that were used to catch the various species. However, it is the habitat requirements of the 45 fish taxa that provide the greatest insights into how and when these fish were caught. Species characteristics such as migratory patterns, spawning grounds and feeding patterns

[122] A large quantity of fish bones were recovered during the AAPP excavations but they have yet to be analysed and published.

are dictated by nature and not by man, meaning that fisherman had to operate within certain parameters. In reconstructing fishing patterns in the Bay of Naples, we must firstly recognize and subsequently adhere to these parameters.[123]

The fish recovered from the sewer inhabit two broad ecological areas, coastal marine waters or brackish/estuary waters (Table 8.3). As the Bay of Naples is fed by only a single large river, the Sarno, the estuary zone is restricted to the marshy area south of Pompeii where the fresh water from the Sarno mixed with the salt water of the Mediterranean (Pescatore *et al.* 2001: 81; Vogel and Märker 2010: 68-69) (see Fig. 8.13).[124] There are only three taxa that live primarily in freshwater while the remaining 42 taxa can be found in marine waters. The marine taxa consist of 13 migratory species and 31 non-migratory species. Thus fishing in the Bay of Naples took place primarily off the coast or in the Sarno estuary in varying degrees of intensity based on the season.

8.4.3.1 Fishing in the Sarno estuary

Estuary waters are used by many fish species as a spawning ground.[125] Consequently, at particular times of the year the number of species and the number of individuals that can be found in a river estuary will increase dramatically (Koutrakis and Tsikliras 2003). The summer would have been the peak fishing season in the Sarno estuary as many valuable migratory species include anchovy, Mediterranean horse mackerel and sea bass entered the Bay of Naples and the Sarno at that time (Olivar *et al.* 2001: 111; Ragonese *et al.* 2003: 100; Froese and Pauly 2013). The other peak season would have been the winter when the pilchard arrived and the Anguillidae made their journey from the river to the sea (Vøllestad

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[123] While all of the fish taxa recovered from the sewer are species that can be found throughout the Mediterranean, it will be assumed, for the purposes of the discussion, that all of them were caught locally.
[124] The two small rivers to the east and the west of Herculaneum drained into the Bay but were too small to act as suitable habitats for esturine fish.
[125] Extended versions of this section and the following section on coastal fishing can be found in Rowan 2014.

et al. 1986: 1909; Somarakis *et al.* 2006: 282). None of the non-migratory taxa recovered from the sewer live exclusively in an estuary habitat and thus there was no need for large scale fishing to take place in the estuary outside of the two peak seasons. For example, young *Sardinella* live in estuaries, but the adults live in coastal areas. Since *Sardinella* live in schools it is more likely that they were caught along the coast using casting or draw nets (Whitehead, vol. 1, 1986). The mullets and drums are families of bottom-dwelling fish that can live either in coastal or brackish waters (Whitehead, vol. 2, 1986; Stergiou and Karpouzi 2002: 222; Froese and Pauly 2013). While they can be caught with a simple line and hook, it is easier to catch bottom-dwelling fish with a drag or seine net (Muñiz 2010: 42). Moreover, it is easier to use a drag and seine net along the coast than in the muddy estuary waters and thus mullets and drums were probably also caught along the coast.

8.4.3.2 Coastal fishing

The Mediterranean Sea is characterized as having a narrow coastal shelf that descends into deep basins. The coastal shelf off the western coast of Italy is particularly narrow, extending only 10-20 km from the shore before the sea level reaches depths of more than 200 m (Pinardi *et al.* 2004: 1244-1246). All the taxa, except for the Anguillidae and Percidae (freshwater fish), inhabit the coastal shelf for at least a portion of the year. As regards fishing, even fishing from boats did not need to be done far from the shore nor in deep waters.[126]

Five of the coastal fish are migratory including three species of Sparidae, the horse mackerel and the European conger eel. Adult horse mackerel come closer to the coast and the surface during the summer but move out into deeper waters, up to depths of 600 m, in the winter (Ragonese 2003: 101; Froese and Pauly 2013). The mackerel, bogue and black

[126] In Italy today, the majority of small coastal fish are still caught on the continental shelf by independent fishermen using small boats (Colloca *et al.* 2004).

sea bream are all schooling species and were probably caught using seine nets, gillnets and even long lines, with the mackerel being sold fresh or for use in fish sauce (Whitehead vol. 2. 1986; Desse-Berset and Desse 2000: 81; Sbrana *et al.* 2007: 51; Froese and Pauly 2013 Marzano 2013: 48). Red porgy live in in-shore waters for most of the year and although a solitary species, were probably caught using the same series of nets (Whitehead vol. 2. 1986; Stergiou and Karpouzi 2002: 223).[127] Ecologically, the conger eels are very different, living near the coast during their juvenile stage but moving out to deeper waters as adults (Froese and Pauly 2013). The conger eel bones found in the sewer were from small individuals and therefore were probably caught while still living near the coast.

The remaining 26 taxa are all non-migratory coastal fish. This does not necessarily mean that all the taxa were available throughout the year, simply, that they were present in the Bay of Naples in steady numbers for multiple seasons. Winter, particularly January, would have been the time of least availability as some of the species, including hake and the pearly razorfish spend the winter in deeper waters (Whitehead vol. 2. 1986).

During the warmer months these non-migratory fish can be found in three broad environmental habitats, which, in turn, determined fishing methods. Seven of the taxa, including the weevers and flatfish, can be found in benthic environments; living primarily on the sea floor (Whitehead vol 2. 1986; Froese and Pauly 2013) (Table 8.3). All seven types could be caught using tridents or spears, although, except for the skates, that was probably not the preferred method (Muñiz 2010: 34-36**)**. Using drag nets or seine nets from the shore was a more effective and efficient way of capturing these fish as many could be caught at once.

[127] Seine and gillnets are not designed to catch a single species and many of the taxa recovered from the Cardo V sewer would have been caught at the same time during a single fishing event. Modern studies of gillnets have shown that, in attempts to catch hake, horse mackerel, bogue and common Pandora were caught as well (Sbrana *et al.* 2007: 50).

There are 9 taxa that live just above the sea floor in demersal or benthopelagic habitats (Whitehead vol 2. 1986; Froese and Pauly 2013). This group includes the majority of the Sparidae and thus most of the fish found in the Cardo V assemblage. Long lines and seine nets would have been efficient and effective ways to catch the Sparidae. Since they are all approximately the same size and live above rocky or sandy bottoms in inshore waters they were probably caught at the same time, especially if seine nets were used. The hake are larger than the Sparidae and live in deeper waters, often between 70-370 m (Froese and Pauly 2013.). Since they lived farther from the shore more effort was required to catch them or they were a more rare catch if fisherman had to wait until they swam into shallower waters. Today they are caught primarily by trawling in the Mediterranean although gillnets are used in the Tyrrhenian Sea (Oliver and Massuti 1995:184).

The final category of coastal fish are those that inhabit rocky reefs or man-made underwater structures including artificial reefs and breakwaters (Charbonnel *et al.* 2002: 210; Guidetti 2004; Domingues *et al.* 2005: 4052; Froese and Pauly 2013). Shipwrecks and the underwater concrete structures of the many harbours in the Bay of Naples would have increased the available habitat space for these species. If Herculaneum's harbour had a breakwater or permanent underwater structures, it is likely that these rocky reef species could be found there. Although blotched picarel usually inhabit coastal pelagic waters, it too has been found to live on the external side of man-made breakwaters (Guidetti 2004; Froese and Pauly 2013). A single hook and line, traps, and weirs would have been used to collect these fish from the reefs. It would have been impractical to use nets on the reefs as the risk of damaging the net would have been quite high. Dip nets and a single line and hook would have been effective when fishing from the harbour. The tendency of damsel fish to inhabit artificial structures may explain its large presence in the sewer assemblage.

Table 8.3. Habitat locations and probable method of capture for the identified fish taxa from the Cardo V sewer

Taxa	**Habitat and characteristics**	**Size**	**Depth**	**Method of capture***						
				Single hook	**Long line**	**Casting net**	**Draw/ drag net**	**Seine net**	**Traps and weirs**	**Spear/ trident**
European eel (*Anguilla anguilla* L.)	Freshwater/ marine, estuary, catadromus	F: 40-60cm M: 30-40cm	0-700m	X					X	X
Eels (Anguillidae/ Congridae)	Freshwater/ marine, usually catadromous		N/A						X	X
Garfish (*Belone belone* L.)	Coastal, pelagic-oceanic, estuary, migratory	45cm	Shallow waters			X			X	
Bogue (*Boops boops* L.)	Coastal, demersal, gregarious migratory	15-20cm	0-100m	X	X			X	X – gill net	
Damsel fish (*Chromis chromis* L.)	Coastal, reef-associated	8-10cm	2-40m			X	X	X		
Herring/sardines (Clupeidae)	Primarily marine, some freshwater, migratory, schooling		N/A			X	X			
European conger eel (*Conger conger* L.)	Coastal, demersal, migratory	Up to 3m	0-500m		X			X	X	X
European seabass (*Dicentrarchus labrax* L.)	Marine, demersal, estuary, migratory	1m	10-100m	X				X		
Sea bream (*Diplodus* sp.)	Coastal, littoral, gregarious		N/A	X	X	X			X	
Sharks and rays (Elasmobranch)	Marine, coastal		N/A	X	X					X
Dog fish (Elasmobranch)	Marine, coastal		N/A	X	X					X
European anchovy (*Engraulis encrasicholus* L.)	Coastal, pelagic-neritic, estuary, migratory, schooling	12-15cm	0-400m			X	X	X		
Gadids (Gadidae)	Marine		N/A	X						
Wrasses (Labridae)	Coastal, demersal		N/A	X					X	
Cuckoo wrasse (cf. *Labrus mixtus* L.)	Coastal, reef-associated	25-30cm	2-200m	X					X	
Hake (*Merluccius merluccius* L.)	Marine, demersal, lives in shoals in deep water in winter, closer to the shore in summer	30-70cm	70-370m	X	X			X	X – gill net	
Mullets (Mugilidae)	Marine, costal and estuary water		N/A	X		X		X	X	

Taxa	**Habitat and characteristics**	**Size**	**Depth**	**Method of capture***						
				Single hook	**Long line**	**Casting net**	**Draw/ drag net**	**Seine net**	**Traps and weirs**	**Spear/ trident**
Goatfish (cf. *Mullus* sp.)	Coastal, demersal, (rarely estuary water)		N/A	X		X		X	X	
Mediterranean moray eel (cf. *Muraena helena* L.)	Marine, benthic, reef-associated, occasionally enter freshwater	Up to 130cm	15-50m	X				X	X	X
Red sea bream *Pagellus boravageo* Brunnich)	Coastal, benthopelagic	25-35cm	150-300m	X	X			X	X	
Common pandora (*Pagellus erythrinus* L.)	Cosatal, benthopelagic	20-25cm	20-100m	X	X			X	X – gill net	
Red porgy (*Pagrus pagrus* L.)	Coastal, benthopelagic, migratory	30-35cm	10-80	X	X	X		X	X	
Perch (cf. Percidae)	Freshwater, estuary		N/A	X						
Flatfishes (Pleuronectiformes)	Coastal, benthic		N/A					X		X
Skates (Rajidae)	Marine, benthic		N/A	X						X
European pilchard (*Sardina pilchardus* Walbaum)	Coastal, littoral, pelagic-neritic; estuary, migratory, schooling	15-20cm	25-55m day, 10-35m at night			X	X	X	X	
Sardinella (cf. *Sardinella* sp.)	Coastal while adult, young often found in estuaries, pelagic, schooling		N/A			X	X	X	X – gill net	
Drums (cf. Sciaenidae)	Coastal, estuary and coastal		N/A	X						
Mackerel (*Scomber* sp.)	Coastal		N/A	X						
Left-sided flatfish (Scophthalmidae)	Coastal (occasionally brackish), benthic		N/A					X		X
Sea breams (Sparidae)	Coastal		N/A	X	X			X	X	
Seabream (cf. *Sparus* sp.)	Coastal, littoral		N/A	X	X				X	
Blotched picarel (cf. *Spicara maena* L.)	Coastal, pelagic-neritic, breakwaters	21-25cm	30-90m				X	X		
Picarel (*Spicara* sp.)	Coastal		N/A				X	X		

Taxa	Habitat and characteristics	Size	Depth	Method of capture*						
				Single hook	Long line	Casting net	Draw/ drag net	Seine net	Traps and weirs	Spear/ trident
Black sea bream *(Spondyliosoma cantharus* L.*)*	Coastal, benthopelagic, migratory, gregarious	20-30cm	5-300m	X	X			X	X	
Greater weever (*Trachinus draco* L.*)*	Coastal, benthopelagic/ benthic	25-30cm	1-30m					X		X
Weevers (*Trachinus* sp.)	Coastal, benthopelagic/ benthic		N/A					X		
Mediterranean horse mackerel (cf. *Trachurus mediterraneus* Steindachner*)*	Marine, pelagic – oceanic, schooling, estuary, migratory	30cm	5-250m	X					X	
Horse mackerel *(Trachurus trachurus* L.*)*	Coastal, pelagic-neritic, schooling, migratory	22cm	100-200m	X				X	X – gill net	
Mackerel (*Trachurus* sp.)	Marine		N/A	X					X	
Gurnards (Triglidae)	Marine, benthic, junveniles have a pelagic phase		N/A				X			
Pouting (*Trisopterus luscus* L.)	Marine, brackish, benthopelagic	21-25cm	30-100m	X			X	X		
Pout (*Trisopterus* sp.)	Marine, gregarious, younger fish live closer to the shore		N/A	X			X			
Pearly razorfish (cf. *Xyrichthys novacula* L.*)*	Coastal, reef-associated	30cm	1-90m						X	

Whitehead 1986; Froese and Pauly 2013.

*Method of capture is based on archaeological and modern data. For good discussions of fishing gear in the ancient world see Bekker-Nielsen (2002), Thomas (2010) and Muñiz (2010) for discussions of modern fishing methods in the Mediterranean and Tyrrhenian Sea see Stergiou and Karpouzi (2002) and Colloca *et al*. (2004).

8.4.4 The Herculaneum fish market

The fish recovered from the Cardo V sewer began their journeys to *Ins. Or.* II after being caught either in the Bay of Naples or the Sarno estuary. Precisely where, when and how a fish was caught, and in what quantities, depended significantly on its migratory patterns, schooling tendencies and spawning locations (Table 8.3). By combining this ecological data with the sewer material we are able to obtain a clear picture of the life cycles of these fish once they actually reached Herculaneum and subsequently, create a broad reconstruction of the town's fish market. The many migratory species mean that the quantity and variety of available fish would have fluctuated through the year. On a day-to-day basis the market would have been dominated by smaller coastal non-migratory fish that had been caught that day or the previous night, particularly the sea breams. Considering the socioeconomic status of the inhabitants of *Ins. Or.* II, it is therefore not surprising that small, non-migratory fish species, all approximately 20-35 cm, dominate the otolith assemblage (77.6%). Many of these small fish can be caught using seine nets, a method that is not species-specific, and it is probable that they were sold as mixed assortments to be used in stews or to be fried. The presence of species such as the damsel fish, today not considered to be a food item, indicates that all manner of small fish were acceptable as food and that little sorting took place prior to sale.[128] Larger non-migratory fish, such as garfish or rays, as they were more difficult and time consuming to catch, would have occasionally been for sale fresh, although probably divided up and sold as fresh or salted portions. The recovery of bones but the rarity of otoliths from these larger species in the sewer assemblage supports this method of sale.

Summer would have been the peak season for catching and buying fish as many of the migratory species, such as anchovies and horse mackerel arrived then. The majority of

[128] The damsel fish and pearly razor fish may have been unintentional catches, accidentally collected while fishing for picarel along the harbour.

these catches were probably used for the production of fish sauce but as the otolith evidence from the sewer has shown, some were obviously sold fresh as well. Mid-winter was probably the time of least availability as some of the non-migratory species move out to deeper waters and the roughness of the sea would have made fishing more difficult. In addition to fresh and salted fish, the inhabitants of Herculaneum could purchase either locally made or imported fish sauce from Spain and North Africa (De Sena and Ikämeimo 2003: 314).[129] Finally, those living in *Ins. Or.* II probably did some fishing as well, focusing on the small coastal species that could be caught right from the shore. However, considering the range of species and their associated ecological characteristics, it is probable that most fish, and especially the estuary species, were caught by fisherman who had both the necessary time and equipment.

8.4.5 Shellfish collection

Similar to the fish taxa, the ecological characteristics of the shellfish assemblage enables us to determine where the specimens would have been gathered. All 53 shellfish taxa share the same ecological habitat; the littoral zone, ranging from the beach to approximately 60 m into the sea (Abbott and Dance 1991; Palomares and Pauly 2013).[130] Furthermore, most of the species are benthic creatures and live on the beach or the sea floor. The Herculaneum coastline is particularly well suited to the collection of shellfish as the sea front was shallow to a depth of only 0.5-0.7 m (Sigurdsson and Carey 2002: 55).

Modern ethnographic studies suggest that sticks, rakes or shovels were used to dig the creatures out of the sand (Elliott and Hemingway 2002: 458; Occupational Outlook Handbook 2010: 601). Boats were probably occasionally used as well. Today, in the Messolonghi-Etolikon lagoon area of Greece, handmade rakes are used to detach molluscs

[129] For a more detailed view of the fishing economy in Herculaneum see Rowan 2014.
[130] Habitat data can be found in Appendix D.

such as *Mytilus galloprovincialis* and *Modiolus barbatus* from rocks and other hard surfaces (Elliott and Hemingway 2002: 458-459). Both species were recovered from the Cardo V assemblage. Ethnographic work from the western coast of the United States has shown that the Tolowa and Alsea tribes used special hardwood sticks to collect mussels and oysters (Barner 1981: 17). A knife could be used to pry limpets and sea urchins off the rocks (Gabriel *et al.* 2005: 17). Such tools are very difficult to identify in the archaeological record, even in a place such as Herculaneum; shovels, knives and rakes are multi-purpose objects and sticks would appear simply as carbonized wood. The simplicity of the required tools, in addition to the close proximity of the shellfish to the shore means that the inhabitants of *Ins. Or.* II could have collected the majority of the species themselves, although some were probably collected by fishermen as well.

The composition of the Cardo V assemblage enables us to detect patterns in the collection and processing of the material. The assemblage can be divided into three categories of shellfish, distinguishable by species and size. The first category comprises the 32 taxa of edible shellfish while the second category consists of shellfish of the same 32 taxa but of individuals that were too small to be considered edible (Figs. 8.22-8.23) (Table 5.15). The third category consists of 19 small inedible taxa, mostly predatory species, where even the maximum size of the shell or creature was still too small to be considered a foodstuff (Abbott and Dance 1991: 182) (Fig. 8.24). Combined, the categories represent unprocessed material. If they were sold in the market, it was as an unprocessed mixture of species, including the carnivorous species that were still attached to the shells of the edible specimens. Once purchased, or collected by the inhabitants themselves, the shells were then brought back to the insula where the edible shells were sorted from the inedible examples. If the shellfish had been processed and cleaned outside the insula then the assemblage would contain very few examples of categories two and three.

8.5 Conclusions

This chapter has featured three case studies, using material from each of the major forms of preservation found in the sewer: carbonization, mineralization and biogenic preservation. By systematically going through the life cycles of the various remains, from their origins to the time they entered *Ins. Or.* II, the chapter demonstrates that bioarchaeological remains can tell us more about life in Herculaneum beyond nutrition and consumption. The case study for the carbonized assemblage, focusing on the thousands of burnt olives stone fragments, reveals that pomace produced at nearby villas was used as a fuel for heating and cooking. The inhabitants of *Ins. Or.* II were clearly taking advantage of all the resources available in the area, including agricultural by-products. The adoption of pomace fuel was probably due to financial reasons. As the demand for charcoal increased, the price of pomace decreased, especially in the winter when charcoal supplies would have been at their lowest.

The mineralized arable weed and ruderal plant seeds provide information about an entirely different aspect of life in Herculaneum. We can tell that only clean grain was brought into the town, that the flour was not finely sieved and that many weed seeds were consumed along with the bread. The ruderal seeds tell us about the landscape around and within the city, particularly that Herculaneum did not have any nearby bodies of standing water and that it was surrounded primarily by arable fields and pastures.

The fish and shellfish material again provides a very different set of data, this time from an economic perspective. The two assemblages reveal that there was a thriving fish and shellfish market in Herculaneum and that availability and consequently price, fluctuated based on the season. This case study has also highlighted the importance of incorporating ecological data into our reconstructions of economic activities in the ancient world. Although the fish, otolith and shell assemblages are substantial, the majority of the fishing and shellfish collecting patterns in the Bay of Naples could not have been ascertained without also using ecological information such as habitat location, migratory patterns and schooling tendencies. Ethnographic comparisons also played a crucial role in determining the types of equipment used to collect the shellfish.

"The essential diet of the poor could have been little more than coarse bread washed down with water drawn fresh...and, perhaps, the rare addition of some pulses and wine of the roughest sort." (Sippel 1987: 48)

Chapter 9: Review of the major findings and conclusions

This thesis has examined the largest archaeobotanical dataset, and the only dataset with respect to fish and shellfish material, from Herculaneum. At the moment, it represents one of the largest collections of mineralized material from the Bay of Naples and, except for the human skeletons, has the narrowest date range of any bioarchaeological collection recovered from the region. For these reasons, the aims of this thesis were twofold: to assess the taphonomic and depositional history of the material in the Cardo V sewer and subsequently, to use that material to examine the diet, health, and consumption and food acquisition practices of those living in *Ins. Or.* II. This final chapter reviews the major findings of each of the research questions posed in the introduction chapter and discusses the wider implications of these results as they relate to Roman diet, nutrition and the food economy of AD79 Herculaneum.

9.1 Review of the major findings

9.1.1 Movement, preservation and taphonomy in the Cardo V sewer

The six quadrants examined in this thesis, representing 220L of material, produced a total of 194 taxa including 94 botanical, 45 fish, 53 shellfish and two bird taxa. A total of 106 taxa were identified to species while the remainder were identified either to genus, family or order. From the 194 taxa, 114 can be considered edible and thus the majority of the assemblage represents consumable goods.

It was at first hoped that the material beneath each of the *Ins. Or.* II latrine shafts could be related to the shop or apartment above. Density, ubiquity and abundance calculations have confirmed a horizontal downward shift in the material towards the southern end of the sewer with Q3-4 and 5-6 possessing the greatest quantity and diversity of bioarchaeological material. Subsequently, the assemblage has been considered a single archaeological context. SACs were adapted from ecological studies and were found to be an effective method of measuring taxonomic richness in samples containing multiple types of bioarchaeological material.

Mineralization was the primary form of botanical preservation within the sewer. A total of 84 taxa were identified within the mineralized assemblage followed by 27 carbonized and 10 waterlogged taxa. The combination of items within the sewer, including faecal matter, bone and water ensured that mineralization frequently took place while at the same time maintaining a relatively neutral pH, leading to the preservation of rare items such as fish otoliths. The unexpected presence of waterlogged material indicates that the eruption had a sealing effect on the sewer, protecting the material from evaporation, water percolation and bacterial and fungal activity until it was uncovered in the 1940s. The compact nature of the material and the unintentional infilling with sand after the Maiuri investigations probably helped protect the botanical and faunal remains after the sewer was exposed to the elements (Camardo 2008).

The compositions of the botanical assemblages did not deviate significantly from those found at other sites. The carbonized assemblage was composed primarily of olive stones but also contained the usual combination of staple crops, fruit stones and nut shells. The mineralized material consisted predominantly of foods that remain intact during processing and are swallowed whole such as fig pips, seasonings and weed seeds. The preservation conditions were extremely good as evidenced by the recovery of rarely mineralized material such as olive seeds. However, neither the carbonized or mineralized assemblage, for the most part, contained many rare or unusually preserved finds, suggesting that the preservation conditions were excellent but not atypical. The high degree of similarity between the Cardo V material and nine comparative Pompeii assemblages indicates that the botanical material has been subject to little taphonomic bias. In total, 82 of the sewer’s 94 botanical taxa have been found at Pompeii. Consequently, food items that are missing from the sewer represent true absences or absences due to the effects of food preparation and processing activities such as milling. Items recovered from Pompeii, but that are missing from the sewer assemblage, are expensive foods such as sesame seeds or garden plants such as vervain; items one would not expect to find in dense urban middle to lower class housing. Thus the Cardo V assemblage, with the regards to botanical preservation, can be considered a reliable representation of diet and food preparation and consumption practices taking place in *Ins. Or.* II.

The excellent preservation conditions meant that it was also possible to discern the formation processes, both within and above the sewer, which led to the creation of the botanical and faunal assemblages. As described in chapter 6, the mineralization process took place entirely within the sewer and most of the material was originally deposited as human waste. The survival of mineralized seeds meant that all the recovered carbonized material must have been burnt prior to the eruption and prior to deposition into the sewer. The material was carbonized due to accidental burning during food preparation and due to the intentional burning of fuel or ritual offerings. The majority of the faunal material ended up in the sewer when food processing and cooking waste were thrown down the latrine shafts. The presence of chewed fish bones and smoothed otoliths indicate that some of the fish remains had undergone mastication and digestion.

9.1.2 Dietary diversity

The most striking, and one of the most important aspects of the *Ins. Or.* II diet is its diversity. The people living in this apartment block consumed 114 different foodstuffs including seven types of cereals, 12 varieties of fruit and 45 species of fish. Being situated in the fertile Vesuvian region meant that their diet could be based almost exclusively on locally produced goods. Only the dates, black pepper and sorghum were definitively imported from abroad. The dates probably came from the Middle East, Egypt or North Africa while the black pepper probably came from India by way of Berenike (Cappers 2006: 114-117). The sorghum may have been accidentally incorportated into traded goods at Berenike or arrived from sub-Saharan Africa.

This high degree of dietary diversity challenges two long-held beliefs about the "average" Roman diet. Firstly, there is the theory that the diets of the lower classes must have been dull and monotonous because the combination of limited food supply and high cost provided them with little choice (Fidanza 1979: 88-89; Sippel 1987: 49-50; Garnsey 1999: 37, 43-44). Secondly, in archaeology, there is often the desire to link structural remains with financial or social status. The architecture and decoration of a house or building are typically used to assess the wealth of its occupants and in turn their diets and purchasing power as it relates to food (Wallace-Hadrill 1994: 127, 149). The Cardo V assemblage puts us in the rare and invaluable position of being able to estimate wealth and purchasing power based on both the architecture and the food remains. Alone, the architecture, as presented in chapter 2, suggests that *Ins. Or.* II was occupied by middle to lower class shop owners. People lived above and behind their stores in a limited number of small rooms with cramped mezzanine space. *Ins. Or.* II.7 is the only apartment with evidence for a kitchen. Based on this assessment, diets should be limited to cereals, wine and olive oil with few sources of animal protein or vegetables.

The Cardo V finds clearly contradict the theories that food was unavailable or too expensive for those living in modest domestic dwellings. The ubiquity calculations shown in chapter 5 indicate that all the inhabitants of *Ins. Or.* II ate a diet based on a limited number of staple foods such as cereals, grapes and figs, but supplemented on a frequent basis by a wide range of fruits, eggs, herbs, fish and shellfish. It is clear from the fish and shellfish assemblages that the town and the region could support a thriving food economy. The food supply to Herculaneum was extensive and the costs must have been relatively low for people to afford the range of goods available to them. The fertility of both the land and sea no doubt played an important role as it enabled a wide variety of locally produced food to be available with minimal transport costs. In Herculaneum, even small shop owners could afford fish and seafood on a consistent basis. The infrequent recovery of more expensive items such as black pepper shows that while the diets of those living in *Ins. Or.* II were relatively similar, they were not identical and that there was variation in financial status. It is extremely important to note, however, that Herculaneum's ideal geographical location, with access to food from Campania, the Bay of Naples and the imports to Puteoli, may in fact have made it a privileged place relative to other towns in Roman Italy and the Empire. Ongoing research from Pompeii, and in particular the Porta Stabia project, looking at shops and lower class housing, will help to reveal the extent to which Herculaneum was distinctive in the availability and cost of foodstuffs, at least in the Bay of Naples.

9.1.3 Cooking

In addition to the notion that the poorer classes ate a monotonous diet, there is also the belief that those living in small apartments, due to the absence of identifiable kitchens, did not do much cooking at home and instead purchased hot food from nearby *tabernae*

(Stambaugh 1988: 178; Ellis 2000: 159; Holleran 2012: 146). Again, the Cardo V finds contradict this hypothesis. As the earliest surviving multistory domestic dwelling in Italy, the results have important implications for how we view domestic life in towns such as Ostia. Finds of millets and legumes, foods not usually consumed raw, strongly suggest that cooking was taking place in the apartments of *Ins. Or.* II. Many of the fish and shellfish species were probably cooked as well. Evidence of cooking is further supported by the presence and ubiquity of thousands of fragments of carbonized olive stones, which were used as fuel, and, from other sources of evidence, such as the burning of ritual offerings inside the apartments. Cooking was no doubt a common activity, conducted using a portable hearth or a tripod, pot and pan. Consequently, we should no longer assume that those living in urban houses and apartments without a masonry hearth were unable to prepare their own food.

9.1.4 Ancient authors

The utilization and consumption of a wide array of foodstuffs is in accordance with the statements of the ancient authors who discuss or mention hundreds of individual ingredients. Assessing the validity of the ancient authors has been crucial as they are one of our only sources of information on the consumption of particular foodstuffs, such as leafy vegetables, that never appear in the archaeological record. The large degree of overlap between the ancient texts and the food finds, as presented in chapter 7, suggests that the sources are, for the most part, correct in their basic outline of Roman diet, at least in Italy. However, their elite biases remain, as demonstrated by their disregard for shellfish as a worthy food source, and it is still best to exercise caution when using the sources, especially in the absence of any comparative bioarchaeological material.

9.1.5 Nutrition

Dietary diversity, cooking practices and the accuracy of the ancient sources all impact our understanding of health and nutrition in Herculaneum. The results of work on modern food sciences have also proven to be a significant resource. Recent studies have clearly shown that many of the older varieties and cultivars of cereals, fruits and vegetables were more nutrient-dense than those grown today. Based on the nutritional assessment of the Cardo V foodstuffs, we can conclude that the nutritional status of those living in Herculaneum in AD79 was excellent, contradicting the notion that all but the elite must have suffered from malnutrition (Sippel 1987: 51-52). Their varied diet ensured a sufficient supply of both macro- and micronutrients including all of the essential vitamins and minerals. Severe nutrient deficiency was probably rare in Herculaneum. The human skeletal remains present a similar picture; while disease and childhood illness were still common, people were receiving an adequate amount of nutrients to recover from sickness or injury and reach old age. Thus, in opposition to the popular notion that life for the urban dweller was harsh and short (Scheidel 2001: 10; 2003: 158, 173), people in Herculaneum must have generally been in good health and had access to a sufficient quantity and range of foodstuffs. Their cooking and preservation practices, as revealed both by the remains and the ancient sources, suggest that the benefits outweighed most nutrient losses and people were preparing and consuming foods in ways that the enhanced the nutrient potential of these items. For example, the milling of cereals increases their calorific content by removing much of the insoluble dietary fibre while the cooking of fish and shellfish kills harmful bacteria and parasites. Food preservation methods, such as the drying of figs, ensured the year round availability of the essential nutrients. In sum, it is hoped that this study has demonstrated the benefits of using data from modern food sciences and has inspired other scholars to consider this source of information when doing their own bioarchaeological analyses.

9.2 Contributions to archaeobotanical and bioarchaeological methodology and identification

The volume of material within the Cardo V sewer, combined with its extremely high level of preservation, led to utilization of uncommon and, in some cases, the creation of new, methodological techniques. The diversity of the mineralized assemblage led to the adaptation of SACs, which proved to be extremely useful in ensuring that a sufficient volume of remains had been sorted and identified. The graphs shown in chapter 5 indicate that this technique can be used on all types of bioarchaeological material (and is currently being used to assess the charcoal from the sewer) and the author hopes that it will be helpful to other archaeologists.

Since a nutrition analysis was one of the primary goals of this study, it was crucial to identify as many different foodstuffs as possible. The rare preservation of so many fish otoliths created the opportunity to test a modern electronic identification database on archaeological material. Seventy-six otoliths were identified to species using the online AFORO database and the identifications were checked using a modern reference collection (Lombarte *et al.* 2006). The database proved to be highly accurate in its results and consequently, it can be used as an identification starting point by archaeologists who do not specialize in fish remains. Moreover, using AFORO required very little equipment and no additional costs and should be considered an extremely helpful archaeological resource.

9.3 Wider implications

The primary importance of the Cardo V assemblage does not lie in the taxa lists, but in the multitude of small clues it provides about the intricate and intimate relationship that the people of *Ins. Or.* II had with their food. The intricacies of their relationship are in the supply chain, which spreads out like a web across the Bay of Naples, the wider empire and beyond, bringing these people directly or indirectly into contact with individuals living as close as the next shop over and as far away as India. The intimacy is their direct physical relationship with the food; how they prepared and ate it. Many of these small clues have already been described above. However, it is only when we put all the clues back together that we can begin to question and perhaps rethink some of the more traditional beliefs concerning Roman diet in Herculaneum, the Bay of Naples and beyond.

The sheer number of references and descriptions of food in the ancient sources reveal the important social and cultural role that food played within Roman society. We can see, based on the Cardo V assemblage, that the social and cultural importance of food also applied to the middle and lower classes. Herculaneum was able to support a thriving food economy that provided people with more choice than was required for survival or even to simply avoid monotony. Those of middle to lower socioeconomic status were willing to spend money on non-essential but desired goods including the black pepper and fresh fish.

The variety of the diet and the trade networks that were required to supply it means that we should not underestimate the resourcefulness of those living in the Campanian region or perhaps Roman society in general. Very few food items were considered taboo in Roman culture and archaeologists and bioarchaeologists should establish and consider the potential of all available resources in an area. For example, the people living in Herculaneum ate a wider variety of fish and shellfish than are consumed by the area's inhabitants today. Moreover, archaeologists must try to recognize local, cultural and regional patterns of food processing and consumption, as they will have a major impact on the formation of an assemblage and consequently our views on resource exploitation. This means identifying those intimate relationships, such as the tendency in *Ins. Or.* II for people to eat millet as porridge, or to clean and process their shellfish within the apartment. The absence of a material in a deposit, such as marine mollusc shells, should not immediately be considered a lack of resource exploitation or availability but perhaps a different cultural or regional attitude towards the location of shellfish processing. It is hoped that the numerous processing and consumption patterns identified in the Cardo V material, as described in chapter 6, will be of benefit to other archaeologists trying to establish patterns of processing and consumption at their own sites.

The extensive resource exploitation taking place at Herculaneum, as reflected in the assemblage, impacted more than just the diet of those living in *Ins. Or.* II. Merchants not only brought back goods from India, North Africa and the Middle East, but it appears that they also brought back ideas concerning resource management. The evidence of olive pomace as a fuel source within *Ins. Or.* II and at the Pompeiian bakeries indicates that Campania began to follow a Mediterranean-wide trend in fuel use more often noted in drier, less forested locations such as North Africa. The use of pomace fuel also raises questions about deforestation, resource management and affordability as well as the relationship between urban residents and villa owners. A better understanding of the relationship between charcoal and pomace in the Bay of Naples will help to answer these questions. While it may be due to excavation and study bias, at the moment, Herculaneum and Pompeii seem to be isolated in their use of pomace. However, as mentioned above, Herculaneum may perhaps be a unique place in relation to the rest of Roman Italy.

The future importance of this study therefore lies in its contribution to Roman archaeology and bioarchaeology beyond the confines of *Ins. Or.* II or just Herculaneum. As a large, well preserved and fully identified assemblage, the results of this study can be used as a source of comparison for material from Pompeii and other sites throughout the Roman Empire. The assemblage also acts as a method of verification for isotope analyses and as a reminder of the importance of using a holistic approach when studying past health and diet. Relying too much on one methodological approach can easily skew results.

Chapter 8 was designed to highlight some of the economic and trade data that can be gleaned from the foodstuffs. Perhaps more importantly, it demonstrates how we can use food remains to look beyond the immediate vicinity of the finds to see the larger relationships taking place between people and food in antiquity. For example, weed seeds can be indicative of pan-Mediterranean trade routes while olive stones are indicative of the continuation and expansion of millennia-old patterns in fuel use and resource management.

In sum, this study has contributed significantly to our understanding of the preparation and consumption of food in Herculaneum while at the same time challenging many of our ideas concerning the diets of the middle and lower classes. The people living in *Ins. Or.* II had a considerable amount of choice with regards to the types of foods they bought as well as how they prepared and ate them. We can no longer assume that those of moderate means ate an unhealthy and monotonous diet, or that descriptions of foodstuffs in the ancient sources apply only to the wealthy. While the question of Herculaneum's uniqueness remains, there is little doubt as to its wealth and prosperity. Only in a town where people frequently had expendable income could such a large and diverse food economy survive. The variety in the cereals, fruits and seafood indicate close connections with both the nearby land and sea and the inhabitants of Herculaneum took full advantage of their geographical location. Subsequently, they had diets that were nutrient-dense and healthy, enabling them to achieve modern-day stature as well as survive and recover from illness. Further research focusing both on coastal and inland sites will add greatly to our understanding of diet, health and resource exploitation in Roman Italy and will help to identify and differentiate between local and region wide trends in food acquisition and consumption practices. At the moment though, it may also be prudent to examine the Herculaneum diet in relation to our own, especially if you are what you eat.

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ROMAN DIET AND NUTRITION IN THE VESUVIAN REGION: A STUDY OF THE BIOARCHAEOLOGICAL REMAINS FROM THE CARDO V SEWER AT HERCULANEUM

By

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VOLUME II

Thesis submitted in fulfilment of the requirement for the degree of DPhil

St. Cross College

University of Oxford, Oxford, Hilary term 2014

FIGURES

Unless otherwise stated all photographs were taken by the author.

Figure 1.1. Herculaneum's location within the Italian Peninsula. (©Google earth)


Figure 1.2. View of the surviving (and reconstructed) remains of *Insula Orientalis* II. The roof and the majority of the upper floors were destroyed during the AD79 eruption of Vesuvius. (Author's photograph)

Figure 1.3. A machine assisted flotation device. Water is pumped into the flotation tank until it overflows and water, along with the material that floats, is washed across the sieve (Fig. 1.4). (Permission to reproduce photograph granted by Lisa Lodwick, Silchester Town Life project)

Figure 1.4. Carbonized material is caught in the sieve as the water overflows the flotation tank. (Permission to reproduce photograph granted by Lisa Lodwick, Silchester Town Life project)

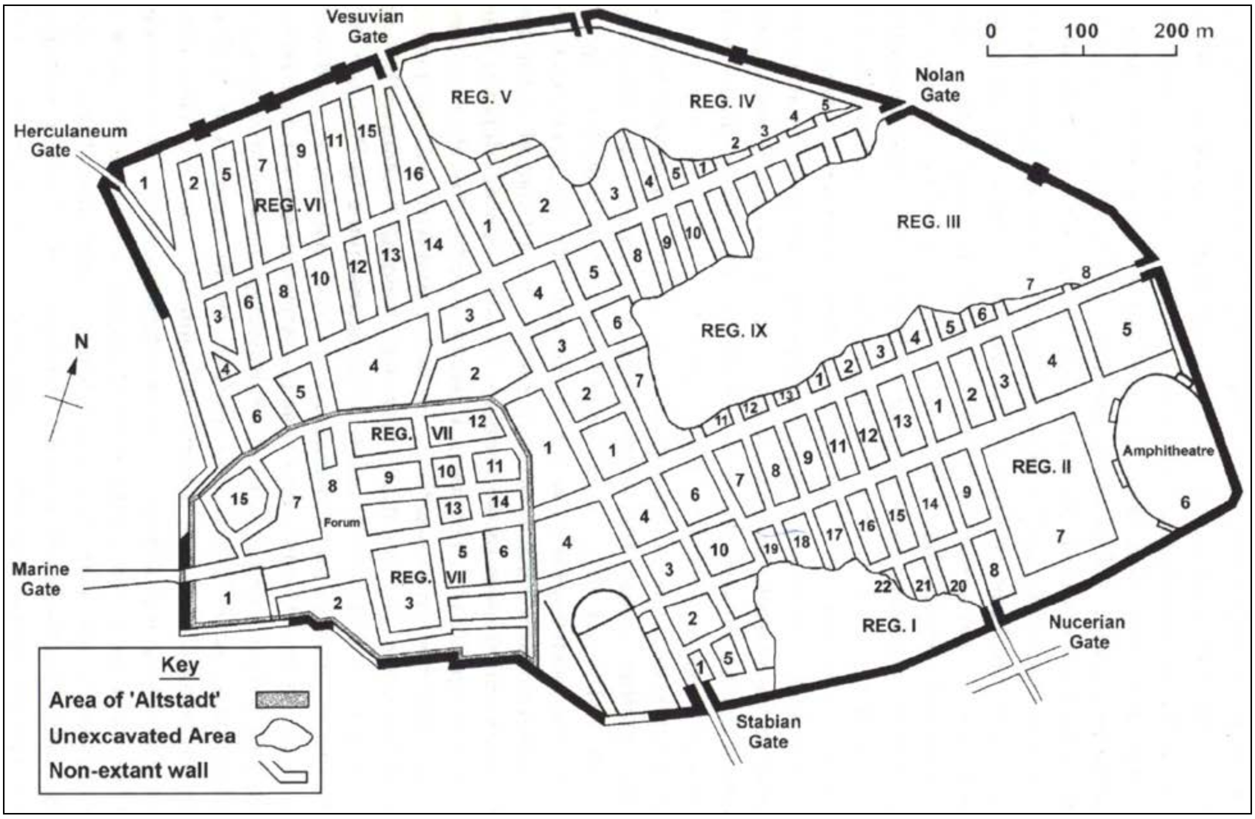


Fig 1.5. Plan of Pompeii showing the regions and *insulae* (Cooley 2003: 118). (Permission to reproduce plan granted by A. Cooley)

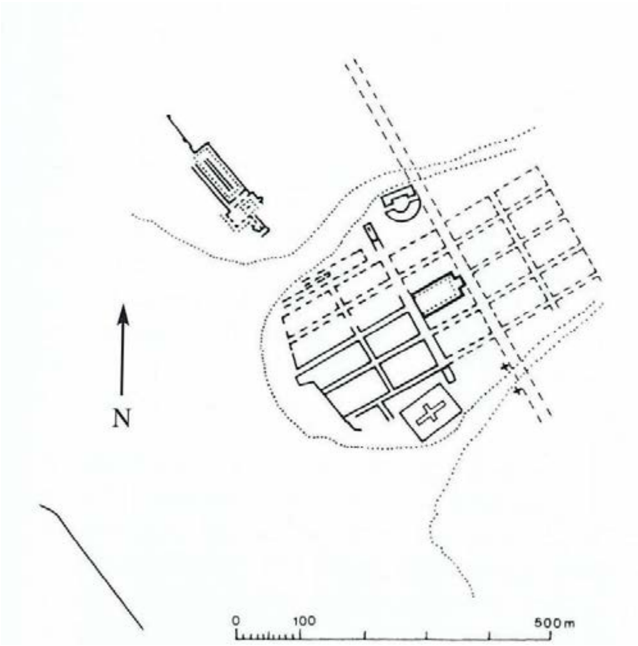


Figure 2.1. Plan of Herculaneum showing the two streams on either side. Excavated section of the town is indicated by solid lines (from DeKind 1998, fig. 2). (© R. DeKind)

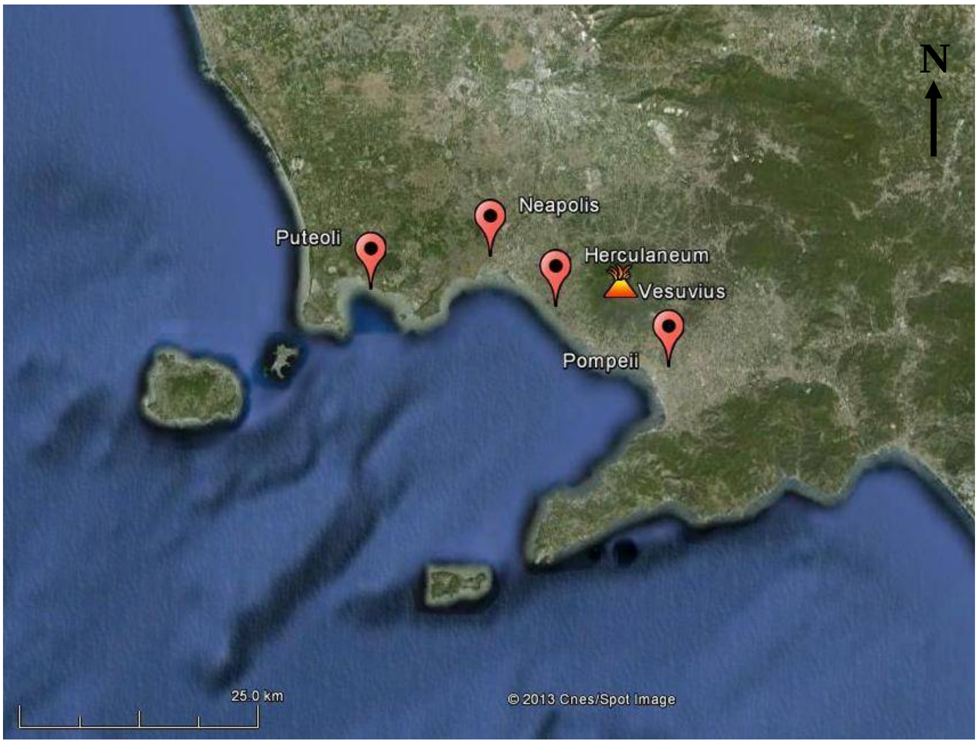
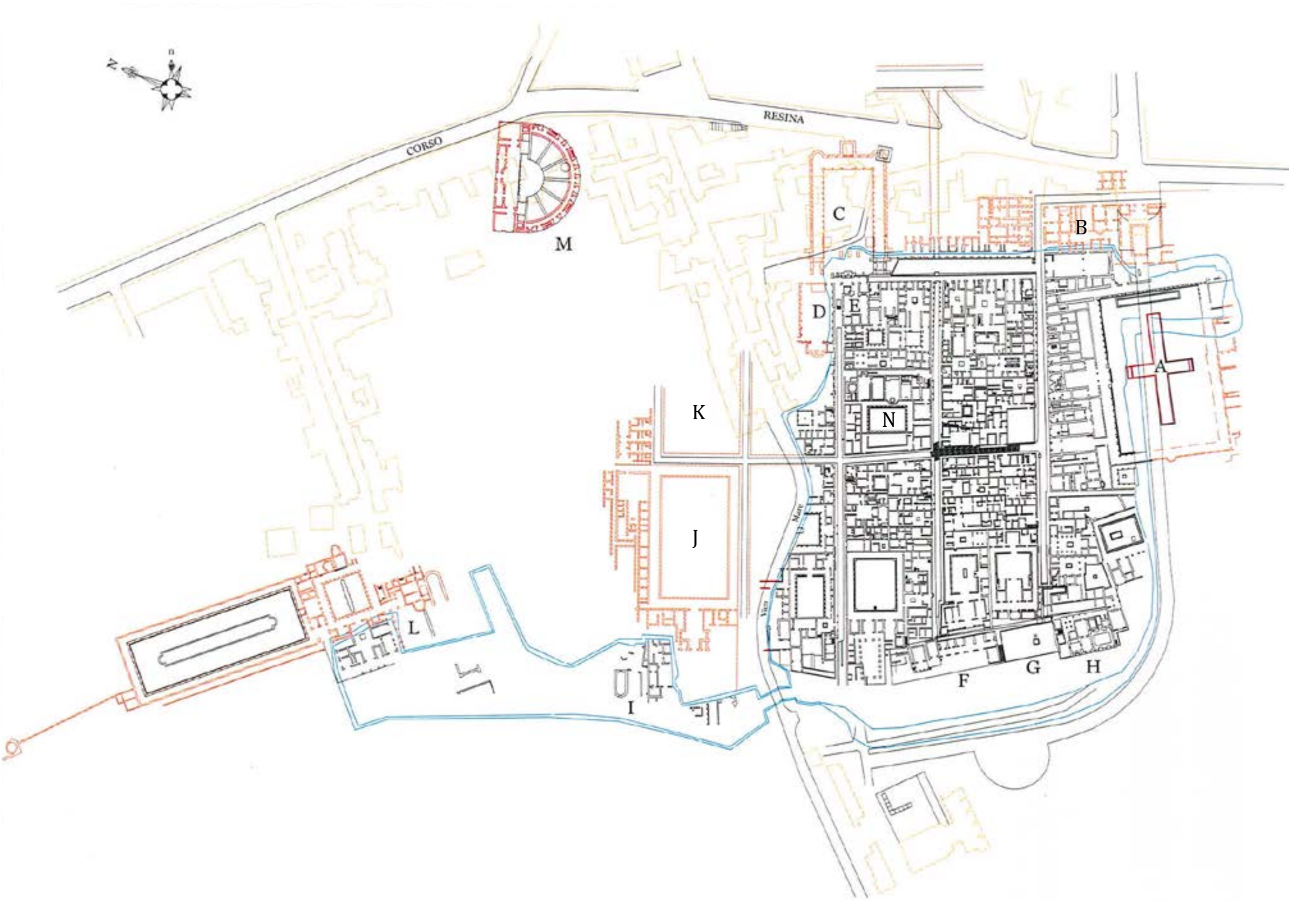


Figure 2.2. Herculaneum's location on the Bay of Naples. (©Google earth)



Area of open air excavations

Area explored by tunnels

Area excavated by tunnels and known from 18th century plans

The limit of the open air excavations

The modern city of Herculaneum

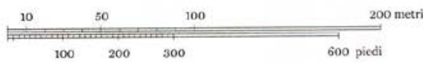


Figure 2.3. Plan of Herculaneum showing the extent of the different forms of excavation. A= palaestra, B = unexcavated multistorey insula, C = so-called basilica, D = Basilica Noniana, E = “College of the Augustales”, F = terrace above the beach with the two small temples to the left, G = terrace and statue of Nonius Balbus, H= suburban baths, I = recently excavated bath complex at Insula Occidentalis north, J = Insula I, K = Insula VIII, L= Villa of the Papyri, M = theatre, N = central baths (adapted from Guidobaldi 2008: 21). (Permission to reproduce plan granted by M. Guidobaldi)

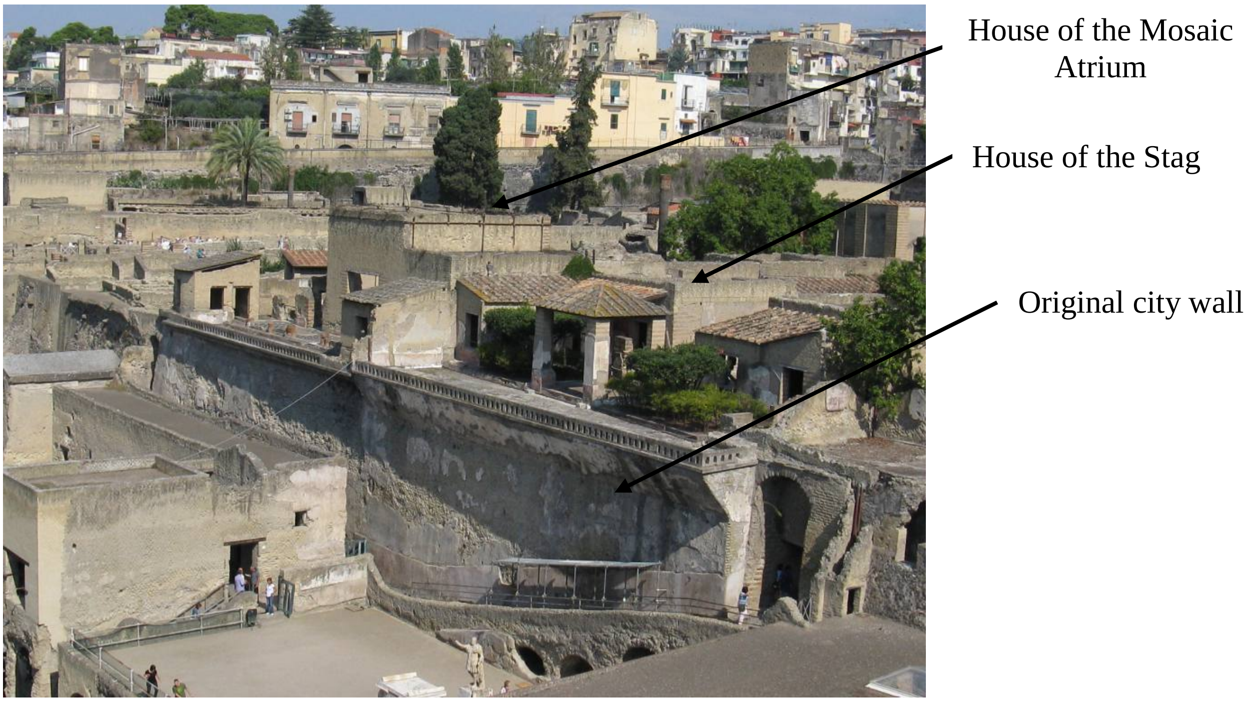


Figure 2.4. The House of the Mosaic Atrium and the House of the Stag are built directly over the city wall. The terrace, with the suburban baths and statue of Nonius Balbus is visible in front of the city wall. (Author’s photograph)

Figure 2.5. Plan of Herculaneum showing the different uses of space. Blue = public spaces/buildings, red = commercial units, grey = houses with no attached shops, white = domestic space with commercial or productive areas attached (adapted from pl. III, Monteix 2010). (Permission to reproduce plan granted by N. Monteix)

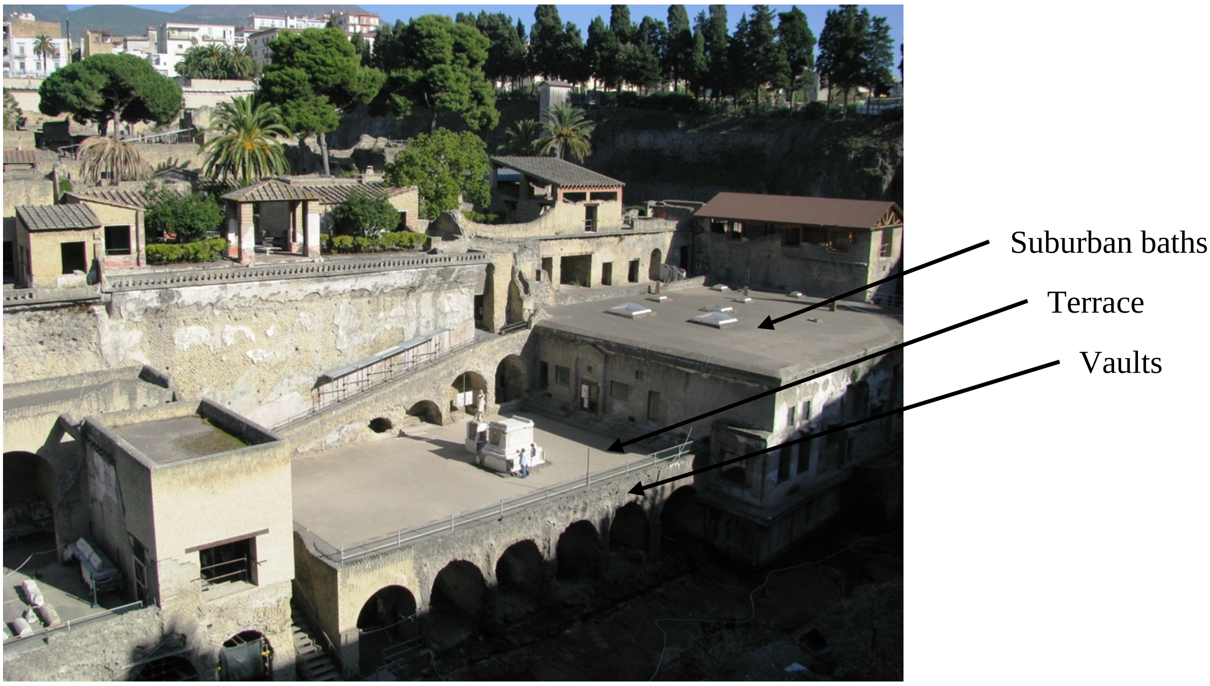


Figure 2.6. The terrace, supported by a series of barrel vaults, located at the very southern end of the town. To the right are the suburban baths. The modern city is visible in the background. (Author’s photograph)

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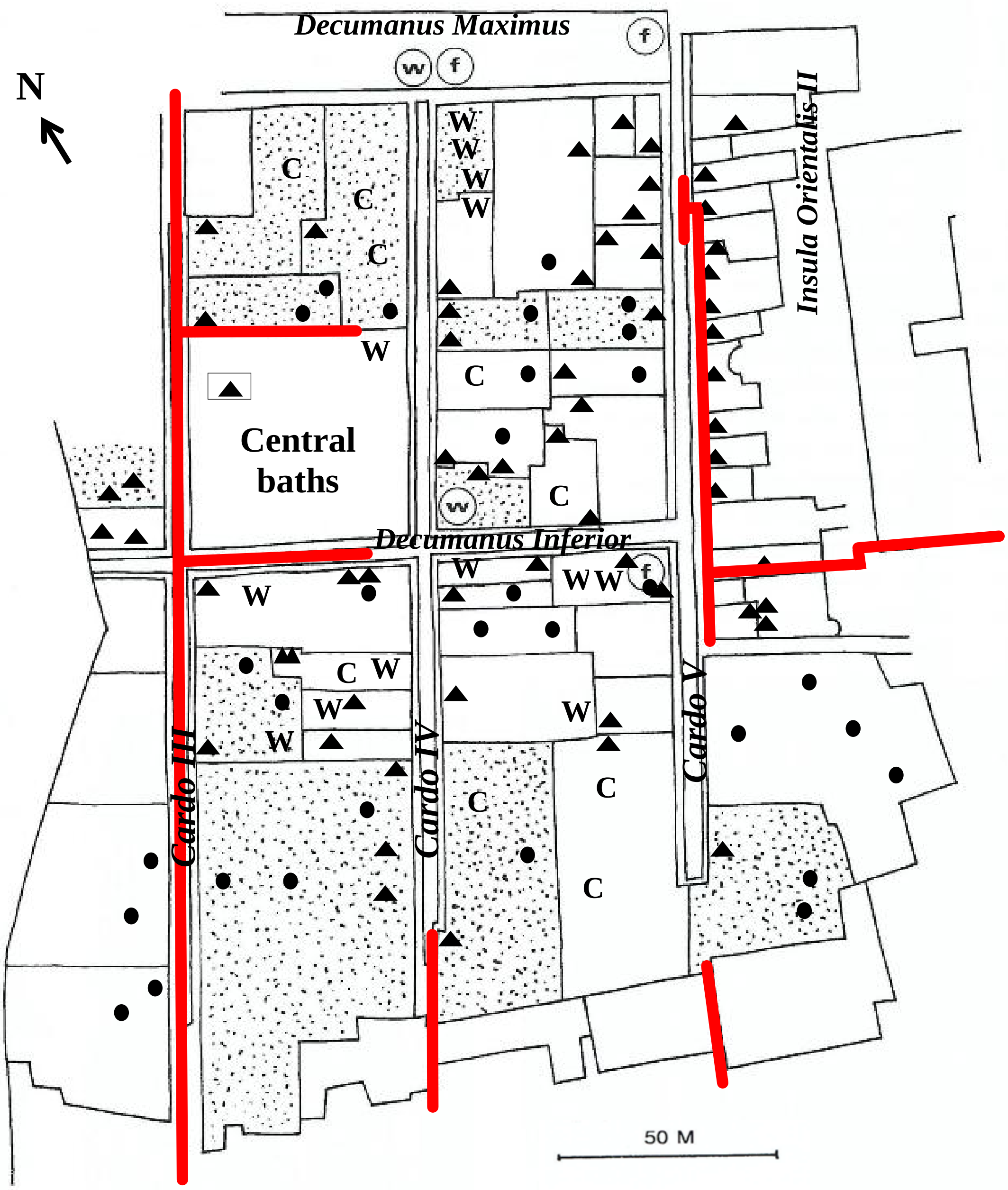


Figure 2.7. Water systems within Herculaneum. f = public water fountain, w = water tower, W = well, C = cistern, ● = well or cistern shaft, ▲= toilet/latrine. Shaded areas indicate houses and public buildings supplied by the aqueduct. The red lines indicate the known locations of the sewers. The latrine in the central baths is the only public latrine known from the excavated portion of Herculaneum (altered from Jansen 2002: 99 (fig. 3.5), 104 (fig. 3.12), 108 (fig. 3.18)). (Permission to reproduce plan granted by G. Jansen)

Figure 2.8. The public water fountain located on the corner of the Cardo V and *decumanus inferior*. (Author's photograph)

Figure 2.9. The slope of the Cardo V as it heads towards the beach to the south. (Author's photograph)

Figure 2.10. The *palaestra*, *Insula Orientalis* II and the Cardo V sewer. Red lines indicate the main N-S and E-W branches of the sewer, blue lines indicate later additions. Dashed line is the channel that drained the pool (adapted from pl. V, Monteix 2010). (Permission to reproduce plan granted by N. Monteix)

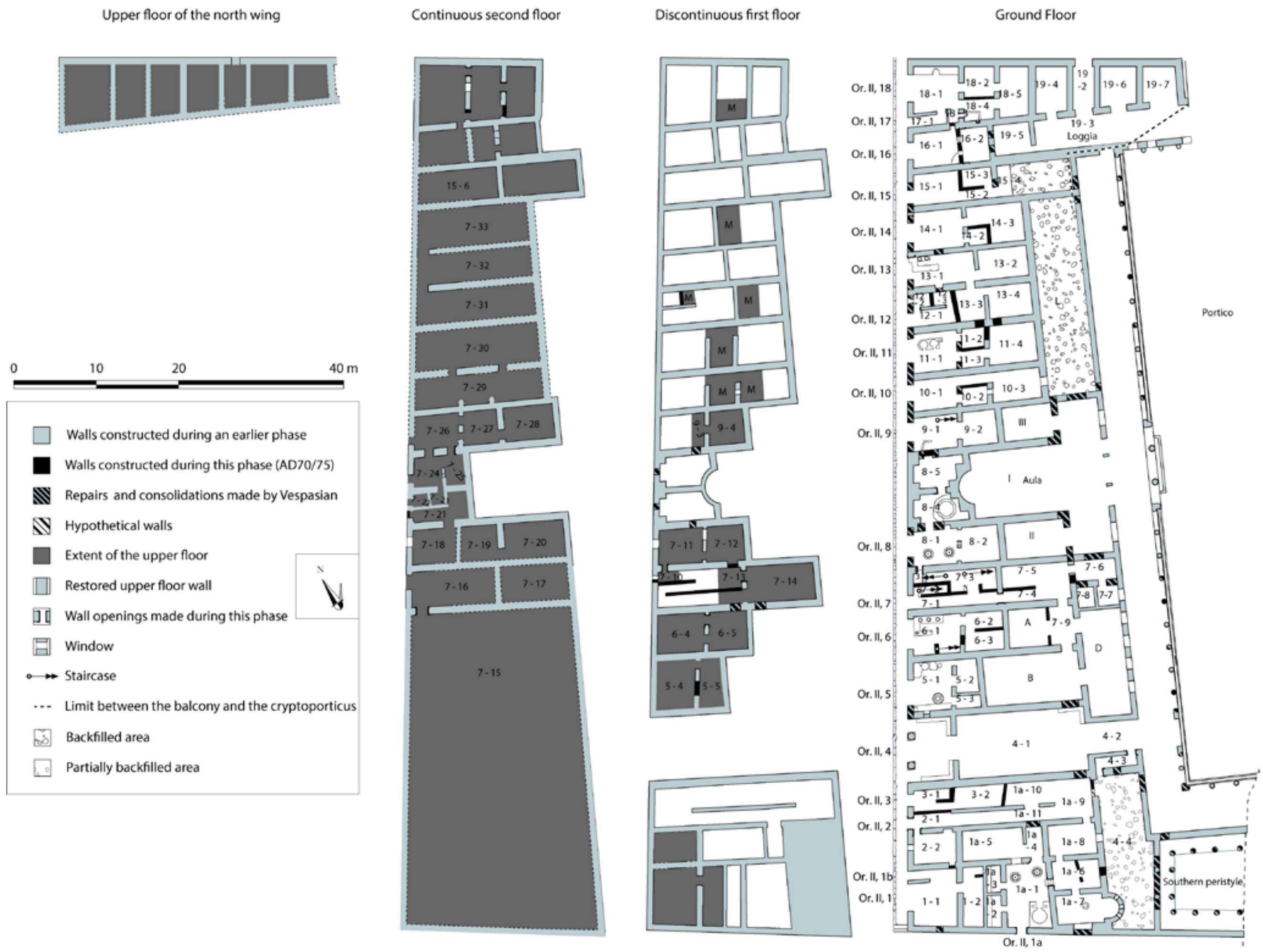


Figure 2.11. Plan of *Insula Orientalis* II showing all three floors and repairs and alterations made around AD70-75. Rooms labelled M are mezzanine levels (adapted from pl. II, Monteix 2010). (Permission to reproduce plan granted by N. Monteix)

Figure 2.12. *Insula Orientalis* II with shaded areas representing the mezzanine levels (adapted from pl. V, Monteix 2010). (Permission to reproduce plan granted by N. Monteix)

Figure 2.13. Showing II.6-14, latrine locations are shown in green, rainwater drains in blue (adapted from pl. V, Monteix 2010). (Permission to reproduce plan granted by N. Monteix)

Figure 2.14. *Ins. Or.* II.6 showing the counter with the four embedded dolia. The beam sockets for the upper floor and some surviving wall plaster are visible on the northern wall. (Author's photograph)

Figure 2.15. One of the millstones from the bakery at *Ins. Or.* II.8. The large preparation room is visible behind. (Author's photograph)

Figure 2.16. *Ins. Or.* II.9 with the wooden amphora rack and a portion of the staircase still preserved. (Author's photograph)

Figure 2.17. *Ins. Or.* II.10 and enclosed room 2 as viewed from room 3, facing towards the Cardo V. (Author's photograph)

Figure 2.18. Bed niche in *Ins. Or.* II.11 room 3. (Author's photograph)

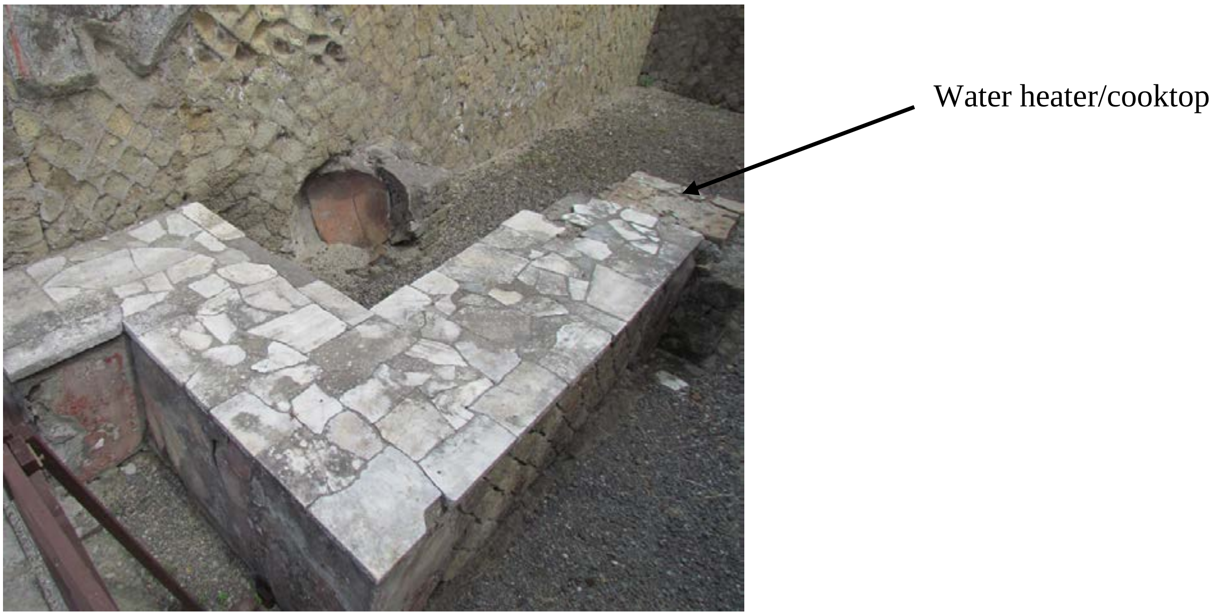


Figure 2.19. Marble topped masonry counter and dolia behind at *Ins. Or.* II.13. The additional masonry block at the end of the counter may have acted as a water heater/cooktop. (Author's photograph)

Figure 2.20. *Ins. Or.* II.14. Extremely little of this unit has survived. (Author’s photograph)

Figure 2.21. Cardo V sewer, looking north towards *Ins. Or.* II.14. Note the support for the piping along the ceiling. (Author’s photograph)

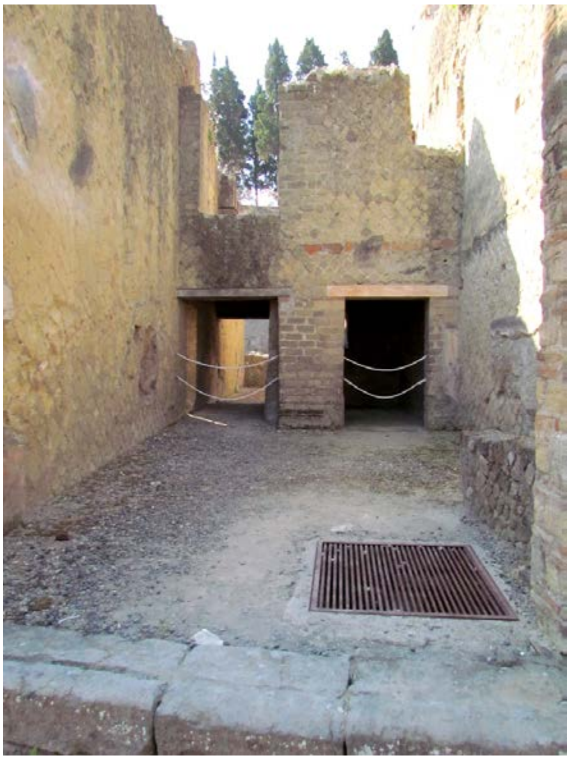


Figure 2.22. Entry shaft into the sewer in *Ins. Or.* II.10, currently covered by a modern grate. (Author's photograph)

Figure 2.23. View down the E-W branch of the Cardo V sewer (HCP 2006-2007). (Permission to reproduce photograph granted by the HCP)

Figure 2.24. Wheat (*Triticum* sp.) stored in a plastic tub in Herculaneum. The 20kg of grain was originally recovered from the upper floor of an apartment on the NE side of the *Decumanus Maximus* (*GdS* 28 July, 1961; Borgongino 2006). (Author's photograph)

Figure 2.25. The back of Ins. Or. II.9-14. The aula is to the left of II.9 while the long room (L in figure 2.10) was filled in during the Vespasianic repairs of AD70/75. (Author's photograph)

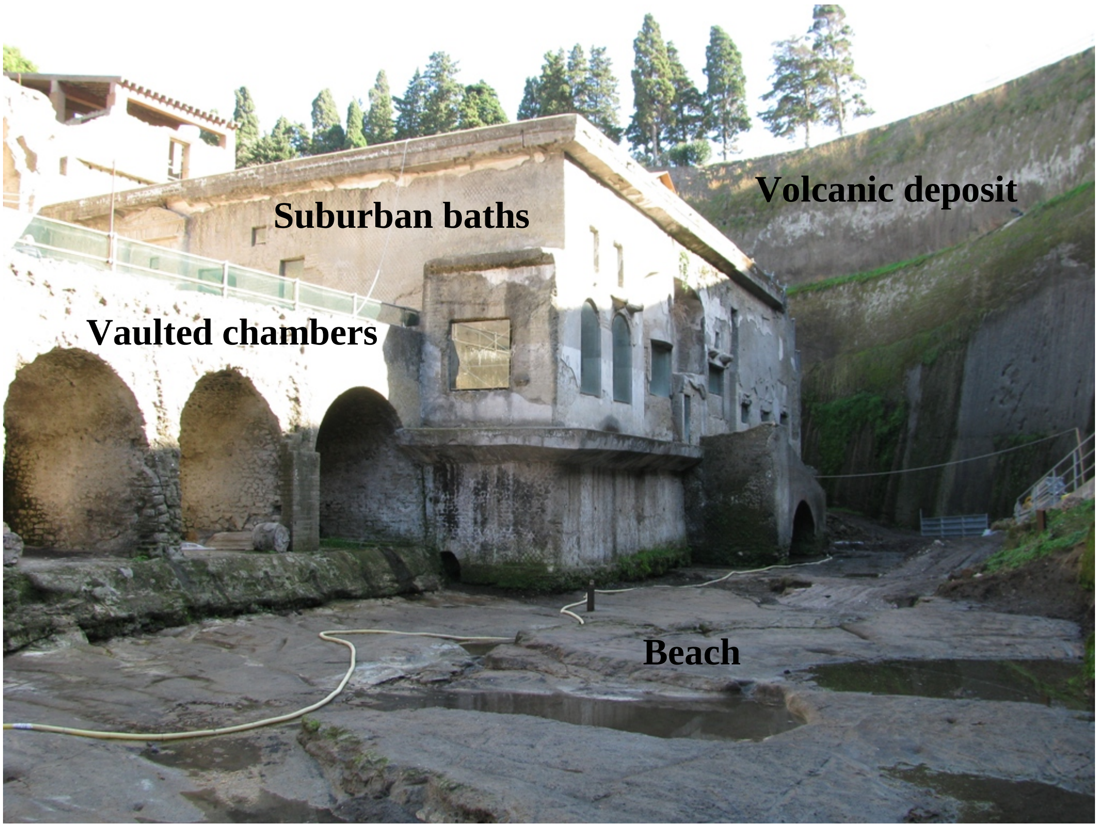


Figure 2.26. The ancient beach, the suburban baths and the vaulted beach front chambers where the skeletons were found. The depth of the volcanic deposit is visible on the right. (Author's photograph)

Figure 2.27. View of the entry ancient shaft in II.14 from inside the sewer. The grate is modern. (Author's photograph)

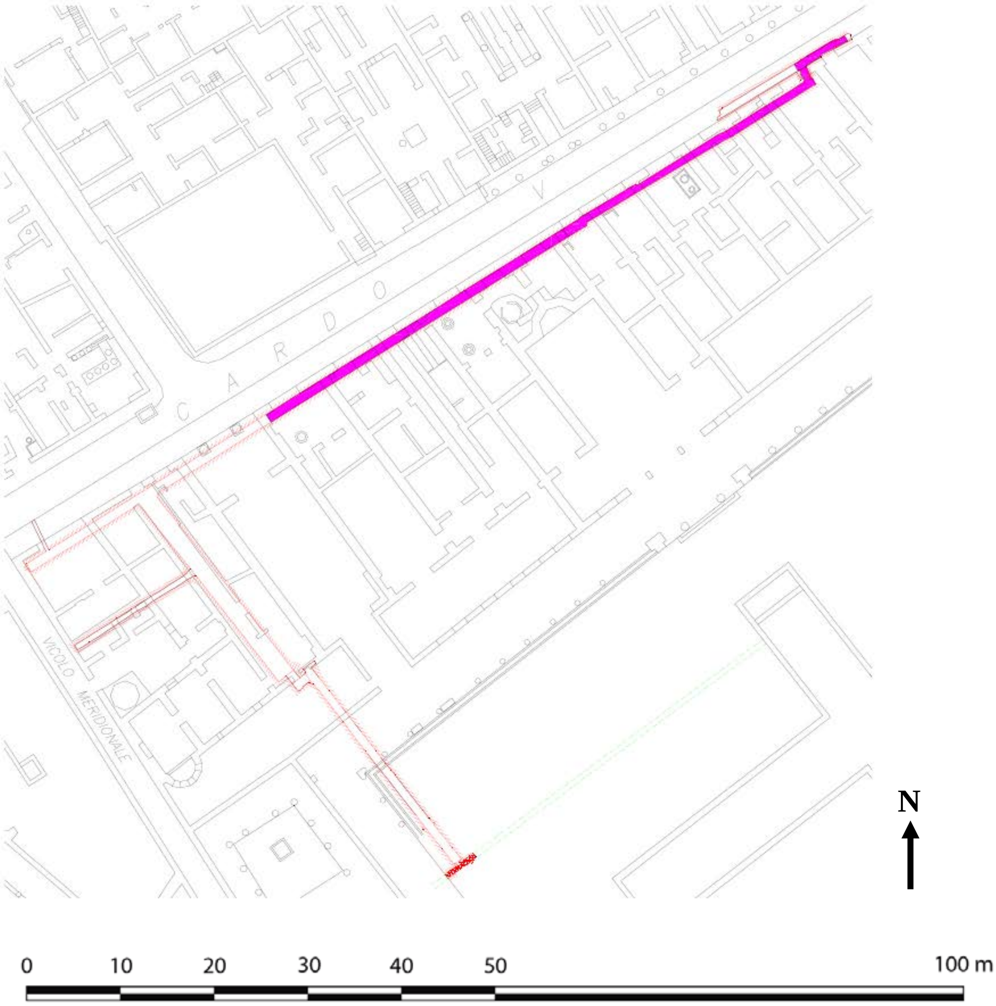


Figure 2.28. Plan of the Cardo V sewer. Areas excavated by the HCP are shown in pink (HCP 2006-2007). (Permission to reproduce plan granted by the HCP)

Figure 2.29. The N-S branch of the Cardo V, still filled with volcanic material. There is a gap between the organic remains on the bottom and the volcanic material on the top. The gap formed when the volcanic material solidified and the organic material continued to decay away after the eruption (HCP 2006-2007). (Permission to reproduce photograph granted by the HCP)

Figure 3.1. Spelt wheat (*Triticum spelta*) glume base from a Roman midden at the site of Marcham UK. (Permission to use photograph granted by the Vale and Ridgeway Project).

Figure 3.2. A modern emmer grain (left) and a carbonized emmer grain (*Triticum dicoccum*) (right) from the Cardo V sewer, Q13-14, US38. Note the way the carbonization process shrinks the item. (Author's photograph)

Figure 3.3. Carbonized emmer wheat (*Triticum dicoccum*) from the Villa of the Papyri at Herculaneum. (Author's photograph)

Figure 3.4. Carbonized lentil (*Lens culinaris*) from Q23-24, US38. (Author's photograph)

Figure 3.5. Carbonized walnut shell (*Juglans regia*) fragment from Q23-24, US38. (Author's photograph)

Figure 3.6. A modern dill mericarp (left) and an ancient mineralized dill mericarp (*Anethum graveolens*) (right) from Q3-4, US38. Note the lack of detail on the mineralized seed. (Author's photograph)

Figure 3.7. A modern lentil (left) and an ancient mineralized lentil (*Lens culinaris*) (right) from Q3-4, US38. Note the colour different between the two examples. (Author's photograph)

Figure 3.8. Mineralized apple/pear seed (*Malus* or *Pyrus* sp.) from Q5-6, US42. (Author's photograph)

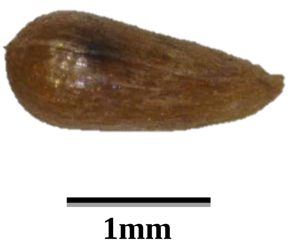


Figure 3.9. Mineralized seed of the arable/ruderal weed corn chamomile (*Anthemis arvensis*) from Q5-6, US42. (Author's photograph)

Figure 3.10.Mineralized diptera (fly) puparium from Q13-14, US38. (Author’s photograph)

Figure 3.11. Waterlogged moss (*Sphagnum* sp.) calyx recovered from a well (8328) in Insula IX at Silchester dated to AD30-55. (Permission to reproduce photograph granted by Lisa Lodwick)

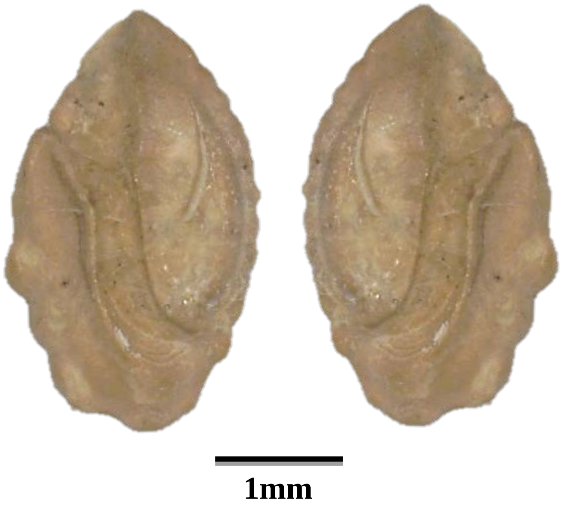


Figure 3.12. Left and right (mirror image of the left) sagittal otoliths of a black sea bream (*Spondyliosoma cantharus*). Left otolith is from the Cardo V sewer, Q3-4, US38. (Author's photograph)

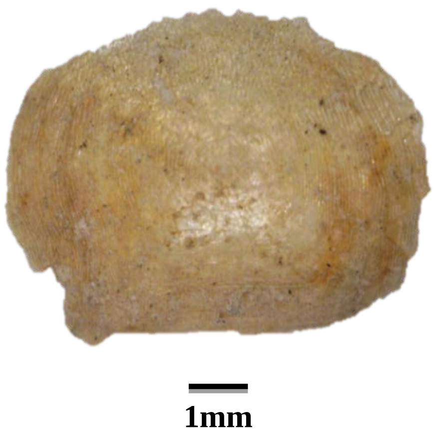


Figure 3.13. A fish scale from a Roman fish salting vat at the site of Utica, Tunisia. (Author's own photograph, with permission from the Tunisian-British Utica Project)

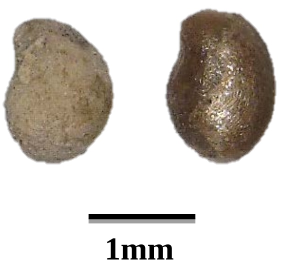


Figure 3.14. A mineralized fig pip (*Ficus carica*) (left) from an Islamic period pit from the site of Utica in Tunisia and one from the Cardo V sewer in Herculaneum (Q5-6, US39) (right). (Author's own photograph, with permission from the Tunisian-British Utica Project)

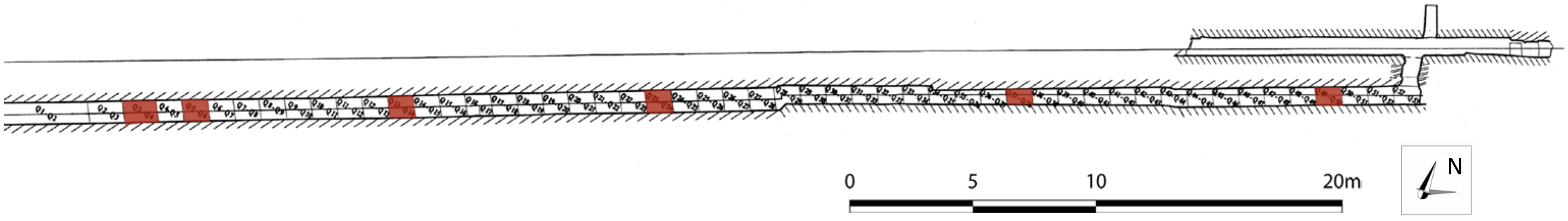


Figure 4.1. Cardo V sewer quadrants. Study quadrants are highlighted in red. From left to right Q3-4, 5-6, 13-14, 23-24, 37-38 and 49-50. (Permission to reproduce and adapt plan granted by the HCP)

Figure 4.2. View of the stratigraphic layers within Q7-8. Layer 12 is the volcanic material from the AD79 eruption. It was left to protect the delicate bioarchaeological material below and only removed as each subsequent quadrant was excavated. Note the large fragments of pottery in the quadrant. (HCP 2006-2007). (Permission to reproduce photograph granted by the HCP)

Figure 4.3. From right to left, the dried bag of flot material, the coarse fraction, the residue and the additional sieved but unprocessed 1L. (Photograph courtesy of Mark Robinson)

0.2mm

Figure 4.4. Modern portulaca (*Portulaca oleracea*) seed from the Cardo V sewer.
(Author’s photograph)

Figure 4.5. The remaining unprocessed bags in storage in Herculaneum (HCP 2006-2007).
(Permission to reproduce photograph granted by the HCP)

Figure 4.6. Plan showing the quadrants and drain locations in relation to the ground floor units of *Ins. Or.* II. Note the presence of drain B8 situated beneath the bakery (Massimo Brizzi/HCP). (Permission to reproduce and adapt plan granted by the HCP)

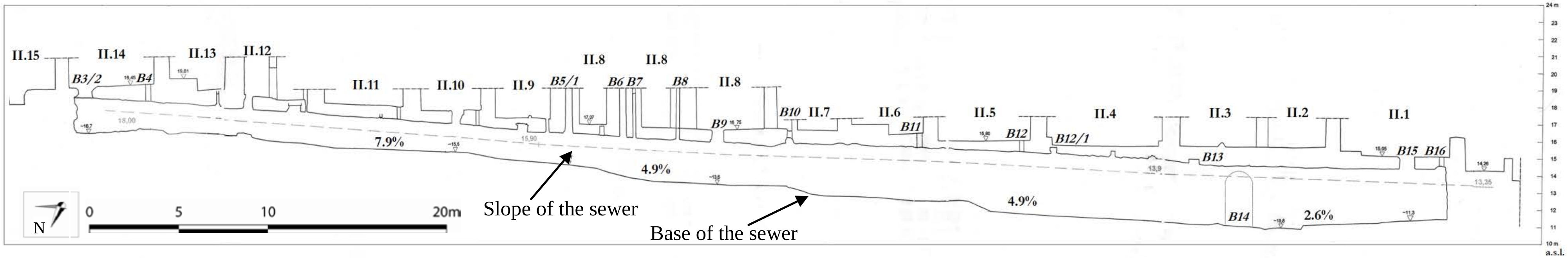


Figure 4.7. Cross sectional view of the Cardo V sewer and the ground floor of *Ins. Or.* II showing both the slope of the sewer and the building. Percentages indicate the degree of slope of the sewer channel. The units of *Ins. Or.* II and the drain/latrine shafts are marked. B14 is the entrance to the E-W branch of the sewer (Massimo Brizzi/HCP). (Permission to reproduce and adapt plan granted by the HCP)

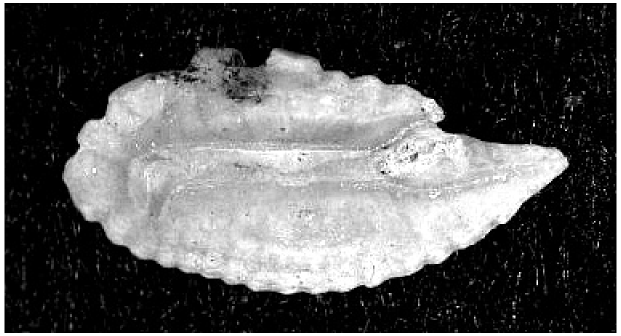


Figure 4.8. Horse mackerel (*Trachurus trachurus*) otolith from Q13-14, US40. (Author's photograph)

```
Otolith Classification Results

(Click here for help: nullhelp-classify.html)

Closer Species Distance:

Hemanthias signifer (1.21)

Trachurus picturatus (1.50)
Trachurus mediterraneus (1.53)
Caranx rhonchus (1.54)
Trachurus trachurus (1.58)


Genus & Species distance:

EPS file: http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R.eps

Input contour: http://www.cmima.csic.es/aforo-imgproc/contorn-1393584347261.png

1st: Hemanthias signifer (TL=325 mm and D=1.21): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R1.png
2nd: Trachurus picturatus (TL=144 mm and D=1.34): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R2.png
3rd: Trachurus picturatus (TL=153 mm and D=1.52): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R3.png
4th: Trachurus mediterraneus (TL=270 mm and D=1.53): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R4.png
5th: Caranx rhonchus (TL=230 mm and D=1.54): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R5.png
6th: Caranx rhonchus (TL=368 mm and D=1.54): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R6.png
7th: Trachurus picturatus (TL=149 mm and D=1.55): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R7.png
8th: Trachurus trachurus (TL=145 mm and D=1.58): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R8.png
9th: Trachurus picturatus (TL=137 mm and D=1.60): http://www.cmima.csic.es/aforo-imgproc/result_1393584366861-R9.png
```

Figure 4.9. AFORO database results for the otolith shown above (Fig. 4.8). TL= Total length of the reference specimen, D= Euclidean distance (Lombarte *et al.* 2006). (Permission to reproduce results granted by A. Lombarte)

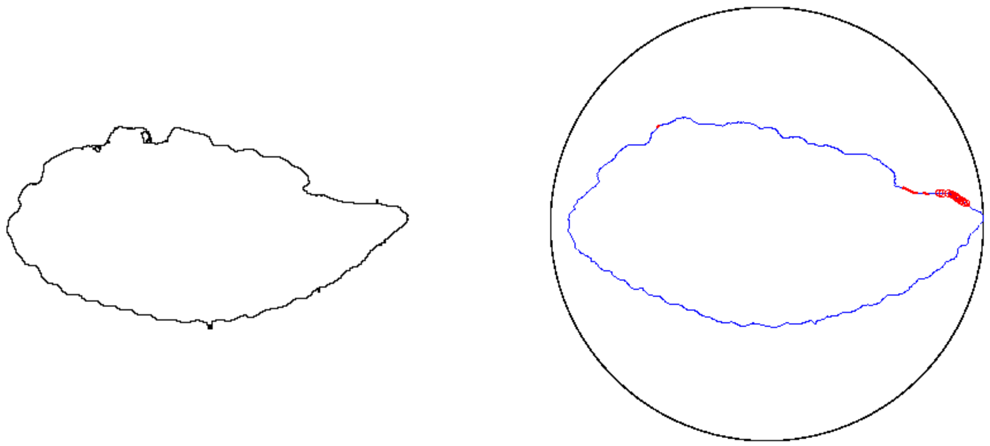


Figure 4.10. Input contour of the hake otolith (left) shown in figure 4.8 and the closest matching contour (right) as provided by the results shown in figure 4.9. The red lines indicate areas of divergence (Lombarte *et al.* 2006). (Permission to reproduce images granted by A. Lombarte)

Figure 4.11. Modern horse mackerel from Dr. Rebecca Nicholson's reference collection (left) and the ancient (right) otolith shown in the images above. (Author's photograph)

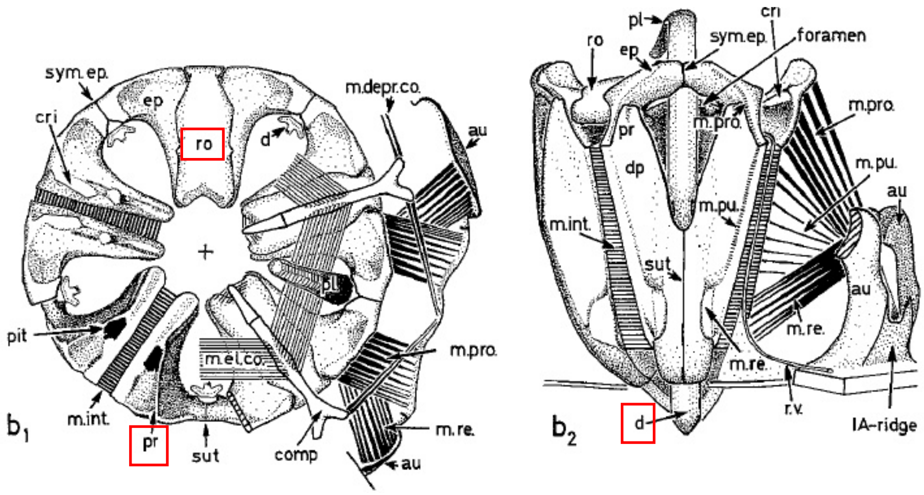


Figure 4.12. Anatomy of Aristotle's lantern (pr = pyramid plate, ro = rotula, d = tooth) (Märkel 1979: 5). (Permission to reproduce images granted by ©Springer)

Figure 4.13. From left to right, purple sea urchin (*Paracentrotus lividus*) jaw fragments and rotula from Q5-6, US39, and a tooth from Q5-6, US5-6, US43. (Author’s photograph)

Figure 5.16. Fragments of mineralized (left) and carbonized hazelnut (*Corylus avellana*) (right) from Q3-4, US38 and Q23-24, US38 respectively. (Author’s photograph)

Figure 5.29. From left to right, mineralized sorghum (*Sorghum* sp.), foxtail (*Setaria italica*) and common millet (*Panicum miliaceum*) from Q5-6, US43. (Author’s photograph)

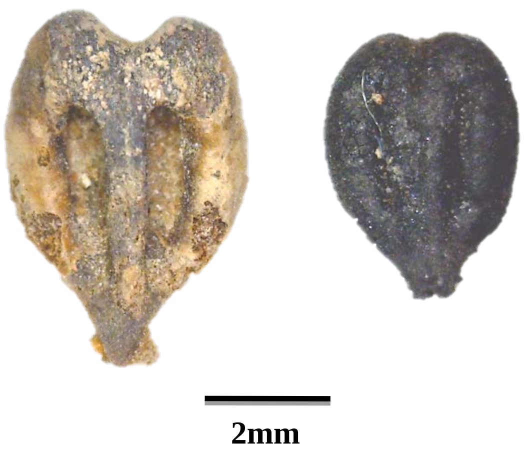


Figure 5.30. Mineralized (left) and carbonized grapes (*Vitis vinifera*) (right) from Q5-6, US43 and Q3-4, US38 respectively. (Author’s photograph)

0.2mm

Figure 5.31. Mineralized mint (*Mentha* sp.) from Q5-6, US40. (Author’s photograph)

1mm

Figure 5.32. Mineralized fennel (*Foeniculum vulgare*) from Q5-6, US43. (Author’s photograph)

0.2mm

Figure 5.33. Mineralized poppy seed (*Papaver somniferum*) from Q5-6, US40. (Author’s photograph)

Figure 5.34. Mineralized peppercorn (*Piper nigrum*) from Q49-50, US42. (Author's photograph)

Figure 5.35. Mineralized common stinging nettle seed (*Urtica dioica*) from Q5-6, US42. (Author's photograph)

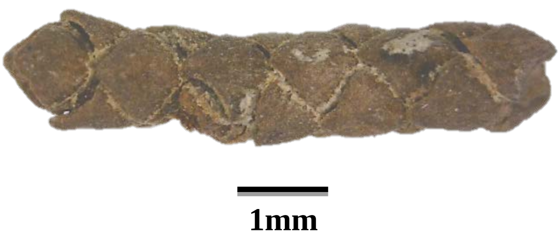


Figure 5.36. Fragment of mineralized cypress twig (*Cupressus sempervirens*) from Q3-4, US38. (Author's photograph)

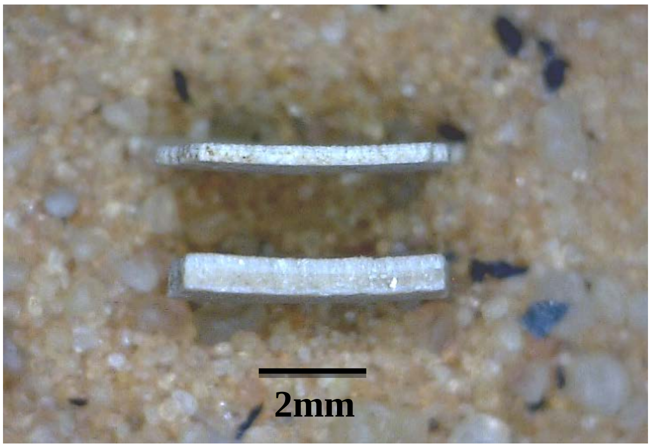


Figure 5.37. Eggshell fragments of differing thickness from Q13-14, US39. (Author's photograph)

Figure 5.53. Trickling filter fly pupa (*Psychoda alternate*) from Q13-14, US38. (Author's photograph)

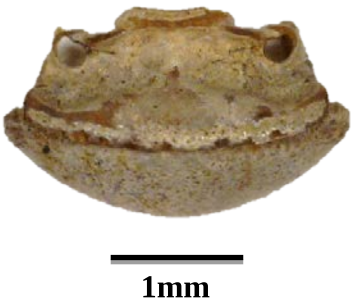


Figure 5.54. Head sclerite of a woodlouse (Isopoda) from Q13-14, US38. (Author's photograph)

Figure 6.1. Carbonized barley caryopsis fragment (*Hordeum vulgare*) from Q5-6, US40. (Author's photograph)

Figure 6.2. Carbonized grape pip (*Vitis vinifera*) from Q3-4, US38. (Author's photograph)

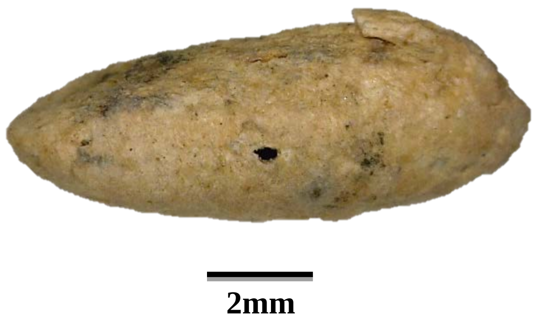
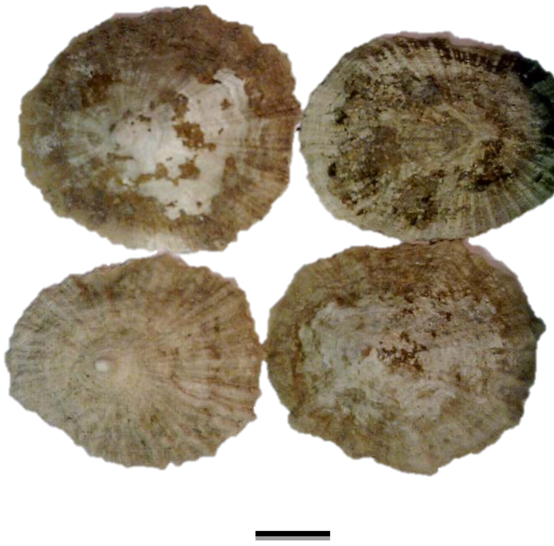


Figure 6.3. Mineralized olive seed (*Olea europaea*) from Q23-24, US38. While olive stones readily carbonized, it is extremely rare to find the mineralized seeds. (Author's photograph)



50mm

Figure 6.4. Limpets (*Patella* sp.) from Q13-14, US40. (Author's photograph)

2mm

Figure 6.5. Modern carrot (*Daucus carota*) (left) and an ancient waterlogged specimen (right) from Q13-14, US40. (Author's photograph)

2mm

Figure 6.6. Modern blackberry seed (*Rubus fruticosus* (agg)) (left) and an ancient waterlogged specimen (right) from Q13-14, US38. (Author's photograph)

Figure 6.7. Purple sea urchin (*Paracentrotus lividus*) spine (left) and body fragment (right) from Q5-6, US43. (Author's photograph)

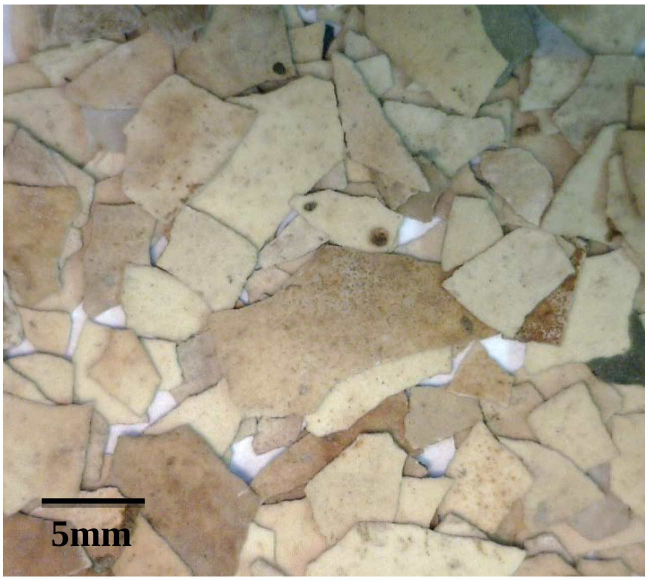


Figure 6.8. Fragments of eggshell from Q23-24, US38. (Author's photograph)

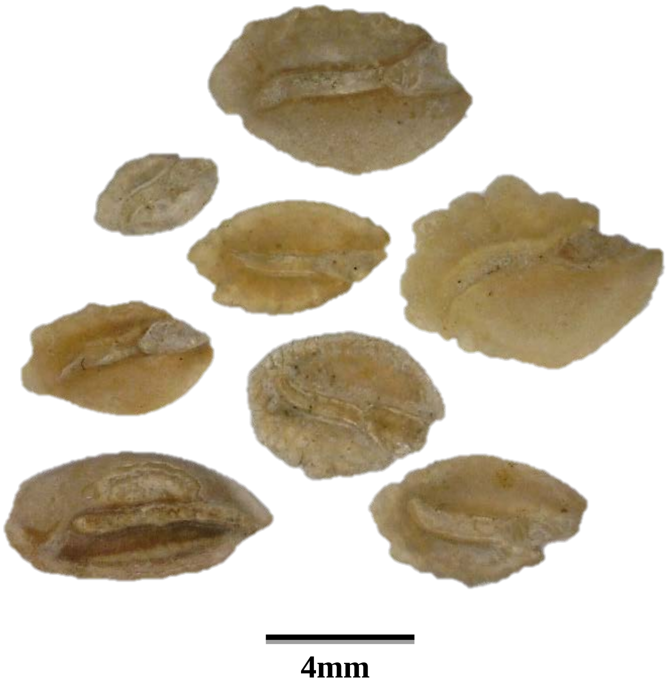


Figure 6.9. A collection of well-preserved otoliths from the Cardo V sewer. (Author's photograph)

Figure 6.10. Mineralized (left) and carbonized common millet (*Panicum miliaceum*) (right) from Q5-6, US43 and Q49-50, US39 respectively. (Author's photograph)

Figure 6.11. Carbonized goosefoot seed (*Chenopodium* sp.) from Q3-4, US41. (Author's photograph)

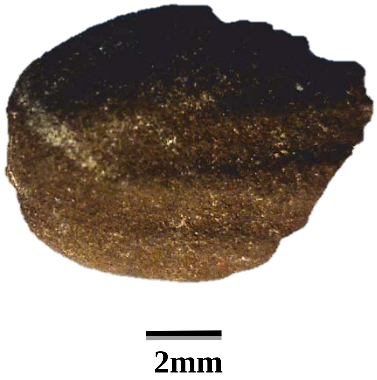


Figure 6.12. Carbonized pine nut bract fragment (*Pinus pinea*) from Q3-4, US40. (Author's photograph)

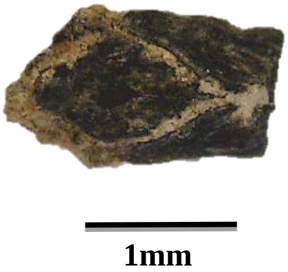


Figure 6.13. Fragment of carbonized cypress (*Cupressus sempervirens*) from Q49-50, US42. (Author's photograph)

Figure 6.14. Fragment of carbonized bread from Q5-6, US43. (Author's photograph)

Figure 6.15. Mineralized fig pips (*Ficus carica*) from Q3-4, US38. (Author’s photograph)

Figure 6.16. Mineralized coriander mericarp (*Coriandrum sativum*) from Q5-6, US43. (Author’s photograph)

Figure 6.17. Two conger eel (Congridae) vertebrae from the Cardo V sewer. The one on the right has been chewed. (Author’s photograph)

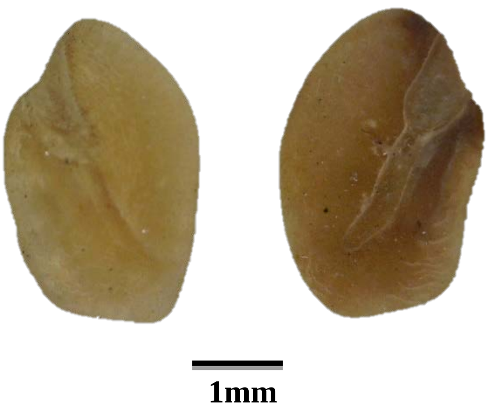


Figure 6.18. Two otoliths from Q13-14, US38 with smoothed edges, indicating digestion. (Author’s photograph)

Figure 8.1. Fragments of carbonized olive (*Olea europaea*) stones from the Cardo V sewer. (Author’s photograph)

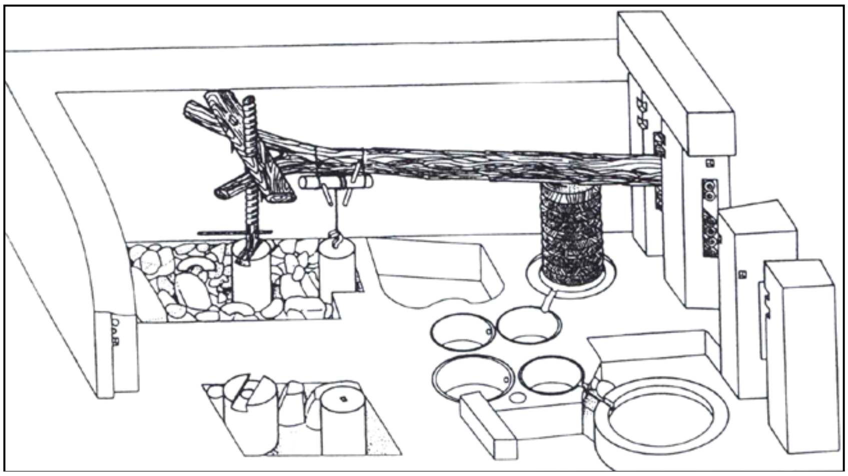


Figure 8.2. Reconstruction of an olive screw press at Horvat Karkara, Israel dating to the 7th century AD. The stack of press baskets are clearly visible (from Brun 2004: 133). (Permission to reproduce plan granted by J-P Brun)

Figure 8.3. A late Roman olive press bed from Thuburbo Maius in Tunisia. (Author’s photograph)

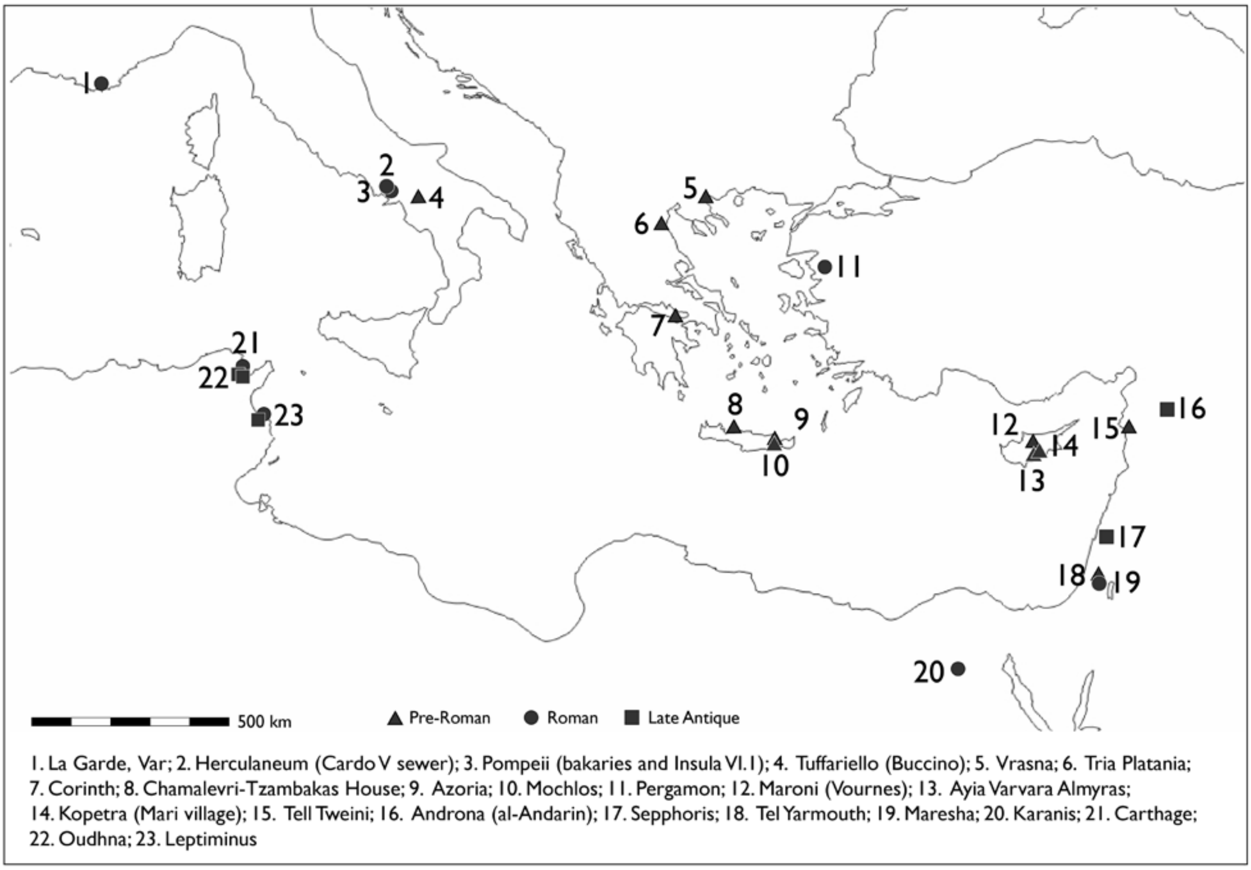


Figure 8.4. Sites throughout the Mediterranean demonstrating Roman and pre-Roman evidence for pomace fuel. Spain is notably absent from this map. Other gaps in the map, particularly Algeria, are probably due to an absence of survey, excavation and recording of environmental samples (Rowan 2015). (Map created by Maxine Anastasi)

Figure 8.5. Bread oven from Pompeii. (Author's photograph)

Image not available

Figure 8.6. *Trapetum* from the Villa della Pisanella, room U (Inv. 41518) now on display in the National Antiquarium of Boscoreale. Wooden beam is modern (from Stefani 2010: 96)

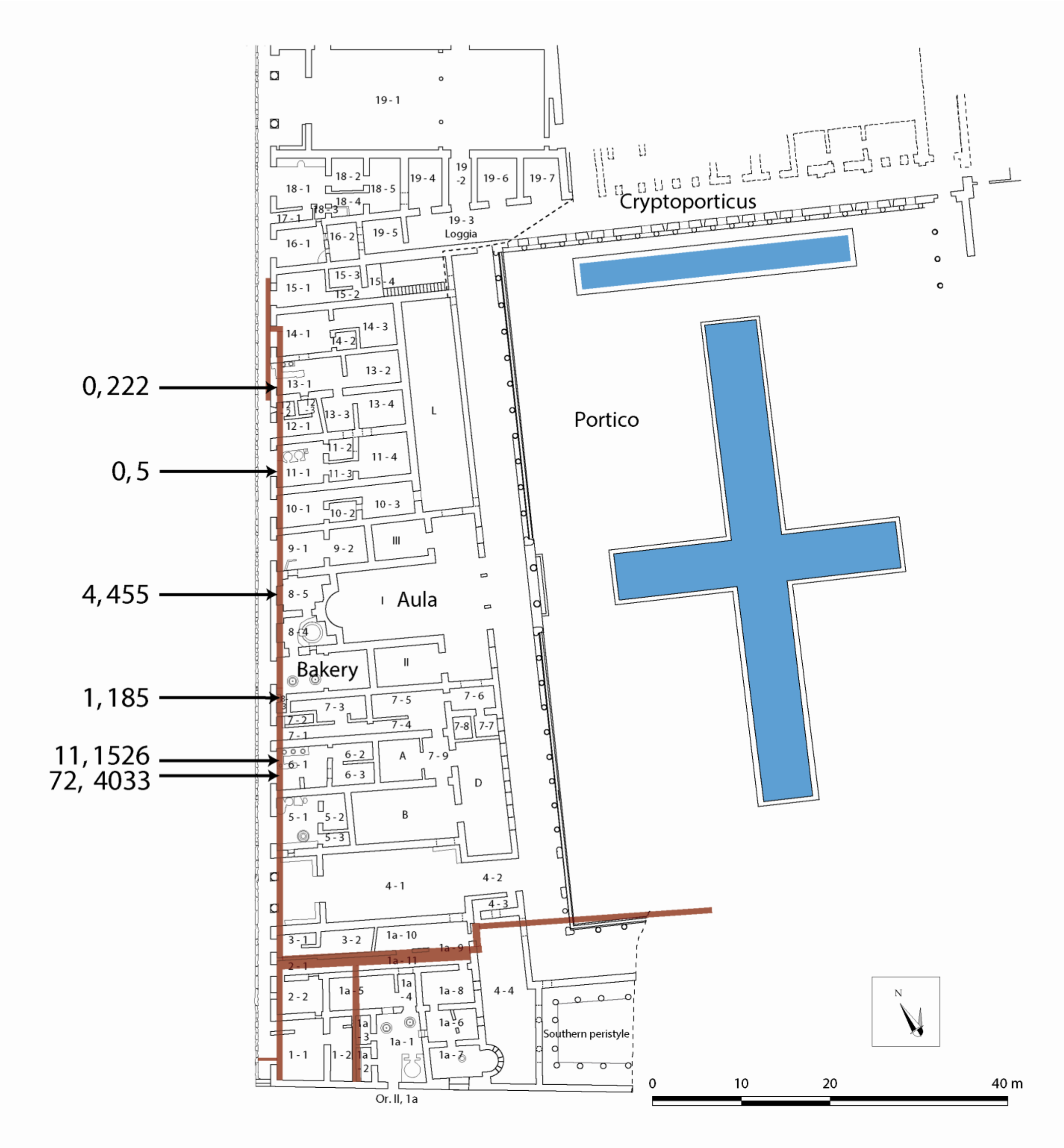


Figure 8.7. Number of whole and fragmentary pieces of carbonized olive endocarp found in the study quadrants of the Cardo V sewer (adapted from pl. V, Monteix 2010). (Permission to reproduce plan granted by N. Monteix)

Figure 8.8. *Ins. Or.* II.11, room 3 showing the doorway and the small window above. (Author’s photograph)

Figure 8.9. Cooking pot with iron tripod from the House of the Tragic Poet (VI.8.3) (MANN 23322) (British Museum 2013). (Author’s photograph)

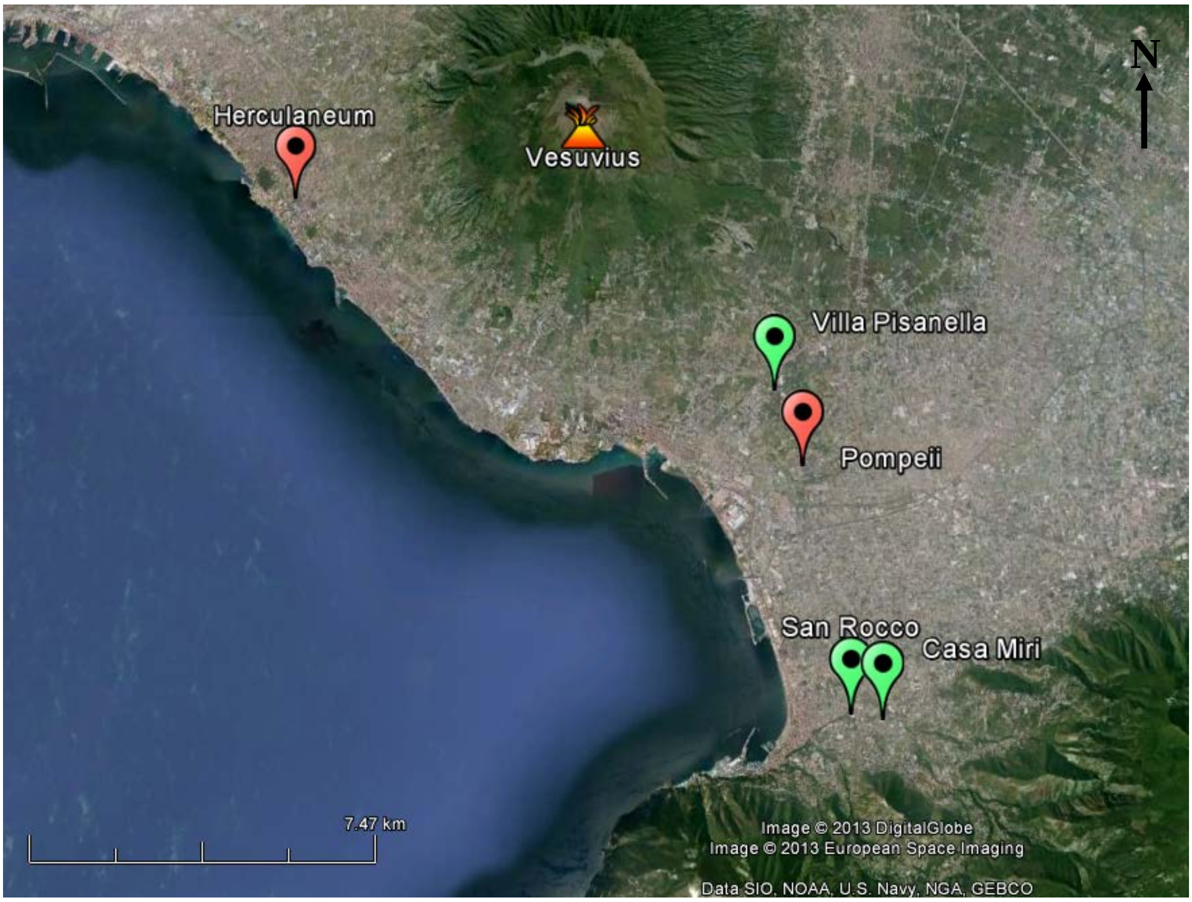


Figure 8.10. Bay of Naples showing the location of Pompeii and nearby villas with archaeological evidence for olive oil production (©Google earth).

Figures 8.11. Mineralized seed of common chickweed (*Stellaria media*) from Q5-6, US43. (Author's photograph)

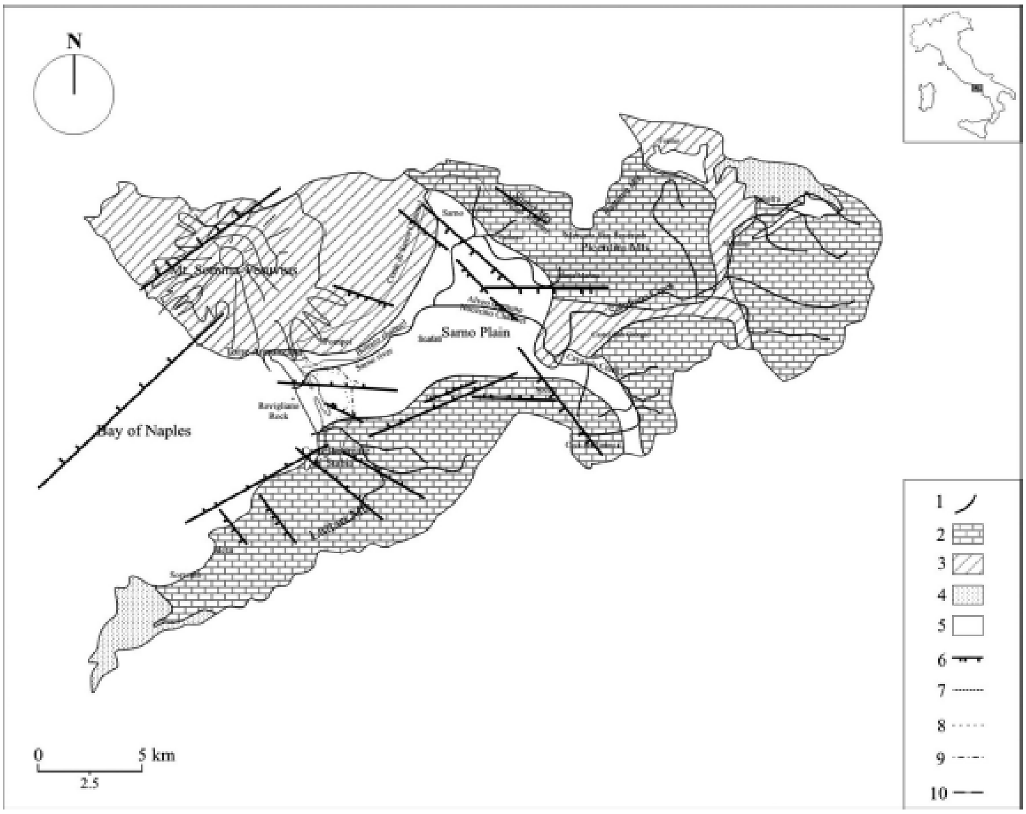


FIG. 1 - Geological simplified scheme of the Sarno River basin: 1) hydrographic network; 2) Mesozoic calcareous-dolomitic rocks; 3) lavas and pyroclastics; 4) late Mesozoic and Tertiary calcareous-marly-clayey flysch; 5) coastal, lagoon and river Quaternary deposits; 6) main faults; 7) Versilian coastline (Messigno); 8) proto-historical coastline (Bottaro-Pioppaino); 9) Roman period coastline (1st century AD); 10) basin watershed.

Figure 8.12. Geological plan of the Sarno River basin (from De Pippo *et al.* 2008: 22). (Permission to reproduce image granted by C. Donadio)

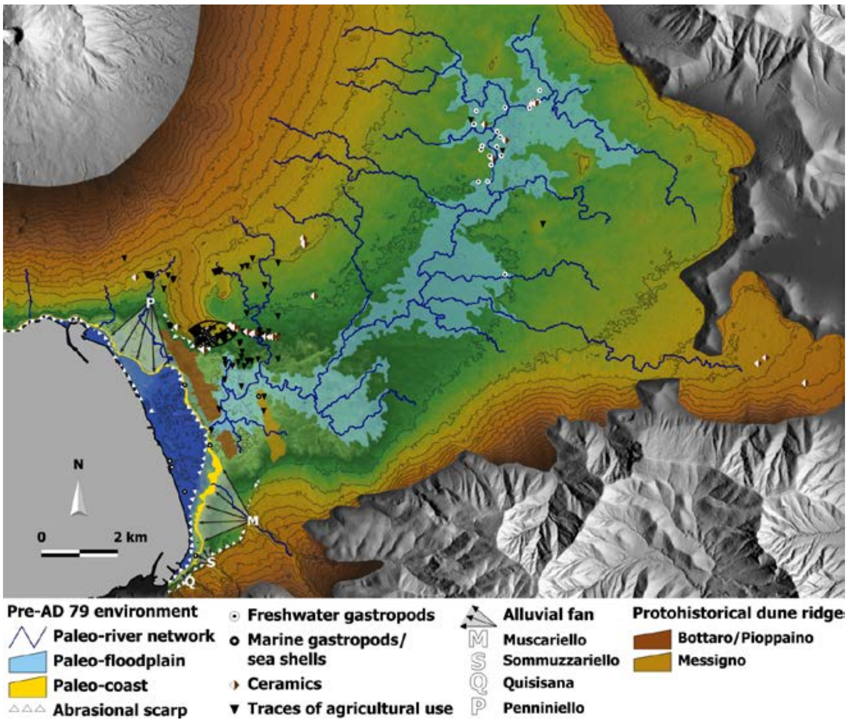


Figure 8.13. Plan showing the pre-AD79 Sarno river plain with environmental features. Note the large fluvial/estuary area of the Sarno river (Vogel *et al.* 2011: fig. 6b). (Permission to reproduce image granted by S. Vogel)

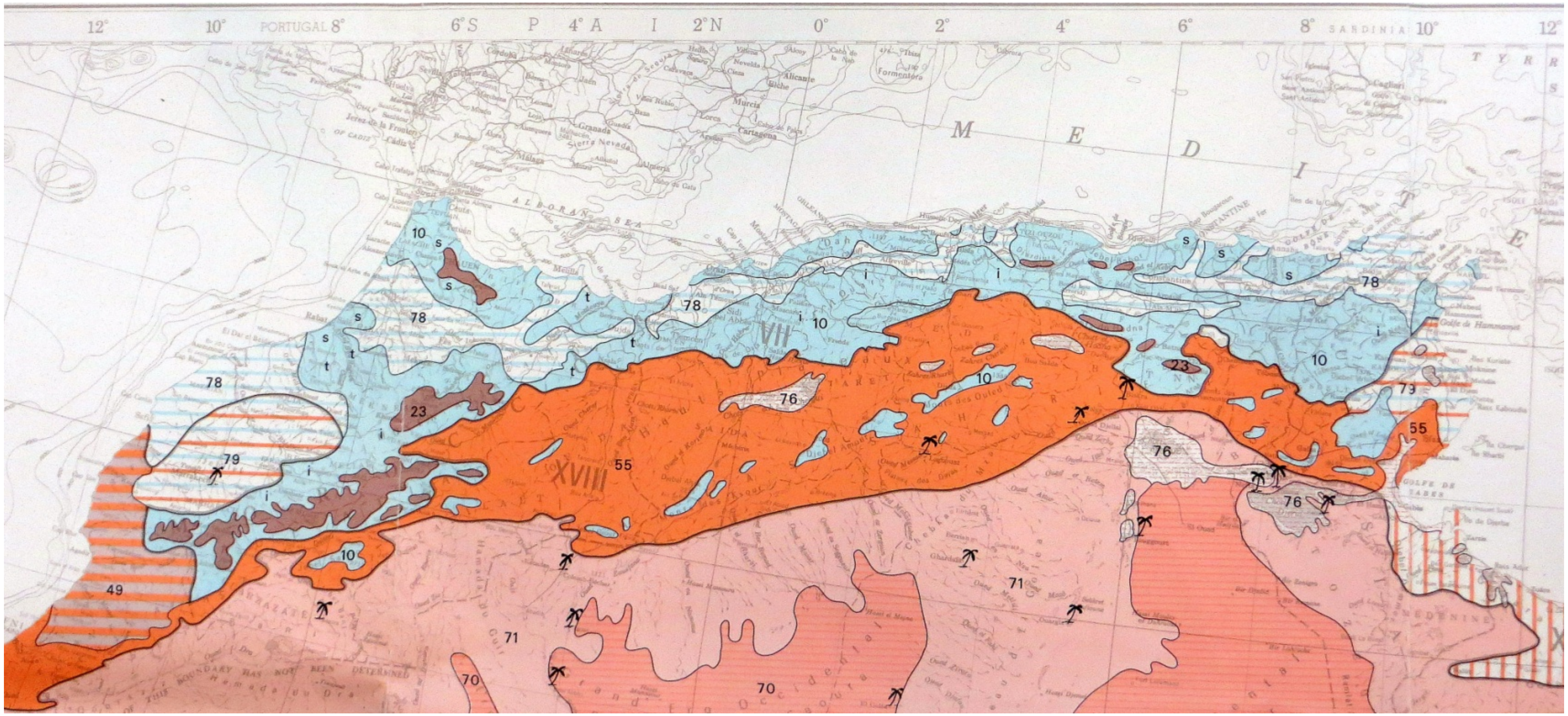


Figure 8.14. Vegetation map of North Africa. The blue region (VII) represents areas with a Mediterranean climate. The orange region (XVIII) represents the Mediterranean/Sahara transition zone (from White 1983). (©UNESCO)

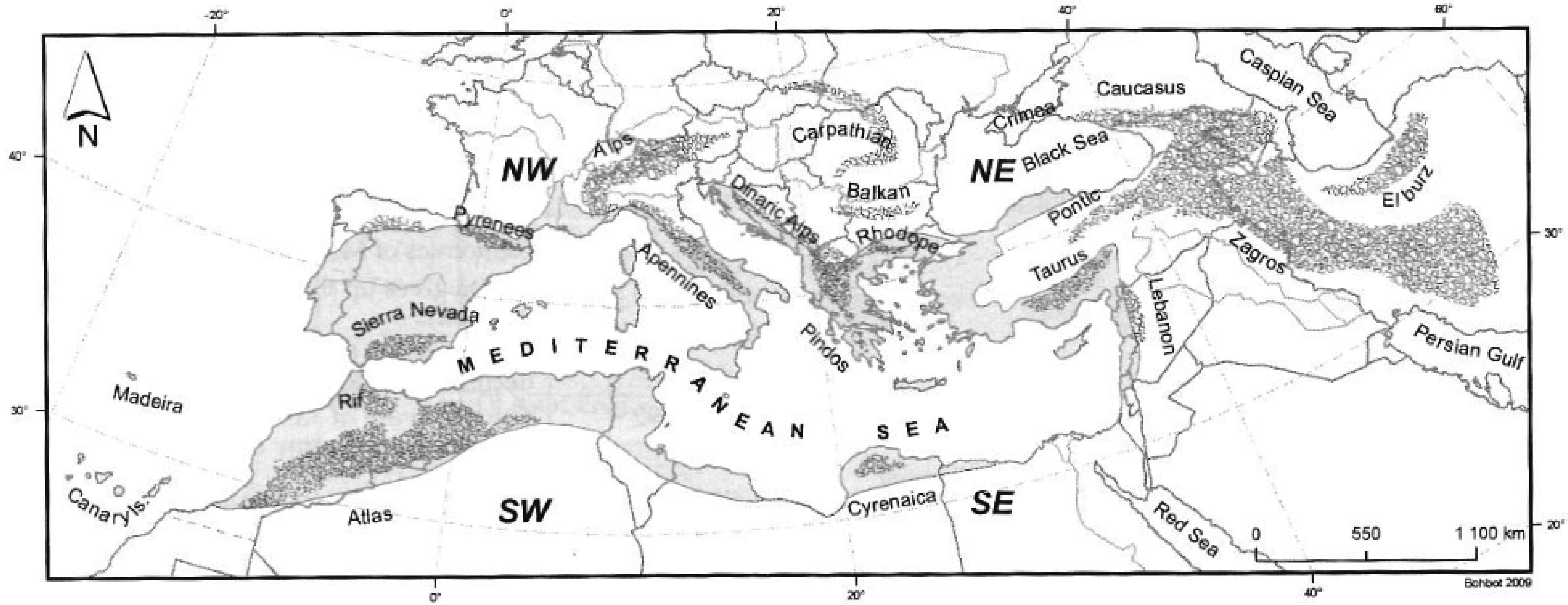


Figure 8.15. The Mediterranean basin. Shaded areas represent the Mediterranean climatic zone (from Blondel *et al.* 2010: 4). (Permission to reproduce image granted by Oxford University Press)

1mm

Figure 8.16. Mineralized sorghum (cf. *Sorghum* sp.) from Q5-6, US43. (Author's photograph)

1mm

Figure 8.17. Mineralized sedge seed (*Carex* sp.) from Q5-6, US40. (Author's photograph)

Figure 8.18. Fishing mosaic from *Hadrumetum,* Tunisia (Sousse Archaeological Museum, Tunisia). (Author's photograph)

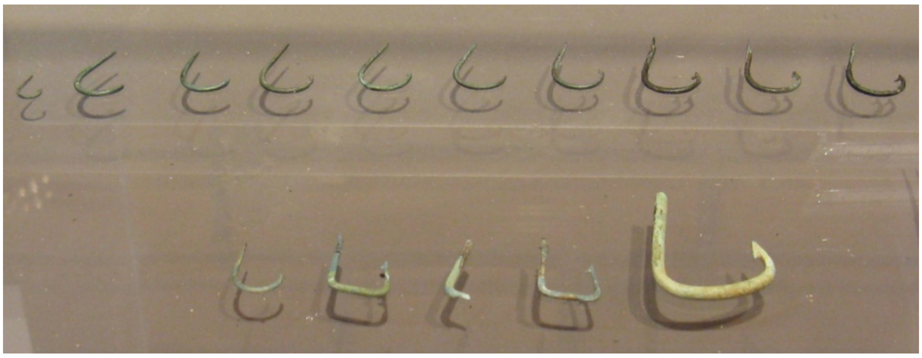


Figure 8.19. Bronze fishing hooks of different sizes from Herculaneum. (Author's photograph)

Figure 8.20. Fish mosaic from House VIII.ii.16 (MANN, inv. no.120177). (from Wikimedia Commons, photograph by Marie-Lan Nguyen (2011))

Figure 8.21. Carbonized long line from Herculaneum, still inside its basket (from Bernal Casasola 2010: 121). (Permission to reproduce image granted by D. Bernal Casasola)

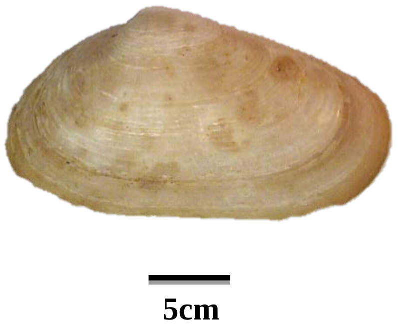


Figure 8.22. An example of category 1. Corneous wedge shell (*Donacilla cornea*) from Q23-24, US40. (Author's photograph)

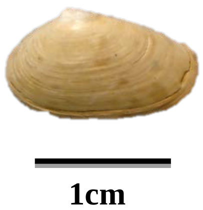


Figure 8.23. An example of category 2. Corneous wedge shell (*Donacilla cornea*) from Q23-24, US40. (Author's photograph)

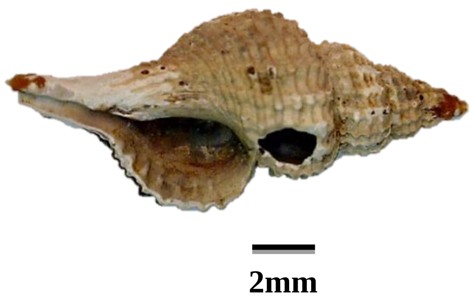


Figure 8.24. An example of category 3. *Fusinus pulchellus* from Q23-24, US40. (Author's photograph)

APPENDICIES

Appendix A: Taxonomic synonyms

Table A1. List of the recently changed or altered taxonomic names and the older versions

	Old name	New name
Plants	Chenopodiaceae	Amaranthaceae
	Umbelliferae (OR)	Apiaceae
	Cruciferae	Brassicaceae
	Compositae	Asteraceae
	Leguminosae (OR)	Fabaceae
	Labiatae (OR)	Lamiaceae
	Gramineae	Poaceae
Shellfish	*Paphia aurea*	*Venerupis aurea*
	Tapes (Ruditapes) decussatus	*Venerupis decussata*

Appendix B: Taxa lists comparing the Pompeii and Cardo V assemblages

Table B1. Carbonized taxa from the Pompeii assemblages and the matching items from the Cardo V carbonized and mineralized assemblages

Carbonized material from Pompeii	Common name	Present in carbonized Cardo V assemblage	Present in mineralized Cardo V assemblage
Cereals			
Avena sativa L.	Oat	-	-
cf. *Avena* sp.	Oat	-	-
Cereals	N/A	-	-
Hordeum sp.	Barley	✓	-
Hordeum sp. rachis fragment	Barley	-	-
Hordeum vulgare L.	Barley	-	-
Panicum miliaceum L.	Common millet	✓	✓
Panicum sp.	Millet	-	-
Secale cereale L.	Rye	-	-
Secale cereale L. cf. rachis internode	Rye	-	-
Setaria italica Beauv.	Foxtail millet	✓	✓
Setaria sp.	Millet	-	-
Triticum. aestivum L.	Bread wheat	✓	-
T. aestivum rachis L. internode	Bread wheat	-	-
T. aestivum/durum L.	Bread/durum wheat	-	-
T. aestivum/durum L. rachis internode	Bread/durum wheat	-	-
T. dicoccum Schübl.	Emmer wheat	✓	✓
T. monoccocum L. or *dicoccum* Schübl.	Einkorn or emmer wheat	-	-
T. cf. *monococcum* L.	Einkorn wheat	✓	-
Triticum sp. spikelet fork	Wheat	-	-
Triticum sp. free threshing	Wheat	✓	-
T. spelta L. or *dicoccum* Schübl.	Spelt or emmer wheat	-	-
Pulses and legumes			
Cicer arietinum L.	Chickpea	-	-
Lens culinaris Medik.	Lentil	✓	✓

Carbonized material from Pompeii	Common name	Present in carbonized Cardo V assemblage	Present in mineralized Cardo V assemblage
Pisum sativum L.	Pea	-	-
Vicia ervilia (L.) Willd.	Bitter vetch	✓	-
Vicia faba L.	Broad bean	-	✓
Vicia faba var. *minuta*	Broad bean	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	✓	✓
Vicia sativa L.	Common vetch	-	-
Vicia sp.	Vetch	-	✓
Vigna/Vicia sp.	Bean/vetch	-	-
Nuts			
Corylus avellana L.	Hazelnut	✓	✓
Castanea sativa Mill.	Chestnut	-	-
Juglans regia L.	Walnut	✓	-
Nuts (generic)		-	-
Pinus pinea L.	Stone pine	✓	✓
Fruits			
Ceratonia siliqua L.	Carob	-	✓
Cucumis melo L.	Melon	-	✓
Ficus carica L.	Fig	✓	✓
Fragaria vesca L.	Wild strawberry	-	-
Fruit exocarp	N/A	-	-
Malus domestica Borkh.	Apple	-	-
Malus sp. (fruit)	Apple	-	✓
Malus/Pyrus/Sorbus sp.	Apple/pear/rowan	-	✓
Malva sp.	Mallow	-	✓
Olea europaea L.	Olive	✓	✓

Carbonized material from Pompeii	Common name	Present in carbonized Cardo V assemblage	Present in mineralized Cardo V assemblage
Phoenix dactylifera L.	Date	✓	✓
Prunus cerasus L.	Sour cherry	-	-
Prunus cerasus or *avium* L.	Sour or wild cherry	-	✓
Prunus cf. *domestica* L.	Plum	-	✓
Prunus dulcis (Miller) D. Webb	Almond	-	-
Prunus persica (L.) Batsch.	Peach	-	-
Prunus sp.	Stone fruit	-	✓
Punica granatum L.	Pomegranate	-	-
Pyrus communis L.	Common pear	✓	-
Pyrus or *Malus* sp.	Pear or apple	✓	-
Sorbus aucuparia L.	Rowan	-	-
Vitis vinifera L.	Grape	✓	✓
Herbs and seasonings			
Allium cepa L.	Onion	-	-
Allium sativum L.	Garlic	-	-
Papaver somniferum L.	Opium poppy	-	✓
Piper nigrum L.	Black pepper	-	✓
Weeds, ruderals and other taxa			
Agrostemma githago L.	Common corncockle	-	-
Anagallis sp.	Pimpernel	-	✓
Apiaceae	Parsley family	✓	-
Arrhenatherum elatius (L.) P. Beauv. var *bulbosum* (Willd.)	False oat-grass	-	-
Asteraceae	Daisy family	-	✓
Astragalus falcatus Lam.	Milk-vetch	-	-
Astragalus/Trigonella type	Milk-vetch/fenugreek	-	-

Carbonized material from Pompeii	**Common name**	**Present in carbonized Cardo V assemblage**	**Present in mineralized Cardo V assemblage**
Avena sp.	Oat	✓	-
Boraginaceae	Borage family	-	✓
Brassicaceae	Cabbage family	-	-
Briza maxima L.	Big quaking grass	-	-
Bromus cf. *secalinus* L.	Rye brome	-	-
Bromus sp.	Brome grass	-	-
Cerastium sp.	Mouse-ear chickweed	-	-
Chenopodiaceae	Goosefoot family	-	✓
Chenopodium cf. *album* L.	Fat-hen	-	✓
Chenopodium murale L.	Nettle-leaved goosefoot	-	-
Chenopodium sp.	Goosefoot	✓	✓
Chenopodium/Atriplex sp.	Goosefoot/orache	-	-
Cupressus sempervirens L.	Mediterranean cypress	✓	✓
Cynareae indet.	Thistles	-	-
Cynosurus echinatus L.	Bristly dogtail grass	-	-
Echinochloa crus-galli (L.) Beauv.	Cockspur	-	-
Echium vulgare L.	Viper's bugloss	-	-
Euphorbia helioscopia L.	Sun spurge	-	-
Euphorbia sp.	Spurge	-	-
Fabaceae	Legume family	-	✓
Festuca gigantea (L.) Vill.	Giant fescue	-	-
Galium aparine L.	Cleavers	-	-
Galium sp.	Cleavers	-	-
cf. *Hedysarum coronarium* L.	French honeysuckle	-	-
Lamiaceae	Mint family	-	✓
Linum catharticum L.	Fairy flax	-	-
Lithospermum arvense L.	Field gromwell	-	✓
Lolium sp.	Rye grasses	-	-
Malvaceae	Mallows	-	-

Carbonized material from Pompeii	Common name	Present in carbonized Cardo V assemblage	Present in mineralized Cardo V assemblage
Medicago minima L.	Bur medick	-	-
Medicago sp.	Medick	-	-
Melilotus/Medicago/Trifolium sp.	Melilot/medik/clover	-	✓
Myrtus communis L.	Common myrtle	-	-
Ornithopus perpusillus L. /*sativus* Brot.	Bird's foot	-	-
Ornithopus sp.	Bird's foot	✓	✓
Persicaria sp.	Bistorts	-	-
Phalaris cf. *tuberosa* L.	Bulbous canarygrass	-	-
Plantago lanceolata L.	Ribwort plantain	-	-
Plantago sp.	Plantains	-	✓
Poaceae	True grasses	✓	✓
Polygonaceae	Knotweed family	-	✓
Polygonum aviculare agg. L.	Knotgrass	-	✓
Polygonum sp.	Knotweed	-	✓
Portulaca oleracea L.	Common purslane	-	-
Primulaceae	Primrose family	-	-
Ranunculus sp.	Buttercup	-	✓
Raphanus raphanistrum L.	Wild radish	-	-
Reseda lutea L.	Wild mignonette	-	-
Reseda sp.	Mignonette	-	✓
Rosaceae	Rose family	-	-
Rubus sp.	Bramble	-	✓
Rumex acetosella agg. L.	Sheep's sorrel	-	✓
Rumex sp.	Dock	✓	✓
Sambucus nigra L.	Elder	-	-
Scrophulariaceae	Figwort family	-	✓
Sherardia arvensis L.	Field madder	-	✓

Carbonized material from Pompeii	Common name	Present in carbonized Cardo V assemblage	Present in mineralized Cardo V assemblage
Silene gallica L.	Small-flowered catchfly	-	✓
Silene sp.	Campion	-	✓
Solanaceae	Nightshade family	-	-
Solanum nigrum L.	European black nightshade	-	-
Stachys sp.	Heal-all	-	-
Stellaria media (L.) Vill.	Common chickweed	✓	✓
Trifolium sp.	Clovers	-	-
Viburnum lantana L.	Wayfaring tree	-	-
Viola S. *Melanium* sp.	Pansy	-	✓

Taxa lists from: The House of Amarantus I.9.12 (Robinson, M. 1999), House of Hercules' Wedding and the House of the Vestals (Ciaraldi 2007), House of the Greek Epigrams (Robinson 2007c), Vesonii tomb, Porta Nocera (Matterne and Derreumaux 2008), Research on the Forum of Pompeii project (Kockel and Flecker, 2008), Pompeii Pistrina project (Monteix 2009, 2010b; Monteix *et al.* 2011), PARP:PS (Fairburn 2012), Insula VI.I (AAPP) (Murphy *et al.* 2013)

Table B2. Mineralized taxa from the Pompeii assemblages and the matching items from the Cardo V mineralized assemblage

Mineralized material from Pompeii	Common name	Present in mineralized Cardo V assemblage	Notes
Cereals			
Panicum miliaceum L.	Common millet	✓	
Panicum sp.	Millet	-	
Setaria italica Beauv.	Foxtail millet	✓	
Setaria sp.	Millet	Sp	
Pulses and legumes			
Lens culinaris Medik.	Lentil	✓	
Nuts			
Corylus avellana L.	Hazelnut	✓	
Pinus pinea L.	Stone pine	✓	
Fruit			
Cerasus avium L.		-	
Citrullus sp.	Watermelons	-	
Citrus sp.	Citrus	-	
Crataeugus sp.	Hawthorns	-	
Cucumis sp.	Cucumber/melons	-	
Cucumis cf. *melo* L.	Muskmelon	✓	
Curcurbitaceae	White bryony family	-	
Ficus carica L.	Fig	✓	
Malus domestica Borkh.	Apple	-	
Malus sp.	Apple	✓	
Malus/Pyrus sp.	Apple/pear	✓	
Malus/Pyrus/Sorbus sp.	Apple/pear/rowan	-	
Malva sp.	Mallow	✓	Can be an ornamental plant

Mineralized material from Pompeii	Common name	Present in mineralized Cardo V assemblage	Notes
Morus sp.	Mulberry	Sp	
Olea europea L.	Olive	✓	
Phoenix dactylifera L.	Date	✓	
Prunus avium L. type	Wild cherry	✓	
Prunus domestica L. type	Plum	✓	
Prunus sp.	Stone fruit	✓	
Punica granatum L.	Pomegranate	-	
Pyrus sp.	Pear	-	
Rubus fruticosus (agg)	Blackberry	✓	
Sorbus aucuparia L. /*aria* (L.) Crantz	Rowan/whitebeam	-	
Sorbus domestica L.	True service tree	-	
Sorbus sp.	Rowans	-	
Vaccinium sp.	Bilberries	-	
Vitis vinifera L.	Grape	✓	
Herbs and seasonings			
Capparis cf. *spinosa* L.	Caper	-	
cf. *Carum carvi* L.	Caraway	-	
Coriandrum sativum L.	Coriander	✓	
Daucus carota L.	Wild carrot	W	
Foeniculum vulgare Mill.	Fennel	✓	
Lamiaceae	Mint Family	✓	
Laurus nobilis L.	Bay tree	-	
Mentha sp.	Mint	✓	
cf. *Origanum* sp.	Oregano/marjoram	-	
Origanum vulgare L.	Oregano	-	
Papaver somniferum L.	Opium poppy	✓	

Mineralized material from Pompeii	Common name	Present in mineralized Cardo V assemblage	Notes
Piper nigrum L.	Balck Pepper	✓	
Raphanus sp.	Radish	-	
Rosmarinus officinalis L.	Rosemary	-	
Satureja/Thymus/Mentha sp.	Savory/thyme/mint	-	
Sesamum indicum L.	Seasame	-	
Weeds, ruderals and other taxa			
Agrostemma githago L.	Common corncockle	-	Poisonous weed of crops
Anagallis sp.	Pimpernel	✓	
Anthemis arvensis L.	Corn chamomile	✓	
Anthemis sp.	Chamomile	Sp	Ornamental plant
Arbutus cf. *unedo* L.	Strawberry tree	-	Ornamental plant
Asteraceae	Daisy family	✓	
Atriplex cf. *hastata* L.	Spear-leaved orache	-	
Atropa belladonna L.	Deadly nightshade	-	
Boraginaceae	Borage family	✓	
Brassica sp.	Cabbage or mustard	✓	
Brassicaceae	Cabbage family	✓	
Bromus sp.	Brome grass	-	
Bromus/Lolium sp.	Brome grass/ryegrass	-	
Bryonia dioica Jacq.	White bryony	-	Poisonous weed
Buxus sempervirens L.	Common box	G	Ornamental plant
Carex sp.	Sedge	✓	
Caryophyllaceae	Carnation family	✓	
Celtis sp.	Hackberry	Sp	
Chenopodiaceae	Goosefoot family	✓	
Chenopodium sp.	Goosefoot	✓	

Mineralized material from Pompeii	Common name	Present in mineralized Cardo V assemblage	Notes
Chenopodium/Atriplex sp.	Goosefoot/saltbush	-	
Chrysanthemum sp.	Mayweeds	-	
Crepis sp.	Hawksbeard	-	
Cupressus sempervirens L.	Mediterranean cypress	✓	Ornamental plant
Cyperaceae	Sedge family	✓	
Echium vulgare L.	Viper's bugloss	-	Grows on field edges
Euphorbia peplis L.	Purple spurge	-	Small weed of disturbed ground
Euphorbia sp.	Spurge	-	
Fabaceae	Legume family	✓	
Fumaria sp.	Fumitory	W	
Galeopsis tetrahit L.	Common hemp-nettle	-	Grows on disturbed ground, roadsides and amongst crops
Galium sp.	Cleavers	-	
Ilex aquifolium L.	Common holly	-	Ornamental plant
Lavatera sp.	Tree mallows	-	Ornamental plant
Leontodon sp.	Hawkbits	-	
cf. *Lolium* sp.	Rye grasses	-	
Linum bienne Miller	Pale flax	-	
Linum sp.	Flax	✓	
Lithospermum arvense L.	Field gromwell	-	
Lithospermum/Buglossoides sp.	Gromwells	Sp	
Luzula sp.	Wood-rushes	-	
Malva cf. *moschata* L.	Musk-mallow	-	Ornamental plant
Medicago cf. *minima* L.	Small medik	-	
Medicago sp.	Medick	✓	
Melilotus cf. *indicus* L.	Small melilot	-	
Meliltos/Medicago/Trifolium sp.	Melilot/medik/clover	✓	
Mercurialis annua L.	Annual mercury	-	Grows on disturbed ground
Myosotis sp.	Forget-me-not	-	
Ornithopus perpusillus L. /*sativus* Brot.	Bird's foot	-	

Mineralized material from Pompeii	Common name	Present in mineralized Cardo V assemblage	Notes
Ornithopus sp.	Bird's foot	✓	
cf. *Papaver* sp.	Poppy	✓	
Phalaris sp.	Canary-grasses	-	
Phleum pratense L.	Timothy-grass	-	Does not grow in the Mediterranean, may be a false identification
Plantago sp.	Plantain	✓	
Poa sp.	Meadow-grass	-	
Poaceae	True grasses	-	
Polygonaceae	Knotweed family	✓	
Polygonum sp.	Knotweed	✓	
Portulaca oleracea L.	Common purslane	-	
Potentilla cf. *argentea* L.	Hoary cinquefoil	-	
Potentilla/Fragaria sp.	Cinquefoil/Strawberry	-	
Pteridium aquilinum (L.) Kuhn	Bracken	✓	
Ranunculus sardous Crantz	Hairy buttercup	-	Grows on disturbed ground
Rhamnus cathartica L.	Buckthorn	-	Ornamental plant
Rosaceae	Rose family	-	
Rubus sp.	Bramble	✓	
Rumex acetosella L.	Sheep's sorrel	✓	
Rumex sp.	Dock	✓	
Sherardia arvensis L.	Field madder	✓	
Silene gallica L.	Small-flowered catchfly	✓	
Solanaceae	Nightshade family	-	
cf. *Solanum dulcamara* L.	Bittersweet	-	Weed of arable crops
Solanum nigrum L.	European black nightshade	-	
Trifolium sp.	Clovers	-	
Umbelliferae	Parsley family	✓	

Mineralized material from Pompeii	Common name	Present in mineralized Cardo V assemblage	Notes
Urtica dioica L.	Common stinging nettle	✓	
Urtica sp.	Nettle	✓	
Urtica urens L.	Small nettle	-	
Valerianella dentata (L.) Pollich	Narrow-fruited cornsalad	-	Grows on disturbed ground and with crops
Valerianella sp.	Corn salad	-	
Verbena officinalis L.	Vervain	-	Ornamental plant
Verbena sp.	Vervain	-	
Viburnum lantana L.	Wayfaring tree	-	Ornamental plant
Viola sp.	Violets	Sp	Ornamental plant

Sp - Identified only to genus in Pompeii assemblage but to species in Herculaneum
G - Identified to species in Pompeii assemblage but only genus in Herculaneum
W - Present as a waterlogged item in the Cardo V assemblage

Taxa lists from: The House of Amarantus I.9.12 (Robinson, M. 1999), House of Hercules' Wedding and the House of the Vestals (Ciaraldi 2007), Research on the Forum of Pompeii project (Kockel and Flecker, 2008), Pompeii Pistrina project (Monteix 2009, 2010b; Monteix *et al.* 2011), PARP:PS (Fairburn 2012), Insula VI.I (AAPP) (Murphy *et al.* 2013).

Appendix C: Dietary reference intake values and nutrient quantities of the Cardo V foodstuffs

Table C1. Dietary reference intakes (DRI) for macronutrients[1]

Life stage group	Total water (L/d)	Energy (kcal/d)	Carbohydrates (g/d)	Total fiber (g/d)	Fat (g/d)	Essential fatty acids[2]		Protein (g/d)
						Linoleic acid (g/d) (omega-6)	α-Linolenic acid (g/d) (omega-3)	
Male 19-30y	3.7	Moderately active - 2600-2800 Active - 3000	130	38	20-35	17	1.6	56
Female 19-30y	2.7	Moderately active - 2000-2200 Active - 2400	130	25	20-35	12	1.1	46

Table C2. Dietary reference intakes (DRI) for vitamins

	Fat soluble vitamins				Water soluble vitamins									
Life stage group	Vitamin A (μg/d)	Vitamin D (μg/d)	Vitamin E (mg/d)	Vitamin K (μg/d)	Vitamin C (mg/d)	Vitamin B_1 (mg/d)	Vitamin B_2 (mg/d)	Vitamin B_3 (mg/d)	Vitamin B_6 (mg/d)	Folate (μg/d)	Vitamin B_{12} (μg/d)	Biotin (μg/d)	Pantothenic acid (mg/d)	Choline (mg/d)
Male 19-30y	900	15	15	120	90	1.2	1.3	16	1.3	400	2.4	30	5	550
Female 19-30y	700	15	15	90	75	1.1	1.1	14	1.3	400	2.4	30	5	425

Table C3. Dietary reference intake (DRI) for minerals. For full mineral names see table 7.1.

Life stage group	Ca (mg/d)	Cr (μg/d)	Cu (μg/d)	F (mg/d)	I (μg/d)	Fe (mg/d)	Mg (mg/d)	Mn (mg/d)	Mo (μg/d)	P (mg/d)	Se (μg/d)	Zn (mg/d)	K (g/d)	Na (g/d)	Cl (g/d)
Male 19-30y	1,000	35	900	4	150	8	400	2.3	45	700	55	11	4.7	1.5	2.3
Female 19-30y	1,000	25	900	3	150	18	310	1.8	45	700	55	8	4.7	1.5	2.3

[1] All data for tables C1-3 provided by the USDA.
http://www.iom.edu/Activities/Nutrition/SummaryDRIs/~/media/Files/Activity%20Files/Nutrition/DRIs/5_Summary%20Table%20Tables%201-4.pdf

[2] Linoleic acid and α-Linolenic acid are polyunsaturated fatty acids and therefore have a double bond within the first seven carbon atoms of their hydrocarbon chain. Although the human body is capable of making fatty acids, it cannot insert a double bond into the first few carbons and so these two acids are considered essential (Webb 2006: 124-128).

Table C4A. Macronutrient values for the Cardo V foodstuffs

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Cereals		**100g**						
Hordeum sp.	Barley	Hulled	354	73.48	17.3	2.3	1.108	12.48
		Flour/meal	345	74.52	10.1	1.6	0.771	10.5
Panicum miliaceum	Common millet	Cooked (no species listed)	119	23.67	1.3	1	0.508	3.51
Setaria italica	Foxtail millet	Dry weight, uncooked*	384	84.2	1.4	3.3	-	10.7
cf. *Sorghum* sp.	Sorghum	No preparation details	339	74.63	6.3	3.3	1.37	11.3
Triticum sp.	Wheat	Wheat flour, bread, unenriched	361	72.53	2.4	1.66	0.727	11.98
		Bread, whole-wheat, prepared from recipe	278	51.4	6	5.4	2.939	8.4
		Durum (no additional details)	339	71.13	-	2.47	0.978	13.68
Triticum aestivum	Bread wheat	100% edible portion of flour**	317	65.2	9.7	2.6	-	12.3
Triticum dicoccum	Emmer wheat	100g edible portion of flour**	335	67.1	6.8	2.5	-	15.1
Triticum monococcum	Einkorn wheat	100g uncooked, whole***	346	-	8.7	2.48	-	18.2
Pulses		**100g**						
Lens culinaris	Lentil	Mature seeds, cooked, boiled, without salt	116	20.13	7.9	0.38	0.175	9.02
Vicia faba	Broad bean	Mature seeds, cooked, boiled, without salt	110	19.65	5.4	0.4	0.164	7.6
Nuts		**100g**						
Corylus avellana	Hazelnut	Nuts, unroasted	628	16.7	9.7	60.75	7.92	14.95
Juglans regia	Walnut	Nuts, unroasted	654	13.71	6.7	65.21	47.174	15.23
Pinus pinea	Stone pine	29% edible portion**	595	4	4.5	50.3	-	31.9
		Pinus and pinus koraiensis, dried	673	13.08	3.7	68.37	34.071	13.69

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Fruit		**100g**						
Cucumis melo or *sativus*	Melon or cucumber	Cucumber - raw with peel	15	3.63	0.5	0.11	0.032	0.65
		Melon - Cantaloupe, raw	34	8.16	0.9	0.19	0.081	0.84
Ficus carica	Fig	Raw	74	19.18	2.9	0.3	0.144	0.75
		Dried, uncooked, mission variety	249	63.87	9.8	0.93	0.345	3.3
Malus sp.	Apple	Several varieties, raw with skin	52	13.81	2.4	0.17	0.051	0.26
Morus nigra	Black mulberry	Raw	43	9.8	1.7	0.39	0.207	1.44
Olea europaea	Olive	Pickled, canned or bottled, green olives	145	3.84	3.3	15.32	1.307	1.03
		Black olives, edible portion - 74%**	235	0.8	3.9	25.1	-	1.6
Phoenix dactylifera	Date	Medjool	277	74.97	6.7	0.15	-	1.81
		Dried, edible portion - 90%**	253	63.1	8.7	0.6	-	2.7
Prunus avium or *cerasus*	Wild or dwarf cherry	Sweet, raw	63	16.01	2.1	0.2	0.052	1.06
Prunus sp.	Stone fruit	(Cherry) sour, red, raw	50	12.18	1.6	0.3	0.09	1
Prunus domestica	Wild plum	Raw	46	11.42	1.4	0.28	0.044	0.7
Pyrus sp.	Pear	Raw	57	15.23	3.1	0.14	0.094	0.36
Rubus fruticosus (agg)	Blackberry	Raw	43	9.61	5.3	0.49	0.28	1.39
Vitis vinifera	Grape	Red or green, European type	69	18.1	0.9	0.16	0.048	0.72
Seasonings		**Approximately 2g**						
Apium graveolens	Wild celery	Seed	8	0.83	0.2	0.51	0.074	0.36
cf. *Anethum graveolens*	Dill	Seed	6	1.16	0.4	0.31	0.021	0.34
Brassica sp.	Mustard	Seeds, ground	10	0.56	0.2	0.72	0.202	0.52
Coriandrum sativum	Coriander	Seed	5	0.99	0.8	0.32	0.032	0.22
Foeniculum vulgare	Fennel	Seed	7	1.05	0.8	0.3	0.034	0.32
Linum usitatissimum	Flax/linseed	Seed	18	0.98	0.9	1.43	0.977	0.62

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Mentha sp.	Mint	Spearmint fresh, leaves (*Mentha spicata*)	5	0.96	0.8	0.08	0.394	0.38
		Spearmint dried, leaves (*Mentha spicata*)	5	0.83	0.5	0.1	0.052	0.32
Papaver somniferum	Opium poppy	Seed	15	0.79	0.5	1.16	0.8	0.5
Piper nigrum	Black pepper	Whole seeds	7	1.85	0.7	0.09	0.029	0.3
Eggs	**Common Name**	**Large, 50g**						
Gallus gallus domesticus	Chicken	Fresh, whole, raw	72	0.36	0	4.76	0.956	6.28
Fish		**100g**						
Anguilla anguilla	European eel	100% of 100g edible portion, trimmed fillet**	319	0.5	0	28.9	-	14.2
		River eel (*Anguilla anguilla*), 71% of 100g portion**	261	0.1	0	23.7	-	11.8
		Raw^	318	0	0	27.7	5.2	18
Anguillidae/ Congridae	Eels	Mixed species, raw^	184	0	0	11.66	0.947	18.44
Belone belone	Garfish	Raw^	110	0	0	2.7	1	21.4
Boops boops	Bogue	Raw or cooked?**	87	0.8	0	1.2	-	18.3
		Fresh, raw^^^	-	1	-	1	-	20
Clupeidae	Herring/sardines	*Clupea harengus*, fresh, 70% edible of 100g portion**	216	0	0	16.7	-	16.5
		Atlantic herring (*Clupea harengus*), raw	158	0	0	9.04	2.133	17.96
Dicentrarchus labrax	European seabass	Skin on, boneless, farmed in Greece and Turkey^^	155	0	0	8.2	3.2	19.3
		Fresh, raw^^^	-	-	-	2	-	21
Elasmobranch	Dog fish	Raw, *Squalus acanthias*^	156	0	0	8.9	-	19.1
Elasmobranch	Sharks and rays	Mix species, raw	130	0	0	4.51	1.195	20.98

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Engraulis encrasicholus	European anchovy	Fresh, 75% of 100g edible portion**	96	1.5	0	2.6		16.8
		Raw	131	0	0	4.84	1.637	20.35
Merluccius merluccius	Hake	Raw, 76% edible of 100g portion**	71	0	0	0.3	-	17
		Fresh, raw^^^		1		2	-	18
Mugilidae	Mullets (grey)	Striped mullet (*Mugil cephalus*), raw	117	0	0	3.79	0.715	19.35
cf. *Mullus* sp.	Goatfish	*Mullus surmuletus* (barbatus), 60% edible of 100g portion**	123	1.1	0	6.2	-	15.8
		Fresh, raw, (*Mullus barbatus*)^^^	-	1	-	3	-	18
Pagellus sp.	Pandora	Fresh, raw, red bream (*Pagellus centrodontus*)^^^	-	-	-	2	-	21
Pleuronectiformes	Flatfishes	Flounder and sole species, raw	70	0	0	1.93	0.374	12.41
Sardina pilchardus	European pilchard	Fresh, 70% edible of 100g portion**	129	1.5	0	4.5	-	20.8
cf. *Sardinella* sp.	Sardinella	Sardines in brine, from Morocco, with bones^^	175	trace	trace	9.6	3.2	21.5
		Atlantic sardine, canned in oil, drained solids with bone	208	0	0	11.45	5.148	24.62
Scomber sp.	Mackerel	Fillet, raw, flesh only, (*Scomber scombrus*)^^	220	0	0	16	3.4	18.7
		Atlantic mackerel (*Scomber scombrus*), raw	205	0	0	13.89	3.35	18.6
cf. *Sparus* sp.	Sea bream	*Sparus aurata*, fresh farmed sea bream fillets, 100% edible of 100g portion**	159	1.2	0	8.4	-	19.7
cf. *Trachurus mediterraneus*	Mediterranean horse mackerel	55% edible of 100g portion**	104	1	0	3	-	18.3
Trachurus trachurus	Horse mackerel	Fresh (then frozen)^^	-	1.48	-	5.42	-	20.81
		Fresh, raw^^^	-	1	-	2	-	20
Triglidae	Gurnards	Fresh, raw (*Trigla lucerna*)^^^	-	3	-	2	-	19
Trisopterus luscus	Pouting	Flesh, raw (*Trisopterus esmarki)*^	84	0	-	1	-	18.5

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Shellfish - bivalva		**100g**						
Donacilla cornea	Corneous wedge clam	Clams (general), 25% edible of 100g**	72	2.2	0	2.5	-	10.2
		Mixed species, raw	86	3.57	0	0.96	0.192	14.67
		Mixed species, cooked, moist heat	148	5.13	0	1.95	0.552	25.55
Mytilus galloprovincialis	Mediterranean mussel	Fresh, raw^^^	-	5	-	1	-	11
		Blue mussel (*Mytilus edulis*), raw	86	3.69	0	2.24	0.606	11.9
		Blue mussel, cooked, moist heat	172	7.39	0	4.48	1.212	23.8
Ostrea edulis	Common oyster	Edible part - 12% of 100g sample**	69	5.4	0	0.9	-	10.2
Pecten jacobaeus	Great scallop/pilgrim's scallop	Scallop, mixed species, raw	69	3.18	0	0.49	0.13	12.06
Other shellfish and shells		**100g**						
Helicidae	Land snail	Snail, raw	90	2	0	1.4	0.252	16.1
Sepia sp.	Cuttlefish	50% edible of 100g portion**	72	0.7	0	1.5	-	14
		Mixed species, raw	79	0.82	0	0.7	0.134	16.24

See bottom of table C4C for references and key

Table C4B. Vitamin values for the Cardo V foodstuffs

Material	Common name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantothe-nic acid (mg)
Cereals		**100g**													
Hordeum sp.	Barley	Hulled	-	23	0	0.57	2.2	0	0.646	0.285	4.604	0.318	19	0	-
		Flour/meal	37.8	0	0	0.57	2.2	0	0.37	0.114	6.269	0.396	8	0	-
Panicum miliaceum	Common millet	Cooked (no species listed)	11.2	3	0	0.02	0.3	0	0.106	0.082	1.33	0.108	19	0	0.171
Setaria italica	Foxtail millet	Dry weight, uncooked*	-	0	-	-	-	0	0.48	0.14	2.48	0	-	-	-
cf. *Sorghum* sp.	Sorghum	No preparation details	-	0	0	0.81	-	0	0.237	0.142	2.927	0.59	20	0	1.25
Triticum sp.	Wheat	Wheat flours, bread, unenriched	10.4	2	0	0.4	0.3	0	0.08	0.06	1	0.037	33	0	0.438
		Bread, whole-wheat, prepared from recipe	26.5	3	0	0.76	9.4	0	0.303	0.227	3.985	0.199	65	0	0.473
		Durum (no additional details	-	0	0	-	-	0	0.419	0.121	6.738	0.419	43	0	-
Triticum aestivum	Bread wheat	100% edible portion of flour**	-	-	-	-	-	-	-	-	5.4	-	-	-	-
Triticum dicoccum	Emmer wheat	100g edible portion of flour**	-	-	-	-	-	-	-	-	-	-	-	-	-
Triticum monococcum	Einkorn wheat	100g uncooked, whole***	-	312	-	-	-	-	0.5	0.45	-	0.49	-	-	3.1
Pulses		**100g**													
Lens culinaris	Lentil	Mature seeds, cooked, boiled, without salt	32.7	8	0	0.11	1.7	1.5	0.169	.0.73	1.06	0.178	181	0	0.638
Vicia faba	Broad bean	Mature seeds, cooked, boiled, without salt	30.6	16	0	0.02	2.9	0.3	0.097	0.089	0.711	0.072	104	0	0.157
Nuts		**100g**													
Corylus avellana	Hazelnut	Nuts, unroasted	45.6	21	0	15.03	14.2	6.3	0.643	0.113	1.8	0.563	113	0	0.918
Juglans regia	Walnut	Nuts, unroasted	39.2	21	0	0.7	2.7	1.3	0.341	0.15	1.125	0.537	98	0	0.57

Material	Common name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantothe-nic acid (mg)
Pinus pinea	Stone pine	Edible portion is 29% of 100g**	-	9	-	-	-	0	0.39	0.25	2.7	-	-	-	-
		Pinus and pinus koraiensis, dried	55.8	30	0	9.33	53.9	0.8	0.364	0.227	4.387	0.094	34	0	0.313
Fruit		**100g**													
Cucumis melo or *sativus*	Melon or cucumber	Cucumber - raw with peel	6	110	0	0.03	16.4	2.8	0.027	0.033	0.098	0.04	7	0	0.259
		Melon - Cantaloupe, raw	7.6	3551	0	0.05	2.5	36.7	0.041	0.019	0.734	0.072	21	0	0.105
Ficus carica	Fig	Raw	4.7	149	0	0.11	4.7	2	0.06	0.05	0.4	0.113	6	0	0.3
		Dried, uncooked, mission variety	15.8	10	0	0.35	15.6	1.2	0.085	0.082	0.619	0.106	9	0	0.434
Malus sp.	Apple	Several varieties, raw with skin	3.4	57	0	0.18	2.2	4.6	0.017	0.026	0.091	0.041	3	0	0.061
Morus nigra	Black mulberry	Raw	12.3	36	0	1.22	10.9	36.4	0.029	0.101	0.141	0.05	6	0	-
Olea europaea	Olive	Pickled, canned or bottled, green olives	14.2	413	0	3.81	1.4	0	0.021	0.007	0.237	0.031	3	-	0.023
		Black olives, edible portion - 74%**	-	15	-	-	-	-	0.1	0.1	1	-	-	-	-
Phoenix dactylifera	Date	Medjool	9.9	156	0	-	2.7	0	0.05	0.06	1.61	0.249	15	-	0.805
		Dried, edible portion - 90%**	-	5	-	-	-	0	-	-	2.2	-	-	-	-
Prunus avium or *cerasus*	Wild or dwarf cherry	Sweet, raw	6.1	67	0	0.07	2.1	7	0.027	0.033	0.154	0.49	4	0	0.199
Prunus sp.	Stone fruit	(Cherry) sour, red, raw	6.1	1347	0	0.07	2.1	10	0.03	0.04	0.4	0.044	8	0	0.143
Prunus domestica	Wild plum	Raw	1.9	362	0	0.26	6.4	9.5	0.028	0.026	0.417	0.026	5	0	0.135
Pyrus sp.	Pear	Raw	5.1	26	0	0.12	4.4	4.3	0.012	0.026	0.161	0.029	7	0	0.049
Rubus fruticosus (agg)	Blackberry	Raw	8.5	225	0	1.17	19.8	21	0.02	0.026	0.646	0.03	25	0	0.276
Vitis vinifera	Grape	Red or green, European type	5.6	69	0	0.19	14.6	3.2	0.069	0.07	0.188	0.086	2	0	0.05

Material	Common name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantothenic acid (mg)
Seasonings		**Approximately 2g**													
Apium graveolens	Wild celery	Seed	0.5	1	0	0.02	0	0.3	0.007	0.006	0.061	0.018	0	0	-
cf. *Anethum graveolens*	Dill	Seed	-	1	0	-	-	0.4	0.009	0.006	0.059	0.005	0	0	-
Brassica sp.	Mustard	Seeds, ground	2.5	1	0	0.1	0.1	0.1	0.016	0.005	0.095	0.008	3	0	0.016
Coriandrum sativum	Coriander	Seed	-	0	0	-	-	0.4	0.004	0.005	0.038	-	0	0	-
Foeniculum vulgare	Fennel	Seed	-	3	0	-	-	0.4	0.008	0.007	0.121	0.009	-	0	-
Linum usitatissimum	Flax/linseed	Seed	2.7	0	0	0.01	0.1	0	0.056	0.005	0.105	0.016	3	0	0.033
Mentha sp.	Mint	Spearmint fresh, leaves (*Mentha spicata*)	-	-	0	485	-	1.5	0.009	0.02	0.108	0.018	12	0	0.028
		Spearmint dried, leaves (*Mentha spicata*)	-	177	0	-	-	0	0.005	0.023	0.105	0.041	8	-	0.022
Papaver somniferum	Opium poppy	Seed	0.2	0	0	0.05	0	0	0.024	0.003	0.025	0.007	2	0	0.009
Piper nigrum	Black pepper	Whole seeds	0.3	17	0	0.03	4.7	0	0.003	0.005	0.033	0.008	0	0	-
Eggs		**Large, 50g**													
Gallus gallus domesticus	Chicken	Fresh, whole, raw	146.9	350	43	0.52	0.2	0	0.02	0.228	0.038	0.085	24	0.44	0.766
Fish		**100g**													
Anguilla anguilla	European eel	100% of 100g edible portion, trimmed fillet**	-	-	-	0.82	-	-	-	-	-	-	-	-	-
		River eel (*Anguilla anguilla*), 71% of 100g portion**	-	1200	-	-	-	2	-	0.2	3.5	-	-	-	-
		Raw^	-	1800	30	8	0	1	0.15	0.31	3.8	0.244	14	4.4	0.141
Anguillidae/ Congridae	Eels	Mixed species, raw^	65	4520	955.3	4	0	1.8	0.15	0.04	3.5	0.067	15	3	0.24
Belone belone	Garfish	Raw^		7	5	1.7	0	2	0.012	0.085	8.5	0.9	1	2.7	0.8

Material	**Common name**	**Type**	**Choline (mg)**	**A (µg)**	**D (µg)**	**E (mg)**	**K (µg)**	**C (mg)**	**B_1 (mg)**	**B2 (mg)**	**B_3 (mg)**	**B6 (mg)**	**Folate (µg)**	**B12 (µg)**	**Pantothe-nic acid (mg)**
Boops boops	Bogue	Raw or cooked?**	-	-	-	-	-	-	-	-	-	-	-	-	-
		Fresh, raw^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeidae	Herring/sardines	*Clupea harengus*, fresh, 70% edible of 100g portion**	-	12	-	-	-	-	-	-	3.5	-	-	-	-
		Atlantic herring (*Clupea harengus*), raw	65	121	171.2	1.07	0.1	0.7	0.092	0.233	3.217	0.302	10	13.67	0.645
Dicentrarchus labrax	European seabass	Skin on, boneless, farmed in Greece and Turkey^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Fresh, raw^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Elasmobranch	Dog fish	Raw, *Squalus acanthias*^	-	239	0.38	0.65	0	0	0.052	0.14	5.2		3.2	1.8	0.69
Elasmobranch	Sharks and rays	Mix species, raw	65	303	24.6	1	0.1	0	0.042	0.062	2.938	0.4	3	1.49	0.695
Engraulis encrasicholus	European anchovy	Fresh, 75% of 100g edible portion**	-	32	-	-	-	-	-	-	14	-	-	-	-
		Raw	-	65	-	0.57	0.1	0	0.055	0.256	14.024	0.143	9	0.62	0.645
Merluccius merluccius	Hake	Raw, 76% edible of 100g portion**	-	-	-	-	-	-	0.05	0.08	2.2	-	-	-	-
		Fresh, raw^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Mugilidae	Mullets (grey)	Striped mullet (*Mugil cephalus*), raw	-	160	62.5	1	0.1	1.2	0.09	0.08	5.2	0.425	9	0.22	0.76
cf. *Mullus* sp.	Goatfish	*Mullus surmuletus* (barbatus), 60% edible of 100g portion**	-	9	-	-	-	-	0.07	0.07	4.2	-	-	-	-
		Fresh, raw, (*Mullus barbatus*)^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Pagellus sp.	Pandora	Fresh, raw, red bream (*Pagellus centrodontus*)^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes	Flatfishes	Flounder and sole species, raw	65	43	115.8	0.63	0.1	0	0.022	0.02	1.04	0.098	5	1.13	0.185
Sardina pilchardus	European pilchard	Fresh, 70% edible of 100g portion**	-	28	-	-	-	-	0.02	0.25	9.7	-	-	-	-

Material	Common name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantothenic acid (mg)
cf. *Sardinella* sp.	Sardinella	Sardines in brine, from Morocco, with bones^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Atlantic sardine, canned in oil, drained solids with bone	75	140	197.8	2.04	2.6	0	0.08	0.227	5.245	0.167	10	8.94	0.642
Scomber sp.	Mackerel	Fillet, raw, flesh only, (*Scomber scombrus*)^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Atlantic mackerel (*Scomber scombrus*), raw	65	217	659.1	1.52	5	0.4	0.176	0.312	9.08	0.399	1	8.71	0.856
cf. *Sparus* sp.	Sea bream	*Sparus aurata*, fresh farmed sea bream fillets, 100% edible of 100g portion**	-	-	-	-	-	-	-	-	-	-	-	-	-
cf. *Trachurus mediterraneus*	Mediterranean horse mackerel	55% edible of 100g portion**	-	-	-	-	-	-	-	-	-	-	-	-	-
Trachurus trachurus	Horse mackerel	Fresh (then frozen)^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Fresh, raw^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Triglidae	Gurnards	Fresh, raw (*Trigla lucerna*)^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
Trisopterus luscus	Pouting	Flesh, raw (*Trisopterus esmarki)*^	-	-	-	-	0	0	0.1	0.09	0.9	-	-	-	-
Shellfish - bivalva		**100g**													
Donacilla cornea	Corneous wedge clam	Clams (general), 25% edible of 100g**	-	16	-	-	-	-	-	-	-	-	-	-	-
		Mixed species, raw	65	390	1	0.68	0.2	0	0.015	0.04	0.35	0.1	5	11.28	0.148
		Mixed species, cooked, moist heat	0	741	-	-	-	22.1	0.15	0.426	3.354	0.11	29	98.89	0.68
Mytilus galloprovincialis	Mediterranean mussel	Fresh, raw^^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Blue mussel (*Mytilus edulis*), raw	65	208	0	0.55	0.1	8	0.16	0.21	1.6	0.05	42	12	0.5
		Blue mussel, cooked, moist heat	-	395	-	-	-	13.6	0.3	0.42	3	0.1	76	24	0.95

Material	Common name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantothe-nic acid (mg)
Ostrea edulis	Common oyster	Edible part - 12% of 100g sample**	-	75	-	-	-	-	0.1	0.2	1.5	-	-	-	-
Pecten jacobaeus	Great scallop/pilgrim 's scallop	Scallop, mixed species, raw	65	4	1	0	0	0	0.007	0.015	0.703	0.073	16	1.41	0.215
Other shellfish and shell		**100g**													
Helicidae	Land snail	Snail, raw	65	130	0	5	0.1	0	0.01	0.12	1.4	0.13	6	0.5	-
Sepia sp.	Cuttlefish	50% edible of 100g portion**	-	25	-	-	-	-	-	-	-	-	-	-	-
		Mixed species, raw	-	488	-	-	-	5.3	0.009	0.91	1.216	0.15	16	3	0.5

See bottom of table C4C for references and key

Table C4C. Mineral values for the Cardo V foodstuffs. For full mineral names see table 7.1

Material	Common name	Type	Ca (mg)	Cr (µg)	Cu (mg)	F (µg)	I (µg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (µg)	Zn (mg)	K (mg)	Na (mg)
Cereals		**100g**													
Hordeum sp.	Barley	Hulled	33	-	0.498	-	-	3.6	133	1.943	264	37.7	2.77	452	12
		Flour/meal	32	-	0.343	-	-	2.68	96	1.034	296	37.7	2	309	4
Panicum miliaceum	Common millet	Cooked (no species listed)	3	-	0.161	-	-	0.63	44	0.272	100	0.9	0.91	62	2
Setaria italica	Foxtail millet	Dry weight, uncooked*	37	-	-	-	-	6.2	0	-	275	2.7	0	281	8
cf. *Sorghum* sp.	Sorghum	No preparation details	28	-	1.08	-	-	4.4	190	1.63	287	12.2	1.54	350	6
Triticum sp.	Wheat	Wheat flours, bread, unenriched	15	-	0.182	-	-	0.9	25	0.792	97	39.7	0.85	100	2
		Bread, whole-wheat, prepared from recipe	33	-	0.253	-	-	3.1	81	1.881	187	38.6	1.5	314	346
		Durum (no additional details	34	-	-	-	-	3.52	144	-	508	-	4.16	431	2
Triticum aestivum	Bread wheat	100% edible portion of flour**	35	-	-	-	-	3.3	-	-	304	-	3.1	-	-
Triticum dicoccum	Emmer wheat	100g edible portion of flour**	43	-	-	-	-	0.7	-	-	420	22.92	-	440	18
Triticum monococcum	Einkorn wheat	100g uncooked, whole***	-	-	-	-	-	4.59	-	4.4	415	27.89	2.24	390	-
			-												
Pulses		**100g**													
Lens culinaris	Lentil	Mature seeds, cooked, boiled, without salt	19	-	0.251	-	-	3.33	36	0.494	180	2.8	1.27	369	2
Vicia faba	Broad bean	Mature seeds, cooked, boiled, without salt	36	-	0.259	-	-	1.5	43	0.421	125	2.6	1.01	268	5
			-	-											
Nuts		**100g**													
Corylus avellana	Hazelnut	Nuts, unroasted	114	-	1.725	-	-	4.7	163	6.175	290	2.4	2.45	680	0
Juglans regia	Walnut	Nuts, unroasted	98	-	1.586	-	-	2.91	158	3.414	346	4.9	3.09	441	2
Pinus pinea	Stone pine	Edible portion is 29% of 100G**	40	-	-	-	-	2	-	-	466	-	-	-	-
		Pinus and pinus koraiensis, dried	16	-	1.324	-	-	5.53	251	8.802	575	0.7	6.45	597	2

Material	Common name	Type	Ca (mg)	Cr (μg)	Cu (mg)	F (μg)	I (μg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (μg)	Zn (mg)	K (mg)	Na (mg)
Fruit		**100g**													
Cucumis melo or *sativus*	Melon or cucumber	Cucumber - raw with peel	16	-	0.041	1.3	-	0.28	13	0.079	24	0.3	0.2	147	2
		Melon - Cantaloupe, raw	9	-	0.041	1	-	0.21	12	0.041	15	0.4	0.18	267	16
Ficus carica	Fig	Raw	35	-	0.07	-	-	0.37	17	0.128	14	0.2	0.15	232	1
		Dried, uncooked, mission variety	162	-	0.287	-	-	2.03	68	0.51	67	0.6	0.55	680	10
Malus sp.	Apple	Several varieties, raw with skin	6	-	0.027	3.3	-	0.12	5	0.035	11	0	0.04	107	1
Morus nigra	Black mulberry	Raw	39	-	0.06	-	-	1.85	18	-	38	0.6	0.12	194	10
Olea europaea	Olive	Pickled, canned or bottled, green olives	52	-	0.12	-	-	0.49	11	-	4	0.9	0.04	42	1556
		Black olives, edible portion - 74%**	62	-		-	-	1.6	-	-	18	-	-	432	54
Phoenix dactylifera	Date	Medjool	64	-	0.362	-	-	0.9	54	0.296	62	-	0.44	696	1
		Dried, edible portion - 90%**	69	-		-	-	2.7	-	-	65	-	-	750	5
Prunus avium or *cerasus*	Wild or dwarf cherry	Sweet, raw	13	-	0.06	2	-	0.36	11	0.07	21	0	0.07	222	0
Prunus sp.	Stone fruit	(Cherry) sour, red, raw	16	-	0.104	-	-	0.32	9	0.112	15	0	0.1	173	3
Prunus domestica	Wild plum	Raw	6	-	0.057	2	-	0.17	7	0.052	16	0	0.1	157	0
Pyrus sp.	Pear	Raw	9	-	0.082	2.2	-	0.18	7	0.048	12	0.1	0.1	116	1
Rubus fruticosus (agg)	Blackberry	Raw	29	-	0.165	-	-	0.62	20	0.646	22	0.4	0.53	162	1
Vitis vinifera	Grape	Red or green, European type	10	-	0.127	7.8		0.36	7	0.071	20	0.1	0.07	191	2
Seasonings		**Approximately 2g**													
Apium graveolens	Wild celery	Seed	35	-	0.027	-	-	0.9	9	0.151	11	0.2	0.14	28	3
cf. *Anethum graveolens*	Dill	Seed	32	-	0.016	-	-	0.34	5	0.038	6	0.3	0.11	25	0
Brassica sp.	Mustard	Seeds, ground	5	-	0.013	-	-	0.18	7	0.049	17	4.2	0.12	15	0
Coriandrum sativum	Coriander	Seed	13	-	0.018	-	-	0.29	6	0.034	7	0.5	0.08	23	1

Material	Common name	Type	Ca (mg)	Cr (µg)	Cu (mg)	F (µg)	I (µg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (µg)	Zn (mg)	K (mg)	Na (mg)
Foeniculum vulgare	Fennel	Seed	24	-	0.021	-	-	0.37	8	0.131	10	-	0.07	34	2
Linum usitatissimum	Flax/linseed	Seed	9	-	0.041	-	-	0.19	13	0.084	22	0.9	0.15	28	1
Mentha sp.	Mint	Spearmint fresh, leaves (*Mentha spicata*)	23	-	0.027	-	-	1.35	7	0.127	7	-	0.12	52	3
		Spearmint dried, leaves (*Mentha spicata*)	24	-	0.025	-	-	1.4	10	0.184	4	-	0.04	31	6
Papaver somniferum	Opium poppy	Seed	40	-	0.046	-	-	0.27	10	0.188	24	0.4	0.22	20	1
Piper nigrum	Black pepper	Whole seeds	13	-	0.039	1	-	0.28	5	0.37	5	0.1	0.03	39	1
Eggs		**Large, 50g**	-												
Gallus gallus domesticus	Chicken	Fresh, whole, raw	28	-	0.036	0.6	-	0.88	6	0.014	99	15.4	0.64	69	71
Fish		**100g**	-												
Anguilla anguilla	European eel	100% of 100g edible portion, trimmed fillet**	20	-	-	-	-	-	-	-	480	17	-	-	-
		River eel (*Anguilla anguilla*), 71% of 100g portion**	31	-	-	-	-	1	27	-	218	18	-	217	65
		Raw^	35	1.2	0.03	-	25	0.35	15	0.03	200	26.3	2	256	46
Anguillidae/ Congridae	Eels	Mixed species, raw^	20	-	0.023	-	-	0.5	20	0.035	216	6.5	1.62	272	51
Belone belone	Garfish	Raw^	25	0.47	0.42	-	20	0.4	25	0.02	251	30.9	0.5	298	55
Boops boops	Bogue	Raw or cooked?**	65	-	0.9	-	-	4.1	22	-	-	-	2	348	-
		Fresh, raw^^^	65	0.04	0.9	-	-	4.1	22	0.2	-	-	2	348	-
Clupeidae	Herring/sardines	*Clupea harengus*, fresh, 70% edible of 100g portion**	63	-	-	-	-	0.9	-	-	113	-	-	320	-
		Atlantic herring (*Clupea harengus*), raw	57	-	0.092	-	-	1.1	32	0.035	236	36.5	0.99	327	90
Dicentrarchus labrax	European seabass	Skin on, boneless, farmed in Greece and Turkey^^	-	-	-	-	-	-	-	-	-	-	-	-	0.1
		Fresh, raw^^^	25	0.001	0.7	-	-	4.1	29	0.1	-	-	2.1	307	-

Material	Common name	Type	Ca (mg)	Cr (µg)	Cu (mg)	F (µg)	I (µg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (µg)	Zn (mg)	K (mg)	Na (mg)
Elasmobranch	Dog fish	Raw, *Squalus acanthias*^	13	0.5	0.1	-	260	1.32	20	0.2	253	33.6	0.52	223	100
Elasmobranch	Sharks and rays	Mix species, raw	34	-	0.033	-	-	0.84	49	0.015	210	36.5	0.43	160	79
Engraulis encrasicholus	European anchovy	Fresh, 75% of 100g edible portion**	148	-	1	-	-	2.8	22	-	196	-	4.2	278	-
		Raw	147	-	0.211	-	-	3.25	41	0.07	174	36.5	1.72	383	104
Merluccius merluccius	Hake	Raw, 76% edible of 100g portion**	25	-	0.3	-	-	0.7	20	-	194	16.5	2	320	77
		Fresh, raw^^^	25	0.01	0.3	0.1	-	3.1	20	-	-	-	2	527	-
Mugilidae	Mullets (grey)	Striped mullet (*Mugil cephalus*), raw	41	-	0.051	-	-	1.02	29	0.016	221	36.5	0.52	357	65
cf. *Mullus* sp.	Goatfish	*Mullus surmuletus* (barbatus), 60% edible of 100g portion**	21	-	0.24	-	-	1.1	30	-	218	30	2.4	-	-
		Fresh, raw, (*Mullus barbatus*)^^^	66	0.003	2.4	-	-	5.6	30	0.2	-	-	2.4	719	-
Pagellus sp.	Pandora	Fresh, raw, red bream (*Pagellus centrodontus*)^^^	34	0.004	0.4	-	-	4.3	22	0.1	-	-	1.6	690	-
Pleuronecti-formes	Flatfishes	Flounder and sole species, raw	21	-	0.019	-	-	0.18	18	0.014	252	26.6	0.32	45	296
Sardina pilchardus	European pilchard	Fresh, 70% edible of 100g portion**	33	-	0.2	-	-	1.8	10	-	215	-	0.8	630	66
cf. *Sardinella* sp.	Sardinella	Sardines in brine, from Morocco, with bones^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Atlantic sardine, canned in oil, drained solids with bone	382	-	0.186	-	-	2.92	39	0.108	490	52.7	1.31	397	307
Scomber sp.	Mackerel	Fillet, raw, flesh only, (*Scomber scombrus*)^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Atlantic mackerel (*Scomber scombrus*), raw	12	-	0.073	-	-	1.63	76	0.015	217	44.1	0.63	314	90
cf. *Sparus* sp.	Sea bream	*Sparus aurata*, fresh farmed sea bream fillets, 100% edible of 100g portion**	30	-	-	-	-	-	-	-	1050	-	-	-	-
cf. *Trachurus mediterraneus*	Mediterranean horse mackerel	55% edible of 100g portion**	125	-	0.14	-	-	0.9	31	-	224	-	1.45	212	111
Trachurus trachurus	Horse mackerel	Fresh (then frozen)^^	-	-	-	-	-	-	-	-	-	-	-	-	-
		Fresh, raw^^^	92	0.6	1.9	-	-	14.6	69	0.2	-	-	2.7	986	-
Triglidae	Gurnards	Fresh, raw (*Trigla lucerna*)^^^	-	-	-	-	-	-	-	-	-	-	-	-	-

Material	Common name	Type	Ca (mg)	Cr (µg)	Cu (mg)	F (µg)	I (µg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (µg)	Zn (mg)	K (mg)	Na (mg)
Trisopterus luscus	Pouting	Flesh, raw (*Trisopterus esmarki)*^	-	-	-	-	-	-	-	-	-	-	-	-	-
Shellfish - bivalva		**100g**													
Donacilla cornea	Corneous wedge clam	Clams (general), 25% edible of 100g**	-	-	-	-	-	-	-	-	-	-	-	-	-
		Mixed species, raw	39	-	0.053	-	-	1.62	19	0.085	198	30.6	0.51	46	601
		Mixed species, cooked, moist heat	92	-	0.688	-	-	2.81	18	1	338	64	2.73	628	112
Mytilus galloprovincialis	Mediterranean mussel	Fresh, raw^^^	88	0.01	1.1	-	-	10.9	44	0.8	-	-	4.6	328	-
		Blue mussel (*Mytilus edulis*), raw	26	-	0.094	-	-	3.95	34	3.4	197	44.8	1.6	320	286
		Blue mussel, cooked, moist heat	33	-	0.149	-	-	6.72	37	6.8	285	89.6	2.67	268	369
Ostrea edulis	Common/edible oyster	Edible part - 12% of 100g sample**	186	-		-	-	6	-	-	267	-	-	260	510
Pecten jacobaeus	Great scallop/pilgrim's scallop	Scallop, mixed species, raw	6	-	0.023	-	-	0.38	22	0.017	334	12.8	0.91	205	392
Other shellfish and shell		**100g**													
Helicidae	Land snail	Snail, raw	10	-	0.4	-	-	3.5	250	-	272	27.4	1	382	70
Sepia sp.	Cuttlefish	50% edible of 100g portion**	27	-	1.1	-	-	0.8	32	-	143	-	4.2	273	-
		Mixed species, raw	90	-	0.587	-	-	6.02	30	0.11	387	44.8	1.73	354	372

References and key for tables C4A-C

All data from U.S. Department of Agriculture, Agricultural Research Service. 2013. USDA National Nutrient Database for Standard Reference, Release 26. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl
* Duke and Ayensu 1985
** INRAN 2009
***Ness 2010
^ Saxholt *et al.* 2008
^^ Roe *et al.* 2013
^^^ Karakoltisidis et al. 1995

Nutritional information was not available for the following taxa:

Pulses: *Ceratonia siliqua*, *Vicia* or *Lathyrus* sp., *Vicia* sp.
Fish: *Chromis chromis, Conger conger, Diplodus* sp., Gadidae, Labridae, cf. *Labrus mixtus,* cf. *Muraena helena, Pagellus bogaraveo, Pagellus erythrinus, Pagrus pagrus*, cf. Percidae, Rajidae, cf. Sciaenidae, Scophthalmidae, Sparidae, cf. *Spicara maena, Spicara* sp., *Spondyliosoma cantharus*, *Trachinus draco, Trachinus* sp., *Trachurus* sp., *Trisopterus* sp., cf. *Xyrichtys novacula* L.
Shellfish: all gastropods (see Table 8.5), *Acanthocardia* or *Cerastoderma* sp., *Acanthocardia tuberculata*, *Aequipecten opercularis*, *Arca noae*, *Cerastoderma edule* or *glaucum, Chamelea gallina, Donax trunculus, Ensis minor, Gregariella* cf. *petagnae*, *Glycymeris* sp., Mytilidae indet., *Mytilaster* cf. *minimus, Polititapes aureus, Spondylus gaederopus, Venerupis decussata*
Other shellfish: *Paracentrotus lividus*

Table C5A. Macronutrient values for raw, processed and cooked foods based on the Cardo V material

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Cereals		**100g**						
Panicum miliaceum	Common millet	Cooked (no species listed)	119	23.67	1.3	1	0.508	3.51
Setaria italica	Foxtail millet	Dry weight, uncooked*	384	84.2	1.4	3.3	-	10.7
Pulses		**100g**						
Lens culinaris	Lentil	Raw	343	60.08	30.5	1.06	0.516	25.8
		Mature seeds, cooked, boiled, without salt	116	20.13	7.9	0.38	0.175	9.02
Vicia faba	Broad bean	Mature seeds, raw	341	58.29	25	1.53	0.627	26.12
		Mature seeds, cooked, boiled, without salt	110	19.65	5.4	0.4	0.164	7.6
Nuts		**100g**						
Corylus avellana	Hazelnut	Nuts, unroasted	628	16.7	9.7	60.8	7.92	14.95
		Nuts, dry roasted, without salt added	646	17.6	9.4	62.4	8.463	15.03
Fruit		**100g**						
Ficus carica	Fig	Raw	74	19.18	2.9	0.3	0.144	0.75
		Dried, uncooked, mission variety	249	63.87	9.8	0.93	0.345	3.3
Malus sp.	Apple	Several varieties, raw with skin	52	13.81	2.4	0.17	0.051	0.26
		Dried, sulfured, stewed, without added sugar	57	15.32	2	0.07	0.022	0.22
		Dried, sulfured, uncooked	243	65.89	8.7	0.32	0.093	0.93
Pyrus sp.	Pear	Raw	57	15.23	3.1	0.14	0.094	0.36
		USDA commodity, canned, light syrup, drained	62	16.21	1.6	0.15	-	0.28
		Dried, sulfured, uncooked	262	69.7	7.5	0.63	0.148	1.87
Vitis vinifera	Grape	Red or green, European type, 100g	69	18.1	0.9	0.16	0.048	0.72
		Raisins, seeded	296	78.47	6.8	0.54	0.159	2.52
Eggs								
Gallus gallus domesticus	Chicken	Fresh, whole, raw, large, 50g	72	0.36	0	4.76	0.956	6.28
		Whole, cooked, hard boiled, large, 50g	78	0.56	0	5.3	0.707	6.29
		Whole, cooked, fried, large, 46g	90	0.38	0	6.83	1.495	6.26

Material	Common name	Type	Energy (kcal)	Carbohydrates (g)	Total fiber (g)	Fat (g)	Polyunsaturated fatty acids (g)	Protein (g)
Fish		**100g**						
Anguillidae/ Congridae	Eels	Mixed species, raw	184	0	0	11.7	0.947	18.44
		Mixed species, cooked, dry heat	236	0	0	15	1.214	23.65
Mugilidae	Mullets (grey)	Striped mullet (*Mugil cephalus*), raw	117	0	0	3.79	0.715	19.35
		Striped mullet (*Mugil cephalus*), cooked, dry heat	150	0	0	4.86	0.917	24.81
Scomber sp.	Mackerel	Atlantic mackerel (*Scomber scombrus*), raw	205	0	0	13.9	3.35	18.6
		Salted	305	0	0	25.1	6.21	18.5
Pleuronectiformes	Flatfishes	Flounder and sole species, raw	70	0	0	1.93	0.374	12.41
		Flounder and sole species, cooked, dry heat	86	0	0	2.37	0.459	15.24
Shellfish		**100g**						
Mytilus galloprovincialis	Mediterranean mussel	Blue mussel (*Mytilus edulis*), raw	86	3.69	0	2.24	0.606	11.9
		Blue mussel, cooked, moist heat	172	7.39	0	4.48	1.212	23.8
Sepia sp.	Cuttlefish	Mixed species, raw	79	0.82	0	0.7	0.134	16.24
		Mixed species, cooked, moist heat	158	1.64	0	1.4	0.268	32.48

See bottom of table C5C for references and key

Table C5B. Vitamin values for raw, processed and cooked foods based on the Cardo V material

Material	Common Name	Type	Choline (mg)	A (μg)	D (μg)	E (mg)	K (μg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (μg)	B12 (μg)	Pantoth-enic acid (mg)
Cereals		**100g**													
Panicum miliaceum	Common millet	Cooked (no species listed)	11.2	3	0	0.02	0.3	0	0.106	0.082	1.33	0.108	19	0	0.171
Setaria italica	Foxtail millet	Dry weight, uncooked*	-	0	-	-	-	0	0.48	0.14	2.48	0	-	-	-
Pulses		**100g**													
Lens culinaris	Lentil	Raw	96.4	41	0	0.49	5	4.4	0.873	0.211	2.605	0.54	479	0	-
		Mature seeds, cooked, boiled, without salt	32.7	8	0	0.11	1.7	1.5	0.169	0.73	1.06	0.178	181	0	0.638
Vicia faba	Broad bean	Mature seeds, raw	0	56	0	0.05	9	1.4	0.555	0.333	2.832	0.366	423	0	0.976
		Mature seeds, cooked, boiled, without salt	30.6	16	0	0.02	2.9	0.3	0.097	0.089	0.711	0.072	104	0	0.157
Nuts		**100g**													
Corylus avellana	Hazelnut	Nuts, unroasted	45.6	21	0	15.03	14.2	6.3	0.643	0.113	1.8	0.563	113	0	0.918
		Nuts, dry roasted, without salt added	-	64	0	15.28		3.8	0.338	0.123	2.05	0.62	88	0	0.923
Fruit		**100g**													
Ficus carica	Fig	Raw	4.7	149	0	0.11	4.7	2	0.06	0.05	0.4	0.113	6	0	0.3
		Dried, uncooked, mission variety	15.8	10	0	0.35	15.6	1.2	0.085	0.082	0.619	0.106	9	0	0.434
Malus sp.	Apple	Several varieties, raw with skin	3.4	57	0	0.18	2.2	4.6	0.017	0.026	0.091	0.041	3	0	0.061
		Dried, sulfured, stewed, without added sugar	3.8	18	0	0.12	0.7	1	0.006	0.019	0.129	0.05	0	0	0.057
		Dried, sulfured, uncooked	17.6	0	0	0.53	3	3.9	0	0.159	0.927	0.125	0	0	

Material	Common Name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantoth-enic acid (mg)
Pyrus sp.	Pear	Raw	5.1	26	0	0.12	4.4	4.3	0.012	0.026	0.161	0.029	7	0	0.049
		USDA commodity, canned, light syrup, drained	-	-	-	0.11	0.3	0.9	0.02	0.14	0.115	0.016	3	-	0.041
		Dried, sulfured, uncooked	23	3	0	0.06	20.4	7	0.008	0.145	1.372	0.072	0	0	0.153
Vitis vinifera	Grape	Red or green, European type, 100g	5.6	69	0	0.19	14.6	3.2	0.069	0.07	0.188	0.086	2	0	0.05
		Raisins, seeded	-	0	0	-	-	5.4	0.112	0.182	1.114	0.188	3	0	0.045
Eggs															
Gallus gallus domesticus	Chicken	Fresh, whole, raw, large, 50g	146.9	350	43	0.52	0.2	0	0.02	0.228	0.038	0.085	24	0.44	0.766
		Whole, cooked, hard boiled, large, 50g	146.9	334	45.1	0.52	0.2	0	0.033	0.256	0.032	0.06	22	0.56	0.699
		Whole, cooked, fried, large, 46g	145.9	463	41	0.6	2.6	0	0.02	0.228	0.038	0.085	23	0.45	0.764
Fish		**100g**													
Anguillidae/ Congridae	Eels	Mixed species, raw	65	4520	955.3	4	0	1.8	0.15	0.04	3.5	0.067	15	3	0.24
		Mixed species, cooked, dry heat	-	4924	-	-	-	1.8	0.183	0.051	4.487	0.077	17	2.89	0.28
Mugilidae	Mullets (grey)	Striped mullet (*Mugil cephalus* L.), raw	117	0	0	3.79	0.72	19.35	0.09	0.08	5.2	0.425	9	0.22	0.76
		Striped mullet (Mugil cephalus L.), cooked, dry heat	-	183	-	-	-	1.2	0.1	0.1	6.3	0.49	10	0.25	0.88
Scomber sp.	Mackerel	Atlantic mackerel (*Scomber scombrus* L.), raw	65	217	659.1	1.52	5	0.4	0.176	0.312	9.08	0.399	1	8.71	0.856
		Salted	101.6	204	1031 .2	2.38	7.8	0	0.02	0.19	3.3	0.41	15	12	-

Material	Common Name	Type	Choline (mg)	A (µg)	D (µg)	E (mg)	K (µg)	C (mg)	B_1 (mg)	B2 (mg)	B_3 (mg)	B6 (mg)	Folate (µg)	B12 (µg)	Pantoth-enic acid (mg)
Pleuronecti-formes	Flatfishes	Flounder and sole species, raw	65	43	115.8	0.63	0.1	0	0.022	0.02	1.04	0.098	5	1.13	0.185
		Flounder and sole species, cooked, dry heat	79.9	49	139	0.77	0.1	0	0.026	0.025	1.278	0.115	6	1.31	0.227
Shellfish		**100g**													
Mytilus galloprovinc-ialis	Mediterra-nean mussel	Blue mussel (*Mytilus edulis*), raw	65	208	0	0.55	0.1	8	0.16	0.21	1.6	0.05	42	12	0.5
		Blue mussel, cooked, moist heat	-	395	-	-	-	13.6	0.3	0.42	3	0.1	76	24	0.95
Sepia sp.	Cuttlefish	Mixed species, raw	-	488	-	-	-	5.3	0.009	0.91	1.216	0.15	16	3	0.5
		Mixed species, cooked, moist heat	-	878	-	-	-	8.5	0.017	1.729	2.189	0.27	24	5.4	0.9

See bottom of table C4C for references and key

Table C5C. Mineral values for raw, processed and cooked foods based on the Cardo V material. For full mineral names see table 7.1

Material	Common Name	Type	Ca (mg)	Cu (mg)	F (µg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (µg)	Zn (mg)	K (mg)	Na (mg)
Cereals		**100g**											
Panicum miliaceum	Common millet	Cooked (no species listed)	3	0.161	-	0.63	44	0.272	100	0.9	0.91	62	2
Setaria italica	Foxtail millet	Dry weight, uncooked*	37	-	-	6.2	0	-	275	2.7	0	281	8
Pulses		**100g**											
Lens culinaris	Lentil	Raw	56	0.519	-	7.54	122	1.33	451	8.3	4.78	955	6
		Mature seeds, cooked, boiled, without salt	19	0.251	-	3.33	36	0.494	180	2.8	1.27	369	2
Vicia faba	Broad bean	Mature seeds, raw	103	0.824	-	6.7	192	1.626	421	8.2	3.14	1062	13
		Mature seeds, cooked, boiled, without salt	36	0.259	-	1.5	43	0.421	125	2.6	1.01	268	5
Nuts		**100g**											
Corylus avellana	Hazelnut	Unroasted	114	1.725	-	4.7	163	6.175	290	2.4	2.45	680	0
		Dry roasted, without salt added	123	1.75	-	4.38	173	5.55	310	4.1	2.5	755	0
Fruit		**100g**											
Ficus carica	Fig	Raw	35	0.07	-	0.37	17	0.128	14	0.2	0.15	232	1
		Dried, uncooked, mission variety	162	0.287	-	2.03	68	0.51	67	0.6	0.55	680	10
Malus sp.	Apple	Several varieties, raw with skin	6	0.027	3.3	0.12	5	0.035	11	0	0.04	107	1
		Dried, sulfured, stewed, without added sugar	3	0.044	-	0.33	4	0.021	9	0.3	0.05	105	20
		Dried, sulfured, uncooked	14	0.191	-	1.4	16	0.09	38	1.3	0.2	450	87
Pyrus sp.	Pear	Raw	9	0.082	2.2	0.18	7	0.048	12	0.1	0.1	116	1
		USDA commodity, canned, light syrup, drained	5	0.03	-	0.28	4	0.037	7	-	0.09	61	5
		Dried, sulfured, uncooked	34	0.371	-	2.1	33	0.327	59	0.2	0.39	533	6
Vitis vinifera	Grape	Red or green, European type, 100g	10	0.127	7.8	0.36	7	0.071	20	0.1	0.07	191	2
		Raisins, seeded	28	0.302	-	2.59	30	0.267	75	0.6	0.18	825	28
Eggs													
Gallus gallus domesticus	Chicken	Fresh, whole, raw, large, 50g	28	0.036	0.6	0.88	6	0.014	99	15.4	0.64	69	71
		Whole, cooked, hard boiled, large, 50g	25	0.007	2.4	0.6	5	0.013	86	15.4	0.52	63	62
		Whole, cooked, fried, large, 46g	29	0.036	0.6	0.87	6	0.014	99	15.2	0.64	70	95

Material	Common Name	Type	Ca (mg)	Cu (mg)	F (µg)	Fe (mg)	Mg (mg)	Mn (mg)	P (mg)	Se (µg)	Zn (mg)	K (mg)	Na (mg)
Fish		**100g**											
Anguillidae/ Congridae	Eels	Mixed species, raw	20	0.023	-	0.5	20	0.035	216	6.5	1.62	272	51
		Mixed species, cooked, dry heat	26	0.029	-	0.64	26	0.04	277	8.3	2.08	349	65
Mugilidae	Mullets (grey)	Striped mullet (*Mugil cephalus* L.), raw	117	0	3.79	19.35	29	0.016	221	36.5	0.52	357	65
		Striped mullet (*Mugil cephalus* L.), cooked, dry heat	31	0.141	-	1.41	33	0.022	244	46.8	0.88	458	71
Scomber sp.	Mackerel	Atlantic mackerel (*Scomber scombrus* L.), raw	12	0.073	-	1.63	76	0.015	217	44.1	0.63	314	90
		Salted	66	0.1	-	1.4	60		254	73.4	1.1	520	4450
Pleuronectiformes	Flatfishes	Flounder and sole species, raw	21	0.019	-	0.18	18	0.014	252	26.6	0.32	45	296
		Flounder and sole species, cooked, dry heat	25	0.023	-	0.23	22	0.017	309	32.6	0.39	197	363
Shellfish		**100g**											
Mytilus galloprovincialis	Mediterranean mussel	Blue mussel (*Mytilus edulis*), raw	26	0.094	-	3.95	34	3.4	197	44.8	1.6	320	286
		Blue mussel, cooked, moist heat	33	0.149	-	6.72	37	6.8	285	89.6	2.67	268	369
Sepia sp.	Cuttlefish	Mixed species, raw	90	0.587	-	6.02	30	0.11	387	44.8	1.73	354	372
		Mixed species, cooked, moist heat	180	0.998	-	10.84	60	0.209	580	89.6	3.46	637	744

No information was available for chromium and iodine

All data from U.S. Department of Agriculture, Agricultural Research Service. 2013. USDA National Nutrient Database for Standard Reference, Release 26. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/ba/bhnrc/ndl

* Duke and Ayensu 1985

Appendix D: Shellfish ecological data

Table D1. Gastropods from the Cardo V sewer. Table includes habitat locations and size.

Scientific name	Common name	Habitat	Average size (cm)	Edible (Y/N)	Other characteristics
Bittium reticulatum (da C.)	Needle whelk	Demersal	--	N	Live in large colonies in shallow water, collected from sublittoral zone
Bittium sp. (*tesselatum* (Mts.))	Horn snail	?	--	N	Lives in shallow waters in large colonies
Bolinus brandaris (L.)	Purple dye murex	Demersal	9	Y	Lives between 1-50m, abundant
cf. *Cerithium* sp.	Cerith	?	--	N	Genus lives in shallow waters, deposit subsurface feeders
Cerithiidae indet.	Cerith	?	--	N	Family lives mainly in large colonies in shallow waters
Columbella rustica (L.)	Rustic dove-shell	Benthic	3	N	Common, family is carnivorous, live in shallow waters
Diodora italica (Def.)	Limpet	Benthic	--	Y	Live on rocks
Fusinus pulchellus (Phil.)	Spindle snail	Benthic	3	N	From a family of carnivorous snails, lives mainly in shallow water
Gibbula albida (Gmel.)	Whitish gibbula	Benthic	2	N	Common, subtidal, lives among the rocks
Gibbula philberti (Récl.)	Top snail	Benthic	--	N	--
Gibbula sp.	Top snail	Benthic	--	Y/N (depends on the size)	--
Hexaplex trunculus (L.)	Trunculus murex	Benthic	7.5	Y	Common, lives in shallow waters
Muricidae indet.	Murex family	?	--	Y	--
Nassarius cf. *corniculum* (Olivi)	Horn nassa	Benthic	2	N	Common, intertidal
Nassarius cf. *costulatus* (Ren.)	Dog welk	Benthic	--	N	--
Nassarius cf. *costulatus* subspecies *cuvierii* (Pay.)	Dog welk	Benthic	--	N	--
Naticidae indet.	Moon shells	?	--	N	Family of carnivorous sand dwellers, can be predators or scavengers
Ocenebra erinaceus (L.)	Hedgehog murex	Demersal/ littoral	3	Y	Common
Ocinebrina aciculata (Lam.)	Sea snail	Benthic	--	N	--
Ocinebrina edwardsii (Pay.)	Sea snail	Benthic	--	N	--
Odostomia eulimoides (Han.)	Pyram	Demersal	--	N	--
Patella sp.	Limpet	Littoral zone	--	Y	Abundant, lives on rocks at the intertidal zone
Tonna galea (L.)	Giant tun	Reef associated	15	Y	Lives between 5-80m
Turritella communis (Riss.)	Auger shell	Benthic	5	N	Lives in sand at depth of 7-200m, is often collected at low tide

Torelli 1982; Abbott and Dance 1991; Poppe and Gotō 1991; Appeltans *et al.* 2012; Davidson 2012; Palomares and Pauly 2013

Table D2. Bivalva from the Cardo V sewer. Table includes habitat locations and size.

Scientific name	**Common name**	**Habitat**	**Average size (cm)**	**Edible (Y/N)**	**Other characteristics**
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	?	--	Y	--
Acanthocardia tuberculata (L.)	Rough cockle	Benthic	6	Y	Lives in fine sand at depths between 15-100m
Aequipecten opercularis (L.)	Queen scallop	Benthic	7	Y	Common, lives between 0-200m, suspension feeder
Arca noae (L.)	Noah's ark shell	Benthic	6	Y	Common, live on subtidal rocks between the low tide and depths of up to 119m
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible cockle or lagoon cockle	Benthic	5	Y	Abundant, lives in shallow water
Chamelea gallina (L.)	Striped venus	Benthic	4	Y	Common, lives on sand flats
Donacilla cornea (Poli)	Corneous wedge clam	Benthic	--	Y	--
Donax trunculus (L.)	Truncate donax	Benthic	3	Y	Common, lives in the intertidal zone on fine sandy beaches
Ensis minor (Che.)	Minor jackknife clam	Benthic	--	Y	Suspension feeder
Glycymeris sp.	Bittersweet clams	?	--	Y	Live in shallow water and on sandy bottoms, suspension feeder
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	Benthic	--	Y/N?	--
Lucinella divaricata (L.)	None	Benthic	--	N	--
Modiolula phaseolina (Phi.)	None	Benthic	--	N	--
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	Benthic	10	Y	Abundant, lives in colonies in the lower intertidal zone, up to 4m, on rocks in quiet waters
Mytilidae indet.	Mussel	?	--	Y	Family lives attached to rocks mainly in intertidal and shallow waters
Mytilaster cf. *minimus* (Poli)	Mussel	Benthic	--	Y	--
Ostrea edulis (L.)	Common/edible oyster	Benthic	8	Y	Common
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	Benthic	--	Y	Usually found at depths between 0-30m
Polititapes aureus (Gmel.)	Golden carpet shell	Benthic	4	Y	Abundant, lives in the intertidal zone
Spondylus gaederopus (L.)	European thorny oyster	Benthic	7.5	Y	Common, live in the intertidal zone to a depth of 20m
Timoclea ovata (Pen.)	Oval venus	Benthic	--	N	--
Venerupis decussata (L.)	Chequered carpet shell	?	5	Y	Common, lives in the intertidal zone

Torelli 1982; Abbott and Dance 1991; Poppe and Gotō 1991; Appeltans *et al.* 2012; Davidson 2012; Palomares and Pauly 2013

Appendix E: Research on the Forum of Pompeii Project - macrobotanical material examined by the author

The Pompeii material provided a crucial set of comparative data as, stated in section 6.3, no other sources of mineralized or sewage material has been identified and excavated in Herculaneum. Additionally, the Herculaneum Cardo V sewer is a unique deposit as it is the size of a drain but was not subject to flushing by pipe or rain water and instead served the function of a cess pit. Therefore, material from rainwater drains running beneath the Forum in ancient Pompeii was used to gain a better understanding of the taphonomy of the Herculaneum sewer. The finds have been included in section 6.3 and in tables 6.4 and B1 and B2.

The drains in the Pompeii forum were excavated by Valentin Kockel and his team at the University of Augsburg in 2008 as part of the Research on the Forum of Project (Kockel and Flecker 2008). Since 2002 the project has been documenting and undertaking small scale excavations in the southern end of the forum near the civic buildings and the basilica (Fig. E1). Three environmental samples were collected from trench 3, two from the north end and one from the southern end, representing material from two different rainwater drains (Fig. E2). A 13L litre sample was taken from the northern canal, stratigraphic unit 10 while a one litre sample was taken from stratigraphic layer 11. The southern drain was much smaller and thus only a one litre sample could be collected from it (Table E1).

The northern samples were recovered from a drain that dates from the 2nd century BC. It was originally designed to drain the portico and the old street situated above. However, between 30-20BC the south portico and the drain were destroyed in order to open up the southern end of the forum. It was during this decade that the drain filled up with material. Stratigraphic layer 10 is quite thick and probably represents this build-up of material while the very thin layer of stratigraphic unit 11 may be from material that was deposited prior to the drain's destruction. The significant quantities of pottery from these two layers date to the third quarter of the first century BC (Flecker 2012).

The southern sample was collected from a smaller angled drain that was designed to drain the roof of the newly build portico. Although there are no precise dates for its construction we know that it was constructed after the first drain was destroyed, sometime between 30/20BC-AD62.

Similarly to the Herculaneum material, all the carbonized, mineralized, shell and fish bones and scales were sorted using a binocular microscope. The fish bones and scales were given to Rebecca Nicholson for identification. All botanical identifications were done by the author and confirmed by Professor Mark Robinson. The results were then entered into a 2007 Access database identical to the one used to record the Herculaneum material (Table E2).

Table E1. List of Pompeii samples

Year	Sample	Volume (L)
2008	Fl. 1 Sch. 3 Nord Kanal 1 Stratigraphic unit 10	13
2008	Fl. 1 Sch. 3 Nord Kanal 1 Stratigraphic unit 11	1
2008	Fl. 1 Sch. 3 Süd Kanal 2	1

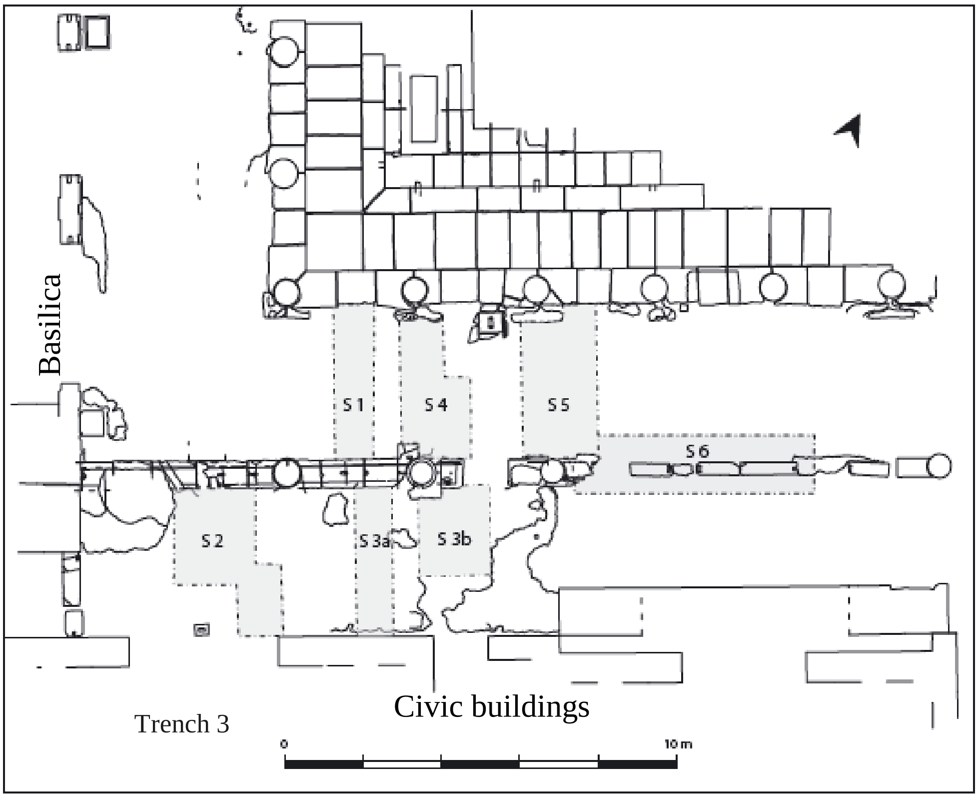


Figure E1. Pompeii forum excavations and trench location (Flecker 2012, plan by Rainer Zahn). (Permission to reproduce plan granted by M. Flecker and V. Kockel)

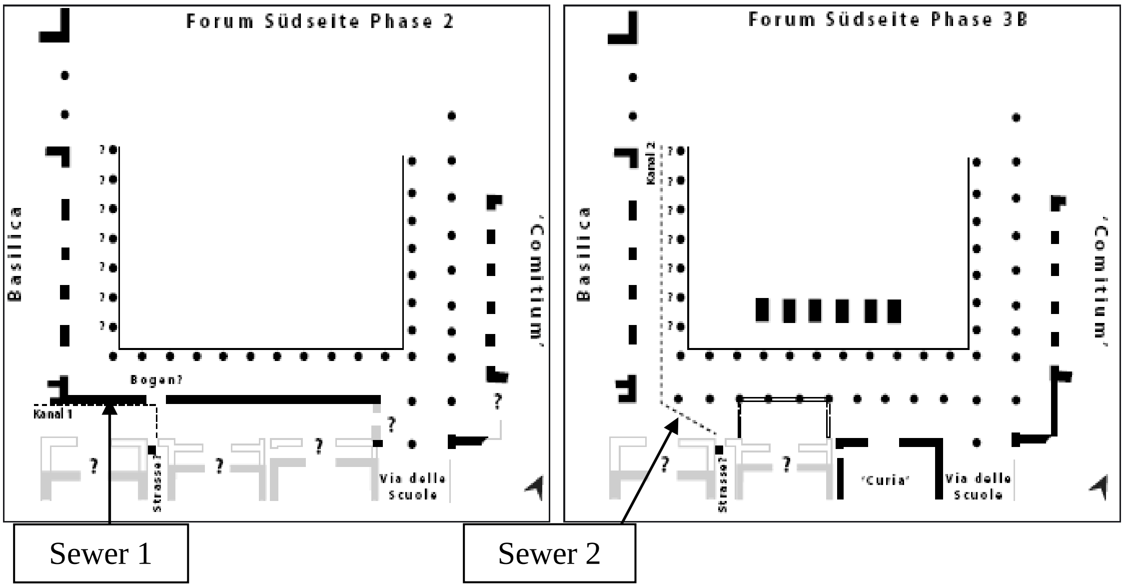


Figure E2. Phase 2 (ca. 120-30/20BC) (left) and phase 3 (right) (Flecker 2012, plan by Valentin Kockel). (Permission to reproduce plan granted by M. Flecker and V. Kockel)

Table E2. Mineralized and carbonized remains from the Pompeii forum

	COMMON NAME	COMPONENT	Kanal 1 Unit 10	Kanal 1 Unit 11	Kanal 2
MINERALIZED MATERIAL					
Foodstuffs					
Ficus carica L.	Fig	Achene	180	1	1
cf. *Foeniculum vulgare* Mill.	Fennel	Mericarp	1	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	2	2	-
Morus sp.	Mulberry	Endocarp	1	-	-
Panicum miliaceum L.	Common millet	Caryopsis	1	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	1	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	1	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	2	1	-
Vitis vinifera L.	Grape	Pip	3	1	-
Weeds, ruderals and other taxa					
Amaranthaceae	Amaranth family		7	-	-
Anthemis arvensis L.	Corn chamomile		-	1	-
Apiaceae	Parsley family		2	-	-
Boraginaceae	Borage family		1	-	-
Brassicaceae	Cabbage family		1	-	-
Carex sp.	Sedge		-	1	-
Carex sp. or *Rumex* sp.	Sedge or dock		1	-	-
Caryophyllaceae	Carnation family		2	-	-
cf. *Chenopodium* sp.	Goosefoot		-	1	-
Chenopodium sp.	Goosefoot		2	2	-
Crepis sp.	Hawksbeard		1	-	-
Euphorbia sp.	Spurge		2	-	-
Fumaria sp.	Fumitory		2	-	-
Lamiaceae	Mint family		1	-	-
Malva sp.	Mallow		2	-	-
cf. *Medicago* sp.	Medick		3	1	-
Ornithopus sp.	Bird's foot		-	1	-
cf. *Papaver* sp.	Poppy		-	1	-
Poaceae	True grasses		1	-	-
Polygonaceae	Knotweed family		-	1	-
Pteridium aquilinum (L.) Kuhn	Bracken		-	1	-

	COMMON NAME	COMPONENT	Kanal 1 Unit 10	Kanal 1 Unit 11	Kanal 2
Silene gallica L.	Small-flowered catchfly		2	-	-
Urtica sp.	Nettle		5	-	-
Unidentified seeds/non-seed items					
Animal coprolite			1	-	-
Thread/string			-	1	-
Unidentified seed			15	18	-
CARBONIZED MATERIAL					
Foodstuffs					
Corylus avellana L.	Hazelnut	Shell fragment	2	-	-
Ficus carica L.	Fig	Achene	100	3	-
Ficus carica L.	Fig	Flesh	10	-	-
Hordeum sp.	Barley	Caryopsis	1	1	-
Hordeum sp.	Barley	Rachis node	1	-	-
Hordeum vulgare L.	Barley	Caryopsis	2	-	-
Hordeum vulgare L.	Barley	Rachis fragment	1	-	-
Juglans regia L.	Walnut	Shell fragment	3	1	-
Olea europaea L.	Olive	Endocarp	6	1	1
Olea europaea L.	Olive	Endocarp with flesh	-	1	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	4	-	-
Pinus pinea L.	Stone pine	Seed	1	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	1	-	-
Triticum sp.	Wheat	Caryopsis	1	-	-
Vitis vinifera L.	Grape	Pip	2	4	-
Weeds, ruderals and other taxa					
cf. *Avena* sp.	Oat		1	-	-
Euphorbia sp.	Spurge		1	-	-
Fabaceae	Legume family		4	-	-
Medicago sp.	Medick		1	-	-
Ornithopus sp.	Bird's foot		3	-	-
Poaceae	True grasses		2	-	-
Polygonum aviculare (agg) L.	Knotgrass		1	-	-
Pooideae	True grasses		-	1	-

	COMMON NAME	COMPONENT	Kanal 1 Unit 10	Kanal 1 Unit 11	Kanal 2
Sherardia arvensis L.	Field madder		1	-	-
Silene gallica L.	Small-flowered catchfly		3	-	-
Unidentified seeds/non-seed items					
Unidentified seed			7	5	-

Appendix F: Raw data for the botanical, otolith, shellfish and eggshell finds

BOTANICAL MATERIAL

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
MINERALIZED REMAINS						
Cereals						
Panicum miliaceum L.	Common millet	Caryopsis	9	1	-	8
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	5	16	4	8
Setaria italica Beauv.	Foxtail millet	Caryopsis	3	-	1	-
cf. *Setaria italica* Beauv.	cf. Foxtail millet	Caryopsis	-	-	-	-
cf. *Sorghum* sp.	Sorghum	Caryopsis	-	-	-	-
Triticum cf. *dicoccum* Schübl.	Emmer wheat	Caryopsis	-	-	-	1
Cereal grain	Cereal	Caryopsis	-	-	-	1
Pulses						
Lens culinaris Medik.	Lentil	Seed	6	-	-	-
cf. *Lens culinaris* Medik.	cf. Lentil	Seed	-	-	-	2
Vicia faba var. *minuta* L.	Broad bean	Seed	1	1	-	-
cf. *Vicia faba* var. *minuta* L.	cf. Broad bean	Seed	-	1	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-	-
Vicia sp.	Vetch	Hilum	-	-	-	-
Nuts						
Corylus avellana L.	Hazelnut	Shell fragment	1	-	-	-
cf. *Pinus pinea* L.	Stone pine	Husk	-	-	-	-
Fruit						
cf. *Celtis australis* L.	Mediterranean hackberry	Berry	1	-	-	-
Cucumis melo L. or *sativus* L.	Melon or cucumber	Seed	4	-	-	-
Ficus carica L.	Fig	Achene	-	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	5	1	-	1
Malus sp.	Apple	Seed	-	-	-	-
Morus nigra L.	Black mulberry	Endocarp	-	-	-	-
cf. *Morus nigra* L.	cf. Black mulberry	Endocarp	-	-	-	-

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
Olea europaea L.	Olive	Seed	1	-	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-	-	-
Prunus avium or *cersus* L.	Wild or sour cherry	Stone	-	-	-	-
Prunus domestica L.	Plum	Stone	-	-	-	-
Prunus cf. *domestica* L.	Plum	Stone	-	-	-	-
Prunus sp.	Stone fruit	Stone	-	1	-	-
cf. *Prunus* sp.	cf. Stone fruit	Stone	-	-	-	3
Rubus fruticosus (agg)	Blackberry	Endocarp	1	-	-	-
cf. *Rubus fruticosus* (agg)	cf. Blackberry	Endocarp	-	-	-	-
Vitis vinifera L.	Grape	Pip	4	3	11	-
Vitis vinifera L.	Grape	Stalk	-	-	-	-
Vitis vinifera or berry	Whole grape or berry	Pip/berry	-	-	-	-
Herbs and seasonings						
cf. *Anethum graveolens* L.	Dill	Mericarp	2	-	-	1
Apium graveolens (Mills.) Pers.	Celery	Mericarp	1	4	-	-
cf. *Apium graveolens* (Mills.) Pers.	cf. Celery	Mericarp	3	-	1	8
Brassica sp.	Cabbage or mustard	Seed	5	8	-	4
cf. *Brassica* sp.	cf. Cabbage or mustard	Seed	-	-	-	-
Coriandrum sativum L.	Coriander	Mericarp	1	-	-	-
cf. *Coriandrum sativum* L.	cf. Coriander	Mericarp	-	-	-	-
Foeniculum vulgare Mill.	Fennel	Mericarp	-	-	-	-
cf. *Foeniculum vulgare* Mill.	cf. Fennel	Mericarp	4	3	-	2
Linum usitatissimum L.	Flax/linseed	Seed	-	-	-	1
cf. *Linum usitatissimum* L.	cf. Flax/linseed	Seed	-	-	-	-
Mentha sp.	Mint	Mericarp	-	1	-	3
cf. *Mentha* sp.	cf. Mint	Mericarp	-	-	-	-
Papaver somniferum L.	Opium poppy	Seed	1	5	3	1
Piper nigrum L.	Black pepper	Berry	-	-	-	-
Other potential foodstuffs						
Ceratonia siliqua L.	Carob	Seed	-	-	-	-
Malva sp.	Mallow	Seed	-	-	-	2
cf. *Malva* sp.	cf. Mallow	Seed	4	-	-	-
Medicago sp.	Medick	Seed	1	-	-	-
cf. *Medicago* sp.	cf. Medick	Seed	-	-	-	5

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
Ornamental plants						
Buxus sp.	Box	Stem	-	-	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	2	-	-	-
Weeds, ruderals and other taxa						
Amaranthaceae	Amaranth family		-	-	-	1
cf. Amaranthaceae	cf. Amaranth family		-	-	-	-
Anagallis sp.	Pimpernel		-	-	-	-
cf. *Anagallis* sp.	cf. Pimpernel		-	-	1	-
Anthemis arvensis L.	Corn chamomile		2	1	-	-
cf. *Anthemis arvensis* L.	cf. Corn chamomile		1	-	-	-
Aphanes sp.	Parsley-piert		-	-	-	-
Apiaceae	Parsley family		58	2	-	11
Asteraceae	Daisy family		-	-	-	-
cf. Asteraceae	cf. Daisy family		-	-	-	-
Boraginaceae	Borage family		1	-	-	-
Brassicaceae	Cabbage family		1	-	-	-
Carduus sp.	Thistle		-	-	-	-
Carex sp.	Sedge		1	1	1	1
cf. *Carex* sp.	cf. Sedge		-	-	-	-
Carex sp. or *Rumex* sp.	Sedge or dock		-	-	-	-
Caryophyllaceae	Carnation family		2	-	-	1
cf. Caryophyllaceae	cf. Carnation family		-	2	9	6
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot		-	-	-	-
cf. *Centaurea* sp.	Knapweed		-	-	-	-
Chara sp.	Green algae		-	-	-	-
Chenopodium album L.	Fat-hen		-	-	-	-
Chenopodium sp.	Goosefoot		-	2	1	-
cf. *Chenopodium* sp.	cf. Goosefoot		-	3	-	-
Cyperaceae	Sedge family		-	-	-	-
cf. Cyperaceae	cf. Sedge family		-	-	-	-
Cyperaceae or Polygonaceae	Sedge or knotweed		4	-	-	-
Fabaceae	Legume family		1	-	-	-
Lamiaceae	Mint family		-	3	1	1
cf. Lamiaceae	cf. Mint family		-	-	-	-
Linum sp. (not *usitatissimum*)	Flax		-	-	-	1

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
cf. *Linum* sp. (not *usitatissimum*)	cf. Flax		-	-	-	1
Lithospermum arvense L.	Field gromwell		-	-	-	-
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot		-	-	-	-
Ornithopus sp.	Bird's foot		4	-	-	-
cf. *Ornithopus* sp.	cf. Bird's foot		-	-	-	-
Ornithopus sp. or *Medicago* sp.	Bird’s foot or medick		-	-	-	-
Papaver sp.	Poppy		-	-	2	1
cf. *Papaver* sp.	cf. Poppy		-	-	-	-
Papaveraceae	Poppy family		-	-	-	-
cf. *Plantago* sp.	Plantain		-	-	-	-
Poaceae	True grasses		1	1	-	1
cf. Poaceae	cf. True grasses		-	-	-	-
Polygonaceae	Knotweed family		-	-	-	-
Polygonum aviculare (agg) L.	Knotgrass		10	3	-	-
cf. *Polygonum aviculare* (agg) L.	cf. Knotgrass		-	-	-	-
Polygonum sp.	Knotweed		2	-	2	15
cf. *Polygonum* sp.	cf. Knotweed		-	-	-	-
Pteridium aquilinum (L.) Kuhn	Bracken		2	-	-	-
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup		2	-	-	-
Ranunculus sp.	Buttercup		-	4	-	1
cf. *Ranunculus* sp.	cf. Buttercup		-	-	-	-
Ranunculus subgens. *Ranunculus*	Buttercup		-	-	-	-
Reseda sp.	Mignonette		-	-	-	1
cf. *Rubus* sp.	Bramble		-	-	-	-
Rumex acetosella (agg) L.	Sheep's sorrel		-	-	-	-
Rumex cf. *acetosella* (agg) L.	Sheep's sorrel		-	-	-	-
Rumex sp.	Dock		1	2	-	-
cf. *Rumex* sp.	cf. Dock		-	-	-	-
Sambucus sp.	Elder		-	-	-	-
Scrophulariaceae	Figwort family		-	-	-	-
Sherardia arvensis L.	Field madder		9	4	-	-
Silene gallica L.	Small-flowered catchfly		1	-	2	2
Silene sp.	Campion		1	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	1	-	-
cf. S*tellaria media* (L.) Vill.	cf. Common chickweed		-	-	-	-
Stellaria sp.	Chickweed		1	-	-	-

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
Urtica dioica L.	Common stinging nettle		-	9	3	1
Urtica sp.	Nettle		6	8	5	1
Viola sp. (subgen.) *Melanium*	Pansy		-	-	-	-
Indeterminate/unidentified seeds						
Anther			-	-	1	-
Berry			1	-	-	-
Cess pit mystery object			-	-	-	-
Possible fern fragment			1	-	-	-
Shoots			-	-	-	-
Unidentified seeds			85	19	15	49
Other (non-seed) items						
Animal dung			-	-	-	-
Cess pit mystery item			-	-	-	-
Leaf			-	-	-	-
Marine plant			-	-	-	-
CARBONIZED MATERIAL						
Cereals						
Hordeum sp.	Barley	Caryopsis	1	-	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	1	-	-	-
Triticum aestivum L.	Bread wheat	Rachis node	-	-	-	-
Triticum dicoccum Schübl.	Emmer wheat	Caryopsis	-	-	-	-
T. dicoccum Schübl. or *T. monococcum* L.	Emmer or einkorn wheat	Caryopsis	-	-	-	-
Triticum monococcum L.	Einkorn wheat	Caryopsis	-	-	-	-
Triticum sp.	Wheat	Caryopsis	-	-	-	-
Cereal grain	Cereal	Caryopsis	-	-	-	3
Pulses						
Lens culinaris Medik.	Lentil	Seed	1	-	-	1
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	2	-	1	-
Nuts						
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-	-

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
Juglans regia L.	Walnut	Shell fragment	1	-	-	-
Pinus pinea L.	Stone pine	Seed	-	-	-	-
Pinus pinea L.	Stone pine	Nut	-	-	1	-
Pinus pinea L.	Stone pine	Bract	-	-	1	1
Fruit						
Ficus carica L.	Fig	Achene	1	-	-	-
Ficus carica L.	Fig	Flesh	-	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-	-
Olea europaea L.	Olive	Endocarp (MNI)	143	21	11	272
Olea europaea L.	Olive	Endocarp (frag.)	1703	253	81	2068
Phoenix dactylifera L.	Date	Endocarp	1	-	-	-
Pyrus sp.	Pear	Seed	1	-	-	-
Vitis vinifera L.	Grape	Pip	8	8	-	7
Vitis vinifera L.	Grape	Stalk	-	-	-	2
Other potential foodstuffs						
Vicia ervilia (L.) Willd.	Bitter vetch	Seed	-	-	-	-
Weeds, ruderals and other taxa						
Apiaceae	Parsley family		-	-	-	-
cf. *Avena* sp.	Oat		-	-	-	-
Chenopodium sp.	Goosefoot		-	-	-	1
Ornithopus sp.	Bird’s foot		-	-	-	1
Poaceae	True grasses	Caryopsis	-	1	-	1
Poaceae	True grasses	Rachis fragment	-	-	-	-
cf. Poaceae	cf. True grasses	Caryopsis	-	-	-	-
Rumex sp.	Dock		-	-	-	1
Stellaria media (L.) Vill.	Common chickweed		-	1	-	-
Ornamental plants			-	-	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-	-	1
Indeterminate/unidentified seeds						
Unidentified seeds			-	-	1	16
Fungal fruiting body			-	-	-	-

QUADRANT 3-4	COMMON NAME	COMPONENT	US38	US39	US40	US41
Other (non-seed) plant items						
Bread fragments			-	-	-	-
Buds			-	-	-	3
Weed seed			-	-	-	1
WATERLOGGED REMAINS						
Fruits						
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-	-
Rubus fruticosus (agg)	Blackberry	Thorn	-	-	-	-
Vitis vinifera L.	Grape	Pip	-	-	-	-
Herbs and seasonings						
Apium graveolens (Mill.) Pers.	Celery	Mericarp	-	-	-	-
Weeds, ruderals and other taxa						
Apiaceae	Parsley family		-	-	-	-
Daucus carota L.	Wild carrot		-	-	-	-
Fumaria sp.	Fumitory		-	-	-	-
Lamiaceae	Mint family		-	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-	-
Indeterminate/unidentified seeds						
Unidentified seeds			-	-	-	-
Other (non-seed) plant items						
Bud			-	-	-	-
Bark			-	-	-	-
Root fragments			-	-	-	-
Stalks			-	-	-	-

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
MINERALIZED REMAINS							
Cereals							
Panicum miliaceum L.	Common millet	Caryopsis	-	-	-	20	4
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	2	-	18	95	36
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-	2	5	-
cf. *Setaria italica* Beauv.	cf. Foxtail millet	Caryopsis	-	-	-	-	-
cf. *Sorghum* sp.	Sorghum	Caryopsis	-	-	-	-	7
Triticum cf. *dicoccum* Schübl.	Emmer wheat	Caryopsis	-	-	-	-	-
Cereal grain	Cereal	Caryopsis	-	-	-	-	-
Pulses							
Lens culinaris Medik.	Lentil	Seed	-	-	-	1	1
cf. *Lens culinaris* Medik.	cf. Lentil	Seed	-	-	1	-	4
Vicia faba var. *minuta* L.	Broad bean	Seed	-	-	-	-	-
cf. *Vicia faba* var. *minuta* L.	cf. Broad bean	Seed	-	-	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-	-	1
Vicia sp.	Vetch	Hilum	-	-	-	-	-
Nuts							
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-	-	-
cf. *Pinus pinea* L.	Stone pine	Husk	1	-	-	-	-
Fruit							
cf. *Celtis australis* L.	Mediterranean hackberry	Berry	-	-	-	-	-
Cucumis melo L. or *sativus* L.	Melon or cucumber	Seed	-	-	-	-	-
Ficus carica L.	Fig	Achene	-	-	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	1	-	8	6
Malus sp.	Apple	Seed	-	1	-	-	-
Morus nigra L.	Black mulberry	Endocarp	-	1	-	2	3
cf. *Morus nigra* L.	cf. Black mulberry	Endocarp	-	-	-	-	1
Olea europaea L.	Olive	Seed	-	1	-	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-	-	-	1
Prunus avium or *cersus* L.	Wild or sour cherry	Stone	-	-	-	-	3
Prunus domestica L.	Plum	Stone	-	-	-	1	1
Prunus cf. *domestica* L.	Plum	Stone	-	-	-	-	2
Prunus sp.	Stone fruit	Stone	-	-	-	-	1

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
cf. *Prunus* sp.	cf. Stone fruit	Stone	-	1	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-	-	-
cf. *Rubus fruticosus* (agg)	cf. Blackberry	Endocarp	-	-	-	11	-
Vitis vinifera L.	Grape	Pip	1	7	8	7	49
Vitis vinifera L.	Grape	Stalk	-	-	-	-	-
Vitis vinifera or berry	Whole grape or berry	Pip/berry	-	1	-	-	-
Herbs and seasonings							
cf. *Anethum graveolens* L.	Dill	Mericarp	1	-	-	-	-
Apium graveolens (Mills.) Pers.	Celery	Mericarp	-	-	-	-	5
cf. *Apium graveolens* (Mills.) Pers.	cf. Celery	Mericarp	-	-	8	12	1
Brassica sp.	Cabbage or mustard	Seed	-	-	-	-	16
cf. *Brassica* sp.	cf. Cabbage or mustard	Seed	-	-	-	-	-
Coriandrum sativum L.	Coriander	Mericarp	-	-	-	-	1
cf. *Coriandrum sativum* L.	cf. Coriander	Mericarp	-	-	-	-	-
Foeniculum vulgare Mill.	Fennel	Mericarp	-	-	-	-	6
cf. *Foeniculum vulgare* Mill.	cf. Fennel	Mericarp	-	-	-	2	2
Linum usitatissimum L.	Flax/linseed	Seed	-	-	-	-	-
cf. *Linum usitatissimum* L.	cf. Flax/linseed	Seed	-	-	-	2	-
Mentha sp.	Mint	Mericarp	-	-	1	-	-
cf. *Mentha* sp.	cf. Mint	Mericarp	-	-	-	-	-
Papaver somniferum L.	Opium poppy	Seed	14	1	11	4	12
Piper nigrum L.	Black pepper	Berry	-	-	-	-	1
Other potential foodstuffs							
Ceratonia siliqua L.	Carob	Seed	-	-	-	-	-
Malva sp.	Mallow	Seed	-	-	5	7	-
cf. *Malva* sp.	cf. Mallow	Seed	-	-	-	-	-
Medicago sp.	Medick	Seed	-	-	-	-	-
cf. *Medicago* sp.	cf. Medick	Seed	-	1	-	2	-
			-	-	-	-	-
Ornamental plants			-	-	-	-	-
Buxus sp.	Box	Stem	-	-	-	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	1	2	-	-

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
Weeds, ruderals and other taxa							
Amaranthaceae	Amaranth family		-	-	-	-	-
cf. Amaranthaceae	cf. Amaranth family		6	-	3	5	-
Anagallis sp.	Pimpernel		-	-	-	-	-
cf. *Anagallis* sp.	cf. Pimpernel		-	-	-	-	-
Anthemis arvensis L.	Corn chamomile		-	-	-	4	1
cf. *Anthemis arvensis* L.	cf. Corn chamomile		-	-	-	-	-
Aphanes sp.	Parsley-piert		-	-	-	-	-
Apiaceae	Parsley family		1	-	14	20	15
Asteraceae	Daisy family		-	-	-	-	-
cf. Asteraceae	cf. Daisy family		-	-	-	-	-
Boraginaceae	Borage family		-	-	-	1	-
Brassicaceae	Cabbage family		-	-	-	-	-
Carduus sp.	Thistle		2	-	-	-	-
Carex sp.	Sedge		-	1	1	6	-
cf. *Carex* sp.	cf. Sedge		-	-	-	-	-
Carex sp. or *Rumex* sp.	Sedge or dock		-	2	-	-	-
Caryophyllaceae	Carnation family		3	-	1	-	2
cf. Caryophyllaceae	cf. Carnation family		-	1	9	15	8
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot		-	-	-	-	-
cf. *Centaurea* sp.	Knapweed		-	-	1	-	-
Chara sp.	Green algae		-	-	-	-	-
Chenopodium album L.	Fat-hen		-	-	4	-	-
Chenopodium sp.	Goosefoot		1	4	-	-	5
cf. *Chenopodium* sp.	cf. Goosefoot		-	-	-	-	-
Cyperaceae	Sedge family		-	-	-	-	-
cf. Cyperaceae	cf. Sedge family		-	-	-	1	-
Cyperaceae or Polygonaceae	Sedge or knotweed		-	-	-	-	-
Fabaceae	Legume family		-	-	-	-	-
Lamiaceae	Mint family		-	4	-	17	2
cf. Lamiaceae	cf. Mint family		-	-	4	-	-
Linum sp. (not *usitatissimum*)	Flax		-	-	-	-	-
cf. *Linum* sp. (not *usitatissimum*)	cf. Flax		-	-	-	-	-
Lithospermum arvense L.	Field gromwell		-	-	-	-	1
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot		-	-	-	-	-
Ornithopus sp.	Bird's foot		-	-	-	-	1

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
cf. *Ornithopus* sp.	cf. Bird's foot		-	-	1	-	-
Ornithopus sp. or *Medicago* sp.	Bird’s foot or medick		-	-	-	-	1
Papaver sp.	Poppy		-	-	-	10	2
cf. *Papaver* sp.	cf. Poppy		-	-	-	-	-
Papaveraceae	Poppy family		-	-	-	-	-
cf. *Plantago* sp.	Plantain		-	-	-	-	-
Poaceae	True grasses		1	-	-	-	1
cf. Poaceae	cf. True grasses		-	-	-	-	-
Polygonaceae	Knotweed family		1	-	34	-	-
Polygonum aviculare (agg) L.	Knotgrass		-	-	-	-	-
cf. *Polygonum aviculare* (agg) L.	cf. Knotgrass		-	-	-	-	1
Polygonum sp.	Knotweed		-	-	-	-	-
cf. *Polygonum* sp.	cf. Knotweed		-	-	-	-	-
Pteridium aquilinum (L.) Kuhn	Bracken		-	-	-	-	-
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup		-	-	-	-	-
Ranunculus sp.	Buttercup		-	-	8	-	-
cf. *Ranunculus* sp.	cf. Buttercup		-	-	-	-	1
Ranunculus subgens. *Ranunculus*	Buttercup		3	-	1	-	-
Reseda sp.	Mignonette		6	-	10	10	-
cf. *Rubus* sp.	Bramble		-	-	-	-	2
Rumex acetosella (agg) L.	Sheep's sorrel		-	-	1	-	-
Rumex cf. *acetosella* (agg) L.	Sheep's sorrel		-	-	-	-	-
Rumex sp.	Dock		-	-	-	-	1
cf. *Rumex* sp.	cf. Dock		-	-	-	-	-
Sambucus sp.	Elder		-	-	-	-	1
Scrophulariaceae	Figwort family		-	-	-	1	-
Sherardia arvensis L.	Field madder		-	-	-	-	-
Silene gallica L.	Small-flowered catchfly		1	-	-	-	1
Silene sp.	Campion		-	-	1	-	-
Stellaria media (L.) Vill.	Common chickweed		2	1	1	3	4
cf. S*tellaria media* (L.) Vill.	cf. Common chickweed		-	-	1	-	-
Stellaria sp.	Chickweed		-	1	-	-	-
Urtica dioica L.	Common stinging nettle		7	1	3	20	2
Urtica sp.	Nettle		-	13	4	3	1
Viola sp. (subgen.) *Melanium*	Pansy		-	-	-	-	-

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
Indeterminate/unidentified seeds							
Anther			1	-	1	5	2
Berry			-	-	-	-	-
Cess pit mystery object			-	-	-	1	-
Possible fern fragment			-	-	-	-	-
Shoots			-	-	-	-	-
Unidentified seeds			9	12	40	20	52
Other (non-seed) items							
Animal dung			-	-	-	1	-
Cess pit mystery item			-	-	-	1	-
Leaf			-	-	-	1	-
Marine plant			-	-	6	-	-
CARBONIZED MATERIAL							
Cereals							
Hordeum sp.	Barley	Caryopsis	-	-	1	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-	-	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-	-	-	-
Triticum aestivum L.	Bread wheat	Rachis node	-	-	-	-	-
Triticum dicoccum Schübl.	Emmer wheat	Caryopsis	-	-	-	-	-
T. dicoccum Schübl. or *T. monococcum* L.	Emmer or einkorn wheat	Caryopsis	-	-	-	-	-
Triticum monococcum L.	Einkorn wheat	Caryopsis	-	-	-	-	-
Triticum sp.	Wheat	Caryopsis	-	-	-	-	1
Cereal grain	Cereal	Caryopsis	-	-	-	-	-
Pulses							
Lens culinaris Medik.	Lentil	Seed	-	-	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-	-	-
Nuts							
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-	-	-
Juglans regia L.	Walnut	Shell fragment	-	-	3	-	-
Pinus pinea L.	Stone pine	Seed	-	-	1	-	-
Pinus pinea L.	Stone pine	Nut	-	-	-	1	-
Pinus pinea L.	Stone pine	Bract	-	-	-	1	-

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
Fruit							
Ficus carica L.	Fig	Achene	-	-	-	5	-
Ficus carica L.	Fig	Flesh	-	6	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-	1	-
Olea europaea L.	Olive	Endocarp (MNI)	31	3	19	54	15
Olea europaea L.	Olive	Endocarp (frag.)	424	49	141	783	137
Phoenix dactylifera L.	Date	Endocarp	-	-	-	-	-
Pyrus sp.	Pear	Seed	-	-	-	-	-
Vitis vinifera L.	Grape	Pip	3	-	2	9	1
Vitis vinifera L.	Grape	Stalk	-	-	-	4	-
Other potential foodstuffs							
Vicia ervilia (L.) Willd.	Bitter vetch	Seed	-	-	-	-	1
Weeds, ruderals and other taxa							
Apiaceae	Parsley family		-	-	-	-	-
cf. *Avena* sp.	Oat		-	-	1	-	-
Chenopodium sp.	Goosefoot		-	-	-	-	-
Ornithopus sp.	Bird's foot		-	-	-	-	-
Poaceae	True grasses	Caryopsis	-	-	-	-	-
Poaceae	True grasses	Rachis fragment	1	-	-	3	-
cf. Poaceae	cf. True grasses	Caryopsis	-	-	-	1	-
Rumex sp.	Dock		-	-	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-	-	-
Ornamental plants							
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	1	-	-	1	1
Indeterminate/unidentified seeds							
Unidentified seeds			-	-	-	1	-
Fungal fruiting body			-	-	-	-	-
Other (non-seed) plant items							
Bread fragments			1	-	-	-	2
Buds			-	-	-	-	-
Weed seed			-	-	-	-	-

QUADRANT 5-6	COMMON NAME	COMPONENT	US38	US39	US40	US42	US43
WATERLOGGED REMAINS							
Fruits							
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-	-	3
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-	-	-
Rubus fruticosus (agg)	Blackberry	Thorn	1	-	-	-	-
Vitis vinifera L.	Grape	Pip	-	-	-	-	-
Herbs and seasonings							
Apium graveolens (Mill.) Pers.	Celery	Mericarp	-	-	-	-	-
Weeds, ruderals and other taxa							
Apiaceae	Parsley family		-	-	-	-	-
Daucus carota L.	Wild carrot		-	-	-	-	-
Fumaria sp.	Fumitory		-	-	-	-	-
Lamiaceae	Mint family		-	-	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-	-	-
Indeterminate/unidentified seeds							
Unidentified seeds			-	-	-	-	-
Other (non-seed) plant items							
Bud			-	-	-	-	-
Bark			-	-	-	-	-
Root fragments			-	-	-	-	-
Stalks			-	-	-	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
MINERALIZED REMAINS					
Cereals					
Panicum miliaceum L.	Common millet	Caryopsis	8	2	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	8	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	4	-	-
cf. *Setaria italica* Beauv.	cf. Foxtail millet	Caryopsis	-	-	-
cf. *Sorghum* sp.	Sorghum	Caryopsis	-	-	-
Triticum cf. *dicoccum* Schübl.	Emmer wheat	Caryopsis	-	-	-
Cereal grain	Cereal	Caryopsis	2	-	-
Pulses					
Lens culinaris Medik.	Lentil	Seed	-	-	-
cf. *Lens culinaris* Medik.	cf. Lentil	Seed	1	-	-
Vicia faba var. *minuta* L.	Broad bean	Seed	-	-	-
cf. *Vicia faba* var. *minuta* L.	cf. Broad bean	Seed	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-
Vicia sp.	Vetch	Hilum	-	-	1
Nuts					
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-
cf. *Pinus pinea* L.	Stone pine	Husk	-	-	-
Fruit					
cf. *Celtis australis* L.	Mediterranean hackberry	Berry	-	-	-
Cucumis melo L. or *sativus* L.	Melon or cucumber	Seed	-	-	-
Ficus carica L.	Fig	Achene	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	2	-	-
Malus sp.	Apple	Seed	-	-	-
Morus nigra L.	Black mulberry	Endocarp	-	-	-
cf. *Morus nigra* L.	cf. Black mulberry	Endocarp	-	-	-
Olea europaea L.	Olive	Seed	-	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-	-
Prunus avium or *cersus* L.	Wild or sour cherry	Stone	-	-	-
Prunus domestica L.	Plum	Stone	-	-	-
Prunus cf. *domestica* L.	Plum	Stone	-	-	-
Prunus sp.	Stone fruit	Stone	-	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
cf. *Prunus* sp.	cf. Stone fruit	Stone	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-
cf. *Rubus fruticosus* (agg)	cf. Blackberry	Endocarp	-	-	-
Vitis vinifera L.	Grape	Pip	1	9	1
Vitis vinifera L.	Grape	Stalk	-	-	-
Vitis vinifera or berry	Whole grape or berry	Pip/berry	-	-	-
Herbs and seasonings					
cf. *Anethum graveolens* L.	Dill	Mericarp	1	-	-
Apium graveolens (Mills.) Pers.	Celery	Mericarp	-	-	-
cf. *Apium graveolens* (Mills.) Pers.	cf. Celery	Mericarp	-	-	-
Brassica sp.	Cabbage or mustard	Seed	-	-	-
cf. *Brassica* sp.	cf. Cabbage or mustard	Seed	4	-	-
Coriandrum sativum L.	Coriander	Mericarp	-	-	-
cf. *Coriandrum sativum* L.	cf. Coriander	Mericarp	-	-	-
Foeniculum vulgare Mill.	Fennel	Mericarp	-	-	-
cf. *Foeniculum vulgare* Mill.	cf. Fennel	Mericarp	1	-	-
Linum usitatissimum L.	Flax/linseed	Seed	-	-	-
cf. *Linum usitatissimum* L.	cf. Flax/linseed	Seed	-	1	-
Mentha sp.	Mint	Mericarp	1	-	1
cf. *Mentha* sp.	cf. Mint	Mericarp	-	-	-
Papaver somniferum L.	Opium poppy	Seed	1	1	1
Piper nigrum L.	Black pepper	Berry	-	-	-
Other potential foodstuffs					
Ceratonia siliqua L.	Carob	Seed	-	-	1
Malva sp.	Mallow	Seed	1	-	-
cf. *Malva* sp.	cf. Mallow	Seed	-	-	-
Medicago sp.	Medick	Seed	-	-	-
cf. *Medicago* sp.	cf. Medick	Seed	-	-	-
Ornamental plants					
Buxus sp.	Box	Stem	1	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	2	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
Weeds, ruderals and other taxa					
Amaranthaceae	Amaranth family		-	-	-
cf. Amaranthaceae	cf. Amaranth family		3	-	-
Anagallis sp.	Pimpernel		-	-	-
cf. *Anagallis* sp.	cf. Pimpernel		-	-	-
Anthemis arvensis L.	Corn chamomile		-	-	2
cf. *Anthemis arvensis* L.	cf. Corn chamomile		-	-	-
Aphanes sp.	Parsley-piert		-	-	-
Apiaceae	Parsley family		4	2	1
Asteraceae	Daisy family		-	-	-
cf. Asteraceae	cf. Daisy family		-	-	-
Boraginaceae	Borage family		-	-	-
Brassicaceae	Cabbage family		-	1	-
Carduus sp.	Thistle		-	-	-
Carex sp.	Sedge		-	-	-
cf. *Carex* sp.	cf. Sedge		-	-	-
Carex sp. or *Rumex* sp.	Sedge or dock		-	-	-
Caryophyllaceae	Carnation family		1	-	5
cf. Caryophyllaceae	cf. Carnation family		-	3	-
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot		-	-	-
cf. *Centaurea* sp.	Knapweed		-	-	-
Chara sp.	Green algae		-	-	-
Chenopodium album L.	Fat-hen		-	-	-
Chenopodium sp.	Goosefoot		1	10	3
cf. *Chenopodium* sp.	cf. Goosefoot		-	-	4
Cyperaceae	Sedge family		-	-	-
cf. Cyperaceae	cf. Sedge family		-	-	-
Cyperaceae or Polygonaceae	Sedge or knotweed		-	-	-
Fabaceae	Legume family		1	-	-
Lamiaceae	Mint family		-	-	1
cf. Lamiaceae	cf. Mint family		-	-	-
Linum sp. (not *usitatissimum*)	Flax		-	-	-
cf. *Linum* sp. (not *usitatissimum*)	cf. Flax		-	-	-
Lithospermum arvense L.	Field gromwell		-	-	-
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot		-	-	-
Ornithopus sp.	Bird's foot		-	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
cf. *Ornithopus* sp.	cf. Bird's foot		-	-	-
Ornithopus sp. or *Medicago* sp.	Bird's foot or medick		-	-	-
Papaver sp.	Poppy		-	-	1
cf. *Papaver* sp.	cf. Poppy		-	1	-
Papaveraceae	Poppy family		-	-	-
cf. *Plantago* sp.	Plantain		-	-	-
Poaceae	True grasses		1	1	-
cf. Poaceae	cf. True grasses		-	-	-
Polygonaceae	Knotweed family		-	-	-
Polygonum aviculare (agg) L.	Knotgrass		-	-	-
cf. *Polygonum aviculare* (agg) L.	cf. Knotgrass		-	-	-
Polygonum sp.	Knotweed		4	-	-
cf. *Polygonum* sp.	cf. Knotweed		-	1	-
Pteridium aquilinum (L.) Kuhn	Bracken		1	-	-
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup		-	-	-
Ranunculus sp.	Buttercup		-	-	-
cf. *Ranunculus* sp.	cf. Buttercup		-	-	-
Ranunculus subgens. *Ranunculus*	Buttercup		-	-	-
Reseda sp.	Mignonette		-	-	-
cf. *Rubus* sp.	Bramble		-	-	-
Rumex acetosella (agg) L.	Sheep's sorrel		-	-	-
Rumex cf. *acetosella* (agg) L.	Sheep's sorrel		-	-	-
Rumex sp.	Dock		-	1	1
cf. *Rumex* sp.	cf. Dock		-	-	-
Sambucus sp.	Elder		-	-	-
Scrophulariaceae	Figwort family		-	-	-
Sherardia arvensis L.	Field madder		4	-	-
Silene gallica L.	Small-flowered catchfly		-	-	-
Silene sp.	Campion		-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	3	1
cf. S*tellaria media* (L.) Vill.	cf. Common chickweed		-	-	-
Stellaria sp.	Chickweed		-	-	-
Urtica dioica L.	Common stinging nettle		-	-	4
Urtica sp.	Nettle		1	8	-
Viola sp. (subgen.) *Melanium*	Pansy		-	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
Indeterminate/unidentified seeds					
Anther			-	1	-
Berry			-	-	-
Cess pit mystery object			-	-	-
Possible fern fragment			-	-	-
Shoots			-	-	-
Unidentified seeds			43	27	15
Other (non-seed) items					
Animal dung			-	-	-
Cess pit mystery item			-	-	-
Leaf			-	-	-
Marine plant			-	-	-
CARBONIZED MATERIAL					
Cereals					
Hordeum sp.	Barley	Caryopsis	1	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-	-
Triticum aestivum L.	Bread wheat	Rachis node	-	-	-
Triticum dicoccum Schübl.	Emmer wheat	Caryopsis	1	-	-
T. dicoccum Schübl. or *T. monococcum* L.	Emmer or einkorn wheat	Caryopsis	-	-	2
Triticum monococcum L.	Einkorn wheat	Caryopsis	1	-	-
Triticum sp.	Wheat	Caryopsis	-	-	-
Cereal grain	Cereal	Caryopsis	-	-	-
Pulses					
Lens culinaris Medik.	Lentil	Seed	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-
Nuts					
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-
Juglans regia L.	Walnut	Shell fragment	-	-	-
Pinus pinea L.	Stone pine	Seed	-	-	-
Pinus pinea L.	Stone pine	Nut	-	-	-
Pinus pinea L.	Stone pine	Bract	-	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
Fruit					
Ficus carica L.	Fig	Achene	-	-	-
Ficus carica L.	Fig	Flesh	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	2	-	-
Olea europaea L.	Olive	Endocarp (MNI)	5	3	7
Olea europaea L.	Olive	Endocarp (frag.)	90	19	77
Phoenix dactylifera L.	Date	Endocarp	-	-	-
Pyrus sp.	Pear	Seed	-	-	-
Vitis vinifera L.	Grape	Pip	2	1	1
Vitis vinifera L.	Grape	Stalk	2	-	-
Other potential foodstuffs					
Vicia ervilia (L.) Willd.	Bitter vetch	Seed	-	-	-
Weeds, ruderals and other taxa					
Apiaceae	Parsley family		-	-	-
cf. *Avena* sp.	Oat		-	-	-
Chenopodium sp.	Goosefoot		-	-	-
Ornithopus sp.	Bird’s foot		-	-	-
Poaceae	True grasses	Caryopsis	-	-	-
Poaceae	True grasses	Rachis fragment	-	-	-
cf. Poaceae	cf. True grasses	Caryopsis	-	-	-
Rumex sp.	Dock		-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-
Ornamental plants					
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-	-
Indeterminate/unidentified seeds					
Unidentified seeds			2	-	1
Fungal fruiting body			-	-	1
Other (non-seed) plant items					
Bread fragments			-	-	-
Buds			-	-	-
Weed seed			-	-	-

QUADRANT 13-14	COMMON NAME	COMPONENT	US38	US39	US40
WATERLOGGED REMAINS					
Fruits					
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	2	-	-
Rubus fruticosus (agg)	Blackberry	Thorn	1	-	-
Vitis vinifera L.	Grape	Pip	4	-	2
Herbs and seasonings					
Apium graveolens (Mill.) Pers.	Celery	Mericarp	1	-	-
Weeds, ruderals and other taxa					
Apiaceae	Parsley family		7	-	-
Daucus carota L.	Wild carrot		4	-	1
Fumaria sp.	Fumitory		2	-	-
Lamiaceae	Mint family		1	-	-
Stellaria media (L.) Vill.	Common chickweed		2	-	-
Indeterminate/unidentified seeds					
Unidentified seeds			20	-	1
Other (non-seed) plant items					
Bud			1	-	-
Bark			1	-	-
Root fragments			12	-	-
Stalks			9	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
MINERALIZED REMAINS					
Cereals					
Panicum miliaceum L.	Common millet	Caryopsis	-	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-	4
Setaria italica Beauv.	Foxtail millet	Caryopsis	8	1	2
cf. *Setaria italica* Beauv.	cf. Foxtail millet	Caryopsis	-	-	8
cf. *Sorghum* sp.	Sorghum	Caryopsis	-	-	-
Triticum cf. *dicoccum* Schübl.	Emmer wheat	Caryopsis	-	-	-
Cereal grain	Cereal	Caryopsis	-	-	-
Pulses					
Lens culinaris Medik.	Lentil	Seed	-	-	-
cf. *Lens culinaris* Medik.	cf. Lentil	Seed	-	-	-
Vicia faba var. *minuta* L.	Broad bean	Seed	-	-	-
cf. *Vicia faba* var. *minuta* L.	cf. Broad bean	Seed	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-
Vicia sp.	Vetch	Hilum	-	-	-
Nuts					
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-
cf. *Pinus pinea* L.	Stone pine	Husk	-	-	-
Fruit					
cf. *Celtis australis* L.	Mediterranean hackberry	Berry	-	-	-
Cucumis melo L. or *sativus* L.	Melon or cucumber	Seed	-	-	-
Ficus carica L.	Fig	Achene	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	6	-	-
Malus sp.	Apple	Seed	-	-	-
Morus nigra L.	Black mulberry	Endocarp	-	1	-
cf. *Morus nigra* L.	cf. Black mulberry	Endocarp	1	-	-
Olea europaea L.	Olive	Seed	17	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-	-
Prunus avium or *cersus* L.	Wild or sour cherry	Stone	-	-	-
Prunus domestica L.	Plum	Stone	-	-	-
Prunus cf. *domestica* L.	Plum	Stone	-	-	-
Prunus sp.	Stone fruit	Stone	2	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
cf. *Prunus* sp.	cf. Stone fruit	Stone	1	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-
cf. *Rubus fruticosus* (agg)	cf. Blackberry	Endocarp	-	-	-
Vitis vinifera L.	Grape	Pip	38	1	1
Vitis vinifera L.	Grape	Stalk	-	-	-
Vitis vinifera or berry	Whole grape or berry	Pip/berry	-	-	-
Herbs and seasonings					
cf. *Anethum graveolens* L.	Dill	Mericarp	-	-	-
Apium graveolens (Mills.) Pers.	Celery	Mericarp	-	-	-
cf. *Apium graveolens* (Mills.) Pers.	cf. Celery	Mericarp	-	-	4
Brassica sp.	Cabbage or mustard	Seed	-	-	-
cf. *Brassica* sp.	cf. Cabbage or mustard	Seed	-	-	-
Coriandrum sativum L.	Coriander	Mericarp	-	-	-
cf. *Coriandrum sativum* L.	cf. Coriander	Mericarp	1	-	-
Foeniculum vulgare Mill.	Fennel	Mericarp	-	-	-
cf. *Foeniculum vulgare* Mill.	cf. Fennel	Mericarp	-	-	-
Linum usitatissimum L.	Flax/linseed	Seed	-	-	-
cf. *Linum usitatissimum* L.	cf. Flax/linseed	Seed	-	-	-
Mentha sp.	Mint	Mericarp	1	-	1
cf. *Mentha* sp.	cf. Mint	Mericarp	-	-	-
Papaver somniferum L.	Opium poppy	Seed	17	-	4
Piper nigrum L.	Black pepper	Berry	-	-	-
Other potential foodstuffs					
Ceratonia siliqua L.	Carob	Seed	-	-	-
Malva sp.	Mallow	Seed	7	-	-
cf. *Malva* sp.	cf. Mallow	Seed	-	-	-
Medicago sp.	Medick	Seed	-	-	-
cf. *Medicago* sp.	cf. Medick	Seed	1	-	-
Ornamental plants					
Buxus sp.	Box	Stem	-	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
Weeds, ruderals and other taxa					
Amaranthaceae	Amaranth family		-	3	-
cf. Amaranthaceae	cf. Amaranth family		-	-	-
Anagallis sp.	Pimpernel		-	-	-
cf. *Anagallis* sp.	cf. Pimpernel		-	-	-
Anthemis arvensis L.	Corn chamomile		-	-	-
cf. *Anthemis arvensis* L.	cf. Corn chamomile		-	-	-
Aphanes sp.	Parsley-piert		-	-	-
Apiaceae	Parsley family		9	-	-
Asteraceae	Daisy family		-	-	-
cf. Asteraceae	cf. Daisy family		1	-	-
Boraginaceae	Borage family		-	-	-
Brassicaceae	Cabbage family		-	-	-
Carduus sp.	Thistle		-	-	-
Carex sp.	Sedge		-	1	-
cf. *Carex* sp.	cf. Sedge		-	-	-
Carex sp. or *Rumex* sp.	Sedge or dock		-	-	-
Caryophyllaceae	Carnation family		2	-	-
cf. Caryophyllaceae	cf. Carnation family		10	-	-
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot		-	-	-
cf. *Centaurea* sp.	Knapweed		-	-	-
Chara sp.	Green algae		-	-	-
Chenopodium album L.	Fat-hen		-	-	-
Chenopodium sp.	Goosefoot		4	2	2
cf. *Chenopodium* sp.	cf. Goosefoot		1	-	-
Cyperaceae	Sedge family		-	-	-
cf. Cyperaceae	cf. Sedge family		-	-	-
Cyperaceae or Polygonaceae	Sedge or knotweed		-	-	-
Fabaceae	Legume family		-	-	-
Lamiaceae	Mint family		1	-	-
cf. Lamiaceae	cf. Mint family		-	-	-
Linum sp. (not *usitatissimum*)	Flax		-	-	-
cf. *Linum* sp. (not *usitatissimum*)	cf. Flax		-	-	-
Lithospermum arvense L.	Field gromwell		-	-	-
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot		-	-	-
Ornithopus sp.	Bird's foot		1	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
cf. *Ornithopus* sp.	cf. Bird's foot		-	-	-
Ornithopus sp. or *Medicago* sp.	Bird's foot or medick		-	-	-
Papaver sp.	Poppy		-	3	-
cf. *Papaver* sp.	cf. Poppy		-	-	-
Papaveraceae	Poppy family		1	-	-
cf. *Plantago* sp.	Plantain		1	-	-
Poaceae	True grasses		1	1	-
cf. Poaceae	cf. True grasses		-	-	-
Polygonaceae	Knotweed family		-	-	-
Polygonum aviculare (agg) L.	Knotgrass		-	-	-
cf. *Polygonum aviculare* (agg) L.	cf. Knotgrass		-	-	-
Polygonum sp.	Knotweed		1	-	-
cf. *Polygonum* sp.	cf. Knotweed		-	-	-
Pteridium aquilinum (L.) Kuhn	Bracken		-	-	-
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup		-	-	-
Ranunculus sp.	Buttercup		-	-	-
cf. *Ranunculus* sp.	cf. Buttercup		-	-	-
Ranunculus subgens. *Ranunculus*	Buttercup		-	-	-
Reseda sp.	Mignonette		-	1	1
cf. *Rubus* sp.	Bramble		-	-	-
Rumex acetosella (agg) L.	Sheep's sorrel		-	-	1
Rumex cf. *acetosella* (agg) L.	Sheep's sorrel		-	-	-
Rumex sp.	Dock		1	-	-
cf. *Rumex* sp.	cf. Dock		1	-	-
Sambucus sp.	Elder		-	-	-
Scrophulariaceae	Figwort family		-	-	-
Sherardia arvensis L.	Field madder		-	-	4
Silene gallica L.	Small-flowered catchfly		-	-	-
Silene sp.	Campion		-	-	-
Stellaria media (L.) Vill.	Common chickweed		2	4	-
cf. S*tellaria media* (L.) Vill.	cf. Common chickweed		-	-	-
Stellaria sp.	Chickweed		-	-	-
Urtica dioica L.	Common stinging nettle		4	-	1
Urtica sp.	Nettle		1	-	-
Viola sp. (subgen.) *Melanium*	Pansy		-	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
Indeterminate/unidentified seeds					
Anther			3	1	-
Berry			-	-	-
Cess pit mystery object			-	-	-
Possible fern fragment			-	-	-
Shoots			-	-	-
Unidentified seeds			60	6	10
Other (non-seed) items					
Animal dung			-	-	-
Cess pit mystery item			-	-	-
Leaf			-	-	-
Marine plant			-	-	-
CARBONIZED MATERIAL					
Cereals					
Hordeum sp.	Barley	Caryopsis	-	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-	-
Triticum aestivum L.	Bread wheat	Rachis node	-	-	1
Triticum dicoccum Schübl.	Emmer wheat	Caryopsis	-	-	-
T. dicoccum Schübl. or *T. monococcum* L.	Emmer or einkorn wheat	Caryopsis	-	-	-
Triticum monococcum L.	Einkorn wheat	Caryopsis	-	-	-
Triticum sp.	Wheat	Caryopsis	-	-	-
Cereal grain	Cereal	Caryopsis	-	-	-
Pulses					
Lens culinaris Medik.	Lentil	Seed	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-
Nuts					
Corylus avellana L.	Hazelnut	Shell fragment	1	-	-
Juglans regia L.	Walnut	Shell fragment	1	-	-
Pinus pinea L.	Stone pine	Seed	1	-	1
Pinus pinea L.	Stone pine	Nut	-	-	-
Pinus pinea L.	Stone pine	Bract	-	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
Fruit					
Ficus carica L.	Fig	Achene	-	-	-
Ficus carica L.	Fig	Flesh	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-
Olea europaea L.	Olive	Endocarp (MNI)	53	1	3
Olea europaea L.	Olive	Endocarp (frag.)	431	5	19
Phoenix dactylifera L.	Date	Endocarp	-	-	-
Pyrus sp.	Pear	Seed	-	-	-
Vitis vinifera L.	Grape	Pip	2	1	1
Vitis vinifera L.	Grape	Stalk	1	-	-
Other potential foodstuffs					
Vicia ervilia (L.) Willd.	Bitter vetch	Seed	-	-	-
Weeds, ruderals and other taxa					
Apiaceae	Parsley family		-	-	-
cf. *Avena* sp.	Oat		-	-	-
Chenopodium sp.	Goosefoot		-	-	-
Ornithopus sp.	Bird’s foot		-	-	-
Poaceae	True grasses	Caryopsis	2	-	1
Poaceae	True grasses	Rachis fragment	-	-	-
cf. Poaceae	cf. True grasses	Caryopsis	-	-	-
Rumex sp.	Dock		-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-
Ornamental plants					
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-	-
Indeterminate/unidentified seeds					
Unidentified seeds			9	-	-
Fungal fruiting body			-	-	-
Other (non-seed) plant items					
Bread fragments			-	-	-
Buds			-	-	-
Weed seed			-	-	-

QUADRANT 23-24	COMMON NAME	COMPONENT	US38	US39	US40
WATERLOGGED REMAINS					
Fruits					
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-
Rubus fruticosus (agg)	Blackberry	Thorn	-	-	-
Vitis vinifera L.	Grape	Pip	-	-	1
Herbs and seasonings					
Apium graveolens (Mill.) Pers.	Celery	Mericarp	-	-	-
Weeds, ruderals and other taxa					
Apiaceae	Parsley family		-	-	-
Daucus carota L.	Wild carrot		-	-	-
Fumaria sp.	Fumitory		-	-	-
Lamiaceae	Mint family		-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-
Indeterminate/unidentified seeds					
Unidentified seeds			-	-	-
Other (non-seed) plant items					
Bud			-	-	-
Bark			-	-	-
Root fragments			-	-	-
Stalks			-	-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
MINERALIZED REMAINS				
Cereals				
Panicum miliaceum L.	Common millet	Caryopsis	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-
cf. *Setaria italica* Beauv.	cf. Foxtail millet	Caryopsis	-	-
cf. *Sorghum* sp.	Sorghum	Caryopsis	-	-
Triticum cf. *dicoccum* Schübl.	Emmer wheat	Caryopsis	-	-
Cereal grain	Cereal	Caryopsis	-	-
Pulses				
Lens culinaris Medik.	Lentil	Seed	-	-
cf. *Lens culinaris* Medik.	cf. Lentil	Seed	-	-
Vicia faba var. *minuta* L.	Broad bean	Seed	-	-
cf. *Vicia faba* var. *minuta* L.	cf. Broad bean	Seed	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-
Vicia sp.	Vetch	Hilum	-	-
Nuts				
Corylus avellana L.	Hazelnut	Shell fragment	-	-
cf. *Pinus pinea* L.	Stone pine	Husk	-	-
Fruit				
cf. *Celtis australis* L.	Mediterranean hackberry	Berry	-	-
Cucumis melo L. or *sativus* L.	Melon or cucumber	Seed	-	-
Ficus carica L.	Fig	Achene	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-
Malus sp.	Apple	Seed	-	-
Morus nigra L.	Black mulberry	Endocarp	1	-
cf. *Morus nigra* L.	cf. Black mulberry	Endocarp	-	-
Olea europaea L.	Olive	Seed	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-
Prunus avium or *cersus* L.	Wild or sour cherry	Stone	-	-
Prunus domestica L.	Plum	Stone	-	-
Prunus cf. *domestica* L.	Plum	Stone	-	-
Prunus sp.	Stone fruit	Stone	-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
cf. *Prunus* sp.	cf. Stone fruit	Stone	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-
cf. *Rubus fruticosus* (agg)	cf. Blackberry	Endocarp	-	-
Vitis vinifera L.	Grape	Pip	-	1
Vitis vinifera L.	Grape	Stalk	-	-
Vitis vinifera or berry	Whole grape or berry	Pip/berry	-	-
Herbs and seasonings				
cf. *Anethum graveolens* L.	Dill	Mericarp	-	-
Apium graveolens (Mills.) Pers.	Celery	Mericarp	-	-
cf. *Apium graveolens* (Mills.) Pers.	cf. Celery	Mericarp	-	-
Brassica sp.	Cabbage or mustard	Seed	-	-
cf. *Brassica* sp.	cf. Cabbage or mustard	Seed	-	-
Coriandrum sativum L.	Coriander	Mericarp	-	-
cf. *Coriandrum sativum* L.	cf. Coriander	Mericarp	-	-
Foeniculum vulgare Mill.	Fennel	Mericarp	-	-
cf. *Foeniculum vulgare* Mill.	cf. Fennel	Mericarp	-	-
Linum usitatissimum L.	Flax/linseed	Seed	-	-
cf. *Linum usitatissimum* L.	cf. Flax/linseed	Seed	-	-
Mentha sp.	Mint	Mericarp	-	-
cf. *Mentha* sp.	cf. Mint	Mericarp	-	2
Papaver somniferum L.	Opium poppy	Seed	4	-
Piper nigrum L.	Black pepper	Berry	-	-
Other potential foodstuffs				
Ceratonia siliqua L.	Carob	Seed	-	-
Malva sp.	Mallow	Seed	-	-
cf. *Malva* sp.	cf. Mallow	Seed	-	-
Medicago sp.	Medick	Seed	-	-
cf. *Medicago* sp.	cf. Medick	Seed	-	-
Ornamental plants				
Buxus sp.	Box	Stem	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
Weeds, ruderals and other taxa				
Amaranthaceae	Amaranth family		-	-
cf. Amaranthaceae	cf. Amaranth family		-	3
Anagallis sp.	Pimpernel		-	-
cf. *Anagallis* sp.	cf. Pimpernel		-	-
Anthemis arvensis L.	Corn chamomile		-	-
cf. *Anthemis arvensis* L.	cf. Corn chamomile		1	-
Aphanes sp.	Parsley-piert		-	-
Apiaceae	Parsley family		-	-
Asteraceae	Daisy family		-	-
cf. Asteraceae	cf. Daisy family		-	-
Boraginaceae	Borage family		-	-
Brassicaceae	Cabbage family		-	-
Carduus sp.	Thistle		-	-
Carex sp.	Sedge		-	-
cf. *Carex* sp.	cf. Sedge		-	-
Carex sp. or *Rumex* sp.	Sedge or dock		-	-
Caryophyllaceae	Carnation family		5	4
cf. Caryophyllaceae	cf. Carnation family		-	-
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot		-	5
cf. *Centaurea* sp.	Knapweed		-	-
Chara sp.	Green algae		-	-
Chenopodium album L.	Fat-hen		-	-
Chenopodium sp.	Goosefoot		2	1
cf. *Chenopodium* sp.	cf. Goosefoot		-	-
Cyperaceae	Sedge family		-	-
cf. Cyperaceae	cf. Sedge family		-	-
Cyperaceae or Polygonaceae	Sedge or knotweed		2	-
Fabaceae	Legume family		-	-
Lamiaceae	Mint family		2	-
cf. Lamiaceae	cf. Mint family		-	-
Linum sp. (not *usitatissimum*)	Flax		-	-
cf. *Linum* sp. (not *usitatissimum*)	cf. Flax		-	-
Lithospermum arvense L.	Field gromwell		-	-
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot		-	-
Ornithopus sp.	Bird's foot		-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
cf. *Ornithopus* sp.	cf. Bird's foot		-	-
Ornithopus sp. or *Medicago* sp.	Bird’s foot or medick		-	-
Papaver sp.	Poppy		-	1
cf. *Papaver* sp.	cf. Poppy		-	-
Papaveraceae	Poppy family		-	-
cf. *Plantago* sp.	Plantain		-	-
Poaceae	True grasses		-	-
cf. Poaceae	cf. True grasses		1	-
Polygonaceae	Knotweed family		-	-
Polygonum aviculare (agg) L.	Knotgrass		-	-
cf. *Polygonum aviculare* (agg) L.	cf. Knotgrass		-	-
Polygonum sp.	Knotweed		-	-
cf. *Polygonum* sp.	cf. Knotweed		-	-
Pteridium aquilinum (L.) Kuhn	Bracken		-	-
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup		-	-
Ranunculus sp.	Buttercup		-	-
cf. *Ranunculus* sp.	cf. Buttercup		-	-
Ranunculus subgens. *Ranunculus*	Buttercup		-	-
Reseda sp.	Mignonette		4	1
cf. *Rubus* sp.	Bramble		-	-
Rumex acetosella (agg) L.	Sheep's sorrel		-	-
Rumex cf. *acetosella* (agg) L.	Sheep's sorrel		1	-
Rumex sp.	Dock		-	-
cf. *Rumex* sp.	cf. Dock		-	-
Sambucus sp.	Elder		-	-
Scrophulariaceae	Figwort family		-	-
Sherardia arvensis L.	Field madder		-	-
Silene gallica L.	Small-flowered catchfly		-	-
Silene sp.	Campion		-	-
Stellaria media (L.) Vill.	Common chickweed		2	2
cf. S*tellaria media* (L.) Vill.	cf. Common chickweed		-	-
Stellaria sp.	Chickweed		-	-
Urtica dioica L.	Common stinging nettle		3	1
Urtica sp.	Nettle		1	1
Viola sp. (subgen.) *Melanium*	Pansy		-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
Indeterminate/unidentified seeds				
Anther			-	-
Berry			-	-
Cess pit mystery object			-	-
Possible fern fragment			-	-
Shoots			-	-
Unidentified seeds			10	9
Other (non-seed) items				
Animal dung			-	-
Cess pit mystery item			-	-
Leaf			-	-
Marine plant			-	-
CARBONIZED MATERIAL				
Cereals				
Hordeum sp.	Barley	Caryopsis	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis		-
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-
Triticum aestivum L.	Bread wheat	Rachis node	-	-
Triticum dicoccum Schübl.	Emmer wheat	Caryopsis	-	-
T. dicoccum Schübl. or *T. monococcum* L.	Emmer or einkorn wheat	Caryopsis		-
Triticum monococcum L.	Einkorn wheat	Caryopsis	-	-
Triticum sp.	Wheat	Caryopsis	-	-
Cereal grain	Cereal	Caryopsis	-	-
Pulses				
Lens culinaris Medik.	Lentil	Seed	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-
Nuts				
Corylus avellana L.	Hazelnut	Shell fragment	-	-
Juglans regia L.	Walnut	Shell fragment	-	-
Pinus pinea L.	Stone pine	Seed	-	-
Pinus pinea L.	Stone pine	Nut	-	-
Pinus pinea L.	Stone pine	Bract	-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
Fruit				
Ficus carica L.	Fig	Achene	-	-
Ficus carica L.	Fig	Flesh	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-
Olea europaea L.	Olive	Endocarp (MNI)	1	-
Olea europaea L.	Olive	Endocarp (frag.)	5	-
Phoenix dactylifera L.	Date	Endocarp	-	-
Pyrus sp.	Pear	Seed	-	-
Vitis vinifera L.	Grape	Pip	1	1
Vitis vinifera L.	Grape	Stalk	-	-
Other potential foodstuffs				
Vicia ervilia (L.) Willd.	Bitter vetch	Seed	-	-
Weeds, ruderals and other taxa				
Apiaceae	Parsley family		-	-
cf. *Avena* sp.	Oat		-	-
Chenopodium sp.	Goosefoot		1	-
Ornithopus sp.	Bird’s foot		-	-
Poaceae	True grasses	Caryopsis	-	-
Poaceae	True grasses	Rachis fragment	-	-
cf. Poaceae	cf. True grasses	Caryopsis	-	-
Rumex sp.	Dock		-	-
Stellaria media (L.) Vill.	Common chickweed		-	-
Ornamental plants				
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-
Indeterminate/unidentified seeds				
Unidentified seeds			1	-
Fungal fruiting body			-	-
Other (non-seed) plant items				
Bread fragments			-	-
Buds			-	-
Weed seed			-	-

QUADRANT 37-38	COMMON NAME	COMPONENT	US38	US40
WATERLOGGED REMAINS				
Fruits				
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-
Rubus fruticosus (agg)	Blackberry	Thorn	-	-
Vitis vinifera L.	Grape	Pip	-	-
Herbs and seasonings				
Apium graveolens (Mill.) Pers.	Celery	Mericarp	-	-
Weeds, ruderals and other taxa				
Apiaceae	Parsley family		-	-
Daucus carota L.	Wild carrot		-	-
Fumaria sp.	Fumitory		-	-
Lamiaceae	Mint family		-	-
Stellaria media (L.) Vill.	Common chickweed		-	-
Indeterminate/unidentified seeds				
Unidentified seeds			-	-
Other (non-seed) plant items				
Bud			-	-
Bark			-	-
Root fragments			-	-
Stalks			-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
MINERALIZED REMAINS							
Cereals							
Panicum miliaceum L.	Common millet	Caryopsis	-	-	-	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	-	-	-	-
Setaria italica Beauv.	Foxtail millet		-	-	-	-	
cf. *Setaria italica* Beauv.	cf. Foxtail millet		-	-	-	-	
cf. *Sorghum* sp.	Sorghum		-	-	-	-	
Triticum cf. *dicoccum* Schübl.	Emmer wheat		-	-	-	-	
Cereal grain	Cereal		-	-	-	-	
Pulses							
Lens culinaris Medik.	Lentil	Seed	-	-	-	-	-
cf. *Lens culinaris* Medik.	cf. Lentil	Seed	-	-	-	-	-
Vicia faba var. *minuta* L.	Broad bean	Seed	-	-	-	-	-
cf. *Vicia faba* var. *minuta* L.	cf. Broad bean	Seed	-	-	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-	-	-
Vicia sp.	Vetch	Hilum	-	-	-	-	-
Nuts							
Corylus avellana L.	Hazelnut	Shell fragment	-	-	1	-	-
cf. *Pinus pinea* L.	Stone pine	Husk	-	-	-	-	-
Fruit							
cf. *Celtis australis* L.	Mediterranean hackberry	Berry	-	-	-	-	-
Cucumis melo L. or *sativus* L.	Melon or cucumber	Seed	-	-	-	-	-
Ficus carica L.	Fig	Achene	-	-	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	1	1	1
Malus sp.	Apple	Seed	-	-	-	-	-
Morus nigra L.	Black mulberry	Endocarp	-	-	-	1	-
cf. *Morus nigra* L.	cf. Black mulberry	Endocarp	-	-	-	-	-
Olea europaea L.	Olive	Seed	-	-	-	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-	-	-	-
Prunus avium or *cersus* L.	Wild or sour cherry	Stone	-	-	-	-	-
Prunus domestica L.	Plum	Stone	-	-	-	-	-
Prunus cf. *domestica* L.	Plum	Stone	-	-	-	-	-
Prunus sp.	Stone fruit	Stone	-	-	-	-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
cf. *Prunus* sp.	cf. Stone fruit	Stone	-	-	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-	-	-
cf. *Rubus fruticosus* (agg)	cf. Blackberry	Endocarp	-	-	-	-	-
Vitis vinifera L.	Grape	Pip	-	2	1	4	-
Vitis vinifera L.	Grape	Stalk	-	-	-	1	-
Vitis vinifera or berry	Whole grape or berry	Pip/berry	-	-	-	-	-
Herbs and seasonings							
cf. *Anethum graveolens* L.	Dill	Mericarp	-	-	-	-	-
Apium graveolens (Mills.) Pers.	Celery	Mericarp	-	-	-	-	-
cf. *Apium graveolens* (Mills.) Pers.	cf. Celery	Mericarp	-	-	-	-	-
Brassica sp.	Cabbage or mustard	Seed	-	-	-	-	-
cf. *Brassica* sp.	cf. Cabbage or mustard	Seed	-	-	-	4	-
Coriandrum sativum L.	Coriander	Mericarp	-	-	-	-	-
cf. *Coriandrum sativum* L.	cf. Coriander	Mericarp	-	-	-	-	-
Foeniculum vulgare Mill.	Fennel	Mericarp	-	-	-	-	-
cf. *Foeniculum vulgare* Mill.	cf. Fennel	Mericarp	-	-	-	-	-
Linum usitatissimum L.	Flax/linseed	Seed	-	-	-	-	-
cf. *Linum usitatissimum* L.	cf. Flax/linseed	Seed	-	-	-	-	-
Mentha sp.	Mint	Mericarp	-	-	-	-	-
cf. *Mentha* sp.	cf. Mint	Mericarp	-	-	-	-	-
Papaver somniferum L.	Opium poppy	Seed	-	-	-	-	3
Piper nigrum L.	Black pepper	Berry	-	-	-	1	-
Other potential foodstuffs							
Ceratonia siliqua L.	Carob	Seed	-	-	-	-	-
Malva sp.	Mallow	Seed	-	-	-	-	-
cf. *Malva* sp.	cf. Mallow	Seed	-	-	-	-	-
Medicago sp.	Medick	Seed	-	-	-	-	-
cf. *Medicago* sp.	cf. Medick	Seed	-	-	-	-	-
Ornamental plants							
Buxus sp.	Box	Stem	-	-	-	-	-
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-	-	-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
Weeds, ruderals and other taxa							
Amaranthaceae	Amaranth family		-	6	-	3	3
cf. Amaranthaceae	cf. Amaranth family		-	-	-	-	-
Anagallis sp.	Pimpernel		-	-	-	-	1
cf. *Anagallis* sp.	cf. Pimpernel		-	-	-	-	-
Anthemis arvensis L.	Corn chamomile		-	-	-	-	-
cf. *Anthemis arvensis* L.	cf. Corn chamomile		-	-	-	-	-
Aphanes sp.	Parsley-piert		1	-	-	-	-
Apiaceae	Parsley family		1	-	-	-	-
Asteraceae	Daisy family		3	-	-	-	-
cf. Asteraceae	cf. Daisy family		-	-	-	-	-
Boraginaceae	Borage family		-	-	-	-	-
Brassicaceae	Cabbage family		-	-	-	-	-
Carduus sp.	Thistle		-	-	-	-	-
Carex sp.	Sedge		-	2	-	-	-
cf. *Carex* sp.	cf. Sedge		6	-	-	-	-
Carex sp. or *Rumex* sp.	Sedge or dock		-	-	-	-	-
Caryophyllaceae	Carnation family		3	-	-	5	2
cf. Caryophyllaceae	cf. Carnation family		-	-	-	-	-
Caryophyllaceae or Chenopodiaceae	Carnation or goosefoot		-	-	-	-	-
cf. *Centaurea* sp.	Knapweed		-	-	-	-	-
Chara sp.	Green algae		-	1	-	-	-
Chenopodium album L.	Fat-hen		-	-	-	-	-
Chenopodium sp.	Goosefoot		2	-	-	-	2
cf. *Chenopodium* sp.	cf. Goosefoot		3	-	-	-	-
Cyperaceae	Sedge family		-	-	-	-	1
cf. Cyperaceae	cf. Sedge family		-	-	-	-	-
Cyperaceae or Polygonaceae	Sedge or knotweed		-	-	-	-	-
Fabaceae	Legume family		-	-	-	1	-
Lamiaceae	Mint family		4	1	-	-	1
cf. Lamiaceae	cf. Mint family		-	-	-	-	-
Linum sp. (not *usitatissimum*)	Flax		-	-	-	-	-
cf. *Linum* sp. (not *usitatissimum*)	cf. Flax		-	-	-	-	-
Lithospermum arvense L.	Field gromwell		-	-	-	-	-
cf. *Medicago* sp. or *Melilotus* sp.	Medick or melilot		1	-	-	-	-
Ornithopus sp.	Bird's foot		-	-	-	-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
cf. *Ornithopus* sp.	cf. Bird's foot		-	-	-	-	-
Ornithopus sp. or *Medicago* sp.	Bird’s foot or medick		-	-	-	-	-
Papaver sp.	Poppy		-	1	-	3	-
cf. *Papaver* sp.	cf. Poppy		-	-	-	-	-
Papaveraceae	Poppy family		-	-	-	-	-
cf. *Plantago* sp.	Plantain		-	-	-	-	-
Poaceae	True grasses		1	-	-	-	-
cf. Poaceae	cf. True grasses		-	-	-	-	-
Polygonaceae	Knotweed family		-	-	-	-	-
Polygonum aviculare (agg) L.	Knotgrass		-	-	-	-	-
cf. *Polygonum aviculare* (agg) L.	cf. Knotgrass		-	-	-	-	-
Polygonum sp.	Knotweed		-	-	-	-	-
cf. *Polygonum* sp.	cf. Knotweed		-	-	-	-	-
Pteridium aquilinum (L.) Kuhn	Bracken		-	-	-	-	-
cf. *Ranunculus parviflorus* L.	Small-flowered buttercup		-	-	-	-	-
Ranunculus sp.	Buttercup		2	-	-	-	-
cf. *Ranunculus* sp.	cf. Buttercup		-	-	-	-	-
Ranunculus subgens. *Ranunculus*	Buttercup		-	-	-	-	-
Reseda sp.	Mignonette		13	5	-	1	-
cf. *Rubus* sp.	Bramble		-	-	-	-	-
Rumex acetosella (agg) L.	Sheep's sorrel		-	-	-	-	-
Rumex cf. *acetosella* (agg) L.	Sheep's sorrel		-	-	-	-	-
Rumex sp.	Dock		-	-	-	-	-
cf. *Rumex* sp.	cf. Dock		-	-	-	-	-
Sambucus sp.	Elder		-	-	-	-	-
Scrophulariaceae	Figwort family		-	-	-	1	-
Sherardia arvensis L.	Field madder		-	-	-	-	-
Silene gallica L.	Small-flowered catchfly		1	1	-	-	1
Silene sp.	Campion		-	-	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-	-	3
cf. S*tellaria media* (L.) Vill.	cf. Common chickweed		-	-	-	-	-
Stellaria sp.	Chickweed		-	-	-	-	-
Urtica dioica L.	Common stinging nettle		9	5	-	3	3
Urtica sp.	Nettle		-	1	-	1	1
Viola sp. (subgen.) *Melanium*	Pansy		-	1	-	-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
Indeterminate/unidentified seeds							
Anther			1	-	-	-	1
Berry			-	-	-	-	-
Cess pit mystery object			-	-	-	1	-
Possible fern fragment			-	-	-	-	-
Shoots			-	-	-	14	-
Unidentified seeds			7	6	-	6	9
Other (non-seed) items							
Animal dung			-	-	-	-	-
Cess pit mystery item			-	-	-	-	-
Leaf			-	-	-	-	-
Marine plant			-	-	-	-	-
CARBONIZED MATERIAL							
Cereals							
Hordeum sp.	Barley	Caryopsis	-	-	-	-	-
Panicum miliaceum L. or *Setaria italica* Beauv.	Common or foxtail millet	Caryopsis	-	1	-	-	-
Setaria italica Beauv.	Foxtail millet	Caryopsis	-	-	-	-	-
Triticum aestivum L.	Bread wheat	Rachis node	-	-	-	-	-
Triticum dicoccum Schübl.	Emmer wheat	Caryopsis	-	-	-	-	-
T. dicoccum Schübl. or *T. monococcum* L.	Emmer or einkorn wheat	Caryopsis		-	-	-	-
Triticum monococcum L.	Einkorn wheat	Caryopsis	-	-	-	-	-
Triticum sp.	Wheat	Caryopsis	-	-	-	-	-
Cereal grain	Cereal	Caryopsis	-	-	-	1	-
Pulses							
Lens culinaris Medik.	Lentil	Seed	-	-	-	-	-
Vicia or *Lathyrus* sp.	Vetch or pea	Seed	-	-	-	-	-
Nuts							
Corylus avellana L.	Hazelnut	Shell fragment	-	-	-	-	-
Juglans regia L.	Walnut	Shell fragment	-	-	1	-	-
Pinus pinea L.	Stone pine	Seed	-	-	-	-	-
Pinus pinea L.	Stone pine	Nut	-	-	-	-	-
Pinus pinea L.	Stone pine	Bract	-	-	-	-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
Fruit							
Ficus carica L.	Fig	Achene	-	-	-	-	-
Ficus carica L.	Fig	Flesh	-	-	-	-	-
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-	-	-
Olea europaea L.	Olive	Endocarp (MNI)	23	2	-	-	-
Olea europaea L.	Olive	Endocarp (frag.)	196	26	-	-	-
Phoenix dactylifera L.	Date	Endocarp	-	-	-	-	-
Pyrus sp.	Pear	Seed	-	-	-	-	-
Vitis vinifera L.	Grape	Pip	1	1	-	1	2
Vitis vinifera L.	Grape	Stalk	-	-	-	1	-
Other potential foodstuffs							
Vicia ervilia (L.) Willd.	Bitter vetch	Seed	-	-	-	-	-
Weeds, ruderals and other taxa							
Apiaceae	Parsley family		1	-	-	-	-
cf. *Avena* sp.	Oat		-	-	-	-	-
Chenopodium sp.	Goosefoot		-	-	-	-	-
Ornithopus sp.	Bird's foot		-	-	-	-	-
Poaceae	True grasses	Caryopsis	-	-	-	-	-
Poaceae	True grasses	Rachis fragment	-	1	-	-	-
cf. Poaceae	cf. True grasses	Caryopsis	-	-	-	-	-
Rumex sp.	Dock		-	-	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-	-	-
Ornamental plants							
Cupressus sempervirens L.	Mediterranean cypress	Twig (with scales)	-	-	-	1	-
Indeterminate/unidentified seeds							
Unidentified seeds			-	-	-	-	-
Fungal fruiting body			-	-	-	-	-
Other (non-seed) plant items							
Bread fragments			-	-	-	-	-
Buds			-	-	-	-	-
Weed seed			-	-	-	-	-

QUADRANT 49-50	COMMON NAME	COMPONENT	US38	US39	US40	US42	US52
WATERLOGGED REMAINS							
Fruits							
Malus or *Pyrus* sp.	Apple or pear	Seed	-	-	-	-	-
Rubus fruticosus (agg)	Blackberry	Endocarp	-	-	-	-	-
Rubus fruticosus (agg)	Blackberry	Thorn	-	-	-	-	-
Vitis vinifera L.	Grape	Pip	-	-	-	-	-
Herbs and seasonings							
Apium graveolens (Mill.) Pers.	Celery	Mericarp	-	-	-	-	-
Weeds, ruderals and other taxa							
Apiaceae	Parsley family		-	-	-	-	-
Daucus carota L.	Wild carrot		-	-	-	-	-
Fumaria sp.	Fumitory		-	-	-	-	-
Lamiaceae	Mint family		-	-	-	-	-
Stellaria media (L.) Vill.	Common chickweed		-	-	-	-	-
Indeterminate/unidentified seeds							
Unidentified seeds			-	-	-	-	-
Other (non-seed) plant items							
Bud			-	-	-	-	-
Bark			-	-	-	-	-
Root fragments			-	-	-	-	-
Stalks			-	-	-	-	-

OTOLITHS

QUADRANTS 3-4 and 5-6	COMMON NAME	US38	US39	US40	US41
Anguilla anguilla L.	European eel	-	-	-	-
Anguillidae/ Congridae	Eels	-	-	-	-
Belone belone L.	Garfish	-	-	-	-
Boops boops L.	Bogue	-	-	-	-
cf. *Boops boops* L.	cf. Bogue	-	-	-	1
Chromis chromis L.	Damsel fish	-	-	-	-
cf. *Chromis chromis* L.	cf. Damsel fish	4	-	-	-
Clupeidae	Herring/Sardines	-	-	-	-
Conger conger L.	European conger eel	-	-	-	-
Dicentrarchus labrax L.	European seabass	-	-	-	-
Diplodus sp.	Sea bream	-	-	1	-
Elasmobranch	Sharks and Rays	-	-	-	-
Elasmobranch	Dog fish	-	-	-	-
Engraulis encrasicholus L.	European anchovy	1	-	-	-
Gadidae	Gadids	-	-	-	-
cf. Gadidae	cf. Gadids	-	-	-	-
Labridae	Wrasses	-	-	-	-
cf. *Labrus mixtus* L.	Cuckoo wrasse	-	-	-	-
Merluccius merluccius* L.	**Hake**	**-**	**-**	**1**	**-**
Mugilidae	Mullets	-	-	-	-
cf. *Mullus* sp.	Goatfish	-	-	-	-
cf. *Muraena helena* L.	Mediterranean moray eel	-	-	-	-
Pagellus bogaraveo Brunnich	Red sea bream	-	-	-	-
Pagellus erythrinus L.	Common pandora	1	-	-	-
Pagellus sp.	Pandora	-	-	-	-
cf. *Pagellus* sp.	cf. Pandora	-	-	-	-
Pagrus pagrus L.	Red porgy	-	-	-	-
cf. Percidae	Perch	-	-	-	-
Pleuronectiformes	Flatfishes	1	-	-	-
Rajidae	Skates	-	-	-	-
Sardina pilchardus Walbaum	European pilchard	-	-	-	-
cf. *Sardinella* sp.	Sardinella	-	-	-	-
cf. Sciaenidae	Drums	-	-	-	-
Scomber sp.	Mackerel	-	-	-	-

QUADRANTS 3-4 and 5-6	COMMON NAME	US38	US39	US40	US41
Scophthalmidae	Left-sided flatfish	-	1	-	-
Sparidae	Sea breams	-	-	1	-
cf. Sparidae	cf. Sea breams	-	-	-	-
cf. *Sparus* sp.	Sea bream	-	-	-	-
cf. *Spicara maena* L.	Blotched picarel	-	-	-	-
Spicara sp.	Picarel	-	-	-	1
cf. *Spicara* sp.	cf. Picarel	1	-	-	-
Spondyliosoma cantharus L.	Black sea bream	4	-	-	-
cf. *Spondyliosoma cantharus* L.	cf. Black sea bream	-	-	1	-
Trachinus draco L.	Greater weever	-	-	-	-
Trachinus sp.	Weevers	-	-	-	-
cf. *Trachurus mediterraneus* Steindachner	Mediterranean horse mackerel	-	-	-	-
Trachurus trachurus L.	Horse mackerel	-	-	-	-
Trachurus sp.	Mackerel	-	-	-	-
Triglidae	Gurnards	-	-	-	-
Trisopterus luscus L.	Pouting	2	-	-	-
Trisopterus sp.	Pout	-	-	1	-
cf. *Xyrichtys novacula* L.	Pearly razorfish	-	-	-	-
Unidentified	N/A	12	4	11	-

*Only otolith identified from Q5-6

QUADRANT 13-14	COMMON NAME	US38	US39	US40
Anguilla anguilla L.	European eel	-	-	-
Anguillidae/ Congridae	Eels	-	-	-
Belone belone L.	Garfish	-	-	-
Boops boops L.	Bogue	1	-	1
cf. *Boops boops* L.	cf. Bogue	-	-	-
Chromis chromis L.	Damsel fish	2	7	-
cf. *Chromis chromis* L.	cf. Damsel fish	-	-	-
Clupeidae	Herring/Sardines	-	-	-
Conger conger L.	European conger eel	-	-	-
Dicentrarchus labrax L.	European seabass	-	-	-
Diplodus sp.	Sea bream	1	2	1
Elasmobranch	Sharks and Rays	-	-	-
Elasmobranch	Dog fish	-	-	-
Engraulis encrasicholus L.	European anchovy	2	-	-
Gadidae	Gadids	-	-	1
cf. Gadidae	cf. Gadids	1	-	-
Labridae	Wrasses	-	-	-
cf. *Labrus mixtus* L.	Cuckoo wrasse	-	-	-
Merluccius merluccius L.	Hake	-	-	-
Mugilidae	Mullets	-	-	-
cf. *Mullus* sp.	Goatfish	-	-	-
cf. *Muraena helena* L.	Mediterranean moray eel	-	-	-
Pagellus bogaraveo Brunnich	Red sea bream	3	-	1
Pagellus erythrinus L.	Common pandora	-	-	-
Pagellus sp.	Pandora	9	1	1
cf. *Pagellus* sp.	cf. Pandora	-	1	1
Pagrus pagrus L.	Red porgy	-	-	-
cf. Percidae	Perch	-	-	-
Pleuronectiformes	Flatfishes	-	-	-
Rajidae	Skates	-	-	-
Sardina pilchardus Walbaum	European pilchard	-	-	-
cf. *Sardinella* sp.	Sardinella	-	-	-
cf. Sciaenidae	Drums	-	-	-
Scomber sp.	Mackerel	-	-	-
Scophthalmidae	Left-sided flatfish	-	-	-
Sparidae	Sea breams	18	-	5

QUADRANT 13-14	**COMMON NAME**	**US38**	**US39**	**US40**
cf. Sparidae	cf. Sea breams	1	-	6
cf. *Sparus* sp.	Sea bream	-	-	-
cf. *Spicara maena* L.	Blotched picarel	-	-	-
Spicara sp.	Picarel	2	-	-
cf. *Spicara* sp.	cf. Picarel	-	-	-
Spondyliosoma cantharus L.	Black sea bream	1	-	1
cf. *Spondyliosoma cantharus* L.	cf. Black sea bream	-	-	-
Trachinus draco L.	Greater weever	2	1	2
Trachinus sp.	Weevers	-	-	-
cf. *Trachurus mediterraneus* Steindachner	Mediterranean horse mackerel	-	-	1
Trachurus trachurus L.	Horse mackerel	-	-	1
Trachurus sp.	Mackerel	-	-	-
Triglidae	Gurnards	-	-	-
Trisopterus luscus L.	Pouting	-	2	1
Trisopterus sp.	Pout	-	-	-
cf. *Xyrichtys novacula* L.	Pearly razorfish	-	1	-
Unidentified	N/A	43	25	16

QUADRANT 23-24	**COMMON NAME**	**US38**	**US40**
Anguilla anguilla L.	European eel	-	-
Anguillidae/ Congridae	Eels	-	-
Belone belone L.	Garfish	-	-
Boops boops L.	Bogue	-	-
cf. *Boops boops* L.	cf. Bogue	1	-
Chromis chromis L.	Damsel fish	-	-
cf. *Chromis chromis* L.	cf. Damsel fish	4	-
Clupeidae	Herring/Sardines	-	-
Conger conger L.	European conger eel	-	-
Dicentrarchus labrax L.	European seabass	-	-
Diplodus sp.	Sea bream	-	-
Elasmobranch	Sharks and Rays	-	-
Elasmobranch	Dog fish	-	-
Engraulis encrasicholus L.	European anchovy	-	-
Gadidae	Gadids	-	-
cf. Gadidae	cf. Gadids	-	-
Labridae	Wrasses	-	-
cf. *Labrus mixtus* L.	Cuckoo wrasse	-	-
Merluccius merluccius L.	Hake	-	-
Mugilidae	Mullets	-	-
cf. *Mullus* sp.	Goatfish	-	-
cf. *Muraena helena* L.	Mediterranean moray eel	-	-
Pagellus bogaraveo Brunnich	Red sea bream	-	-
Pagellus erythrinus L.	Common pandora	1	-
Pagellus sp.	Pandora	1	1
cf. *Pagellus* sp.	cf. Pandora	-	-
Pagrus pagrus L.	Red porgy	1	-
cf. Percidae	Perch	-	-
Pleuronectiformes	Flatfishes	-	-
Rajidae	Skates	-	-
Sardina pilchardus Walbaum	European pilchard	-	-
cf. *Sardinella* sp.	Sardinella	-	-
cf. Sciaenidae	Drums	-	-
Scomber sp.	Mackerel	-	-
Scophthalmidae	Left-sided flatfish	-	-
Sparidae	Sea breams	9	-

QUADRANT 23-24	**COMMON NAME**	**US38**	**US40**
cf. Sparidae	cf. Sea breams	-	5
cf. *Sparus* sp.	Sea bream	-	-
cf. *Spicara maena* L.	Blotched picarel	-	-
Spicara sp.	Picarel	2	2
cf. *Spicara* sp.	cf. Picarel	-	-
Spondyliosoma cantharus L.	Black sea bream	-	-
cf. *Spondyliosoma cantharus* L.	cf. Black sea bream	-	-
Trachinus draco L.	Greater weever	-	1
Trachinus sp.	Weevers	-	-
cf. *Trachurus mediterraneus* Steindachner	Mediterranean horse mackerel	-	-
Trachurus trachurus L.	Horse mackerel	-	-
Trachurus sp.	Mackerel	1	-
Triglidae	Gurnards	-	-
Trisopterus luscus L.	Pouting	-	-
Trisopterus sp.	Pout	-	-
cf. *Xyrichtys novacula* L.	Pearly razorfish	-	-
Unidentified	N/A	5	4

QUADRANT 49-50	**COMMON NAME**	**US39**	**US42**	**US52**
Anguilla anguilla L.	European eel	-	-	-
Anguillidae/ Congridae	Eels	-	-	-
Belone belone L.	Garfish	-	-	-
Boops boops L.	Bogue	-	-	-
cf. *Boops boops* L.	cf. Bogue	-	-	-
Chromis chromis L.	Damsel fish	-	-	-
cf. *Chromis chromis* L.	cf. Damsel fish	-	-	-
Clupeidae	Herring/Sardines	-	-	-
Conger conger L.	European conger eel	-	-	-
Dicentrarchus labrax L.	European seabass	-	-	-
Diplodus sp.	Sea bream	-	-	-
Elasmobranch	Sharks and Rays	-	-	-
Elasmobranch	Dog fish	-	-	-
Engraulis encrasicholus L.	European anchovy	-	-	-
Gadidae	Gadids	-	-	-
cf. Gadidae	cf. Gadids	-	-	-
Labridae	Wrasses	-	-	-
cf. *Labrus mixtus* L.	Cuckoo wrasse	-	-	-
Merluccius merluccius L.	Hake	-	-	-
Mugilidae	Mullets	-	-	-
cf. *Mullus* sp.	Goatfish	-	-	-
cf. *Muraena helena* L.	Mediterranean moray eel	-	-	-
Pagellus bogaraveo Brunnich	Red sea bream	-	-	-
Pagellus erythrinus L.	Common pandora	-	-	-
Pagellus sp.	Pandora	-	-	-
cf. *Pagellus* sp.	cf. Pandora	-	-	-
Pagrus pagrus L.	Red porgy	-	-	-
cf. Percidae	Perch	-	-	-
Pleuronectiformes	Flatfishes	-	-	-
Rajidae	Skates	-	-	-
Sardina pilchardus Walbaum	European pilchard	-	-	-
cf. *Sardinella* sp.	Sardinella	-	-	-
cf. Sciaenidae	Drums	-	1	-
Scomber sp.	Mackerel	-	-	-
Scophthalmidae	Left-sided flatfish	-	-	-
Sparidae	Sea breams	1	-	-

QUADRANT 49-50	COMMON NAME	US39	US42	US52
cf. Sparidae	cf. Sea breams	-	-	-
cf. *Sparus* sp.	Sea bream	-	-	-
cf. *Spicara maena* L.	Blotched picarel	-	-	-
Spicara sp.	Picarel	-	-	-
cf. *Spicara* sp.	cf. Picarel	-	-	-
Spondyliosoma cantharus L.	Black sea bream	-	-	-
cf. *Spondyliosoma cantharus* L.	cf. Black sea bream	-	-	-
Trachinus draco L.	Greater weever	-	-	-
Trachinus sp.	Weevers	-	-	-
cf. *Trachurus mediterraneus* Steindachner	Mediterranean horse mackerel	-	-	-
Trachurus trachurus L.	Horse mackerel	-	-	-
Trachurus sp.	Mackerel	-	-	-
Triglidae	Gurnards	-	-	-
Trisopterus luscus L.	Pouting	-	-	-
Trisopterus sp.	Pout	-	-	-
cf. *Xyrichtys novacula* L.	Pearly razorfish	-	-	-
Unidentified	N/A	2	-	3

SHELLFISH

QUADRANT 3-4	COMMON NAME	US38	US39	US40	US41
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	-	-	-	-
Acanthocardia tuberculata (L.)	Rough cockle	-	-	-	-
cf. *Acanthocardia tuberculata* (L.)	cf. Rough cockle	-	1	-	-
Aequipecten opercularis (L.)	Queen scallop	1	2	-	1
Arca noae (L.)	Noah's ark shell	1	1	1	-
Bittium reticulatum (da C.)	Needle whelk	-	-	-	-
Bittium sp. (*tesselatum* (Mts.))	Horn snail	-	-	-	1
Bolinus brandaris (L.)	Purple dye murex	1	-	1	2
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible or lagoon cockle	1	-	-	-
cf. *Cerastoderma edule* (L.) or *glaucum* (Poir.)	cf. Common/edible or lagoon cockle	1	-	1	1
Cerithiidae indet.	Cerith	-	-	-	-
cf. *Cerithium* sp.	Cerith	-	-	-	-
Chamelea gallina (L.)	Striped venus	-	-	-	-
Columbella rustica (L.)	Rustic dove-shell	-	-	-	-
Crustacea	Crustacean	-	-	1	-
Diodora italica (Def.)	Limpet	-	-	-	-
Donacilla cornea (Poli)	Corneous wedge clam	4	3	23	8
Donax trunculus (L.)	Truncate donax	-	-	2	-
Ensis minor (Che.)	Minor jackknife clam	-	-	-	-
cf. *Eriphia verrucosa*	Warty crab	1	-	-	-
Fusinus pulchellus (Phil.)	Spindle snail	-	-	-	-
Gibbula albida (Gmel.)	Whitish gibbula	-	-	-	-
cf. *Gibbula albida* (Gmel.)	cf. Whitish gibbula	-	-	-	1
Gibbula philberti (Récl.)	Top snail	-	-	-	-
Gibbula sp.	Top snail	1	-	-	-
cf. *Gibbula* sp.	cf. Top snail	-	-	-	-
Glycymeris sp.	Bittersweet clams	1	1	1	-
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	-	-	-	-
cf. *Gregariella* cf. *petagnae* (Sca.)	cf. Half-hairy mussel	-	-	-	-
Helicidae	Land snail	3	2	3	3
Helix pomatia or *aspersa*	Edible snail or garden snail	-	-	-	-
Hexaplex trunculus (L.)	Trunculus murex	-	-	1	-
cf. *Hexaplex trunculus* (L.)	cf. Trunculus murex	-	-	-	-
Lucinella divaricata (L.)	None	-	-	-	-

QUADRANT 3-4	COMMON NAME	US38	US39	US40	US41
Modiolula phaseolina (Phi.)	None	-	-	-	-
Muricidae indet.	Murex family	-	-	1	-
Mytilaster cf. *minimus* (Poli.)	Mussel	1	-	-	1
Mytilidae indet.	Mussel	1	1	-	-
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	-	-	-	-
Nassarius cf. *costulatus* (Ren.)	Dog welk	-	-	-	-
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	-	-	-	-
Nassarius cf. *corniculum* (Olivi)	Horn nassa	-	-	1	-
Naticidae indet.	Moon shells	-	-	-	-
Ocenebra erinaceus (L.)	Hedgehog murex	-	-	-	-
Ocinebrina aciculata (Lam.)	Sea snail	-	-	-	-
Ocinebrina edwardsii (Pay.)	Sea snail	-	-	-	-
Odostomia eulimoides (Han.)	Pyram	-	-	-	-
cf. *Odostomia eulimoides* (Han.)	cf. Pyram	-	-	-	-
Ostrea edulis (L.)	Common/edible oyster	-	-	-	-
cf. *Ostrea edulis* (L.)	cf. Common/edible oyster	-	-	-	-
Patella sp.	Limpet	2	2	3	2
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	-	-	1	1
Polititapes aureus (Gmel.)	Golden carpet shell	-	-	-	-
Sepia sp.	Cuttlefish	-	-	-	-
Spatangoida	Heart urchins	1	-	-	-
Spondylus gaederopus (L.)	European thorny oyster	-	-	1	-
Timoclea ovata (Pen.)	Oval venus	-	-	-	-
Tonna galea (L.)	Giant tun	-	-	-	-
cf. *Tonna galea* (L.)	cf. Giant tun	-	-	-	-
Turritella communis (Riss.)	Auger shell	-	-	-	-
Venerupis decussata (L.)	Chequered carpet shell	1	1	1	1
SEA URCHIN					
Paracentrotus lividus (Lam.)	Purple sea urchin, body fragments	100+	100+	10+	10+
Paracentrotus lividus (Lam.)	Purple sea urchin, spines	100+	100+	100+	100+
Paracentrotus lividus (Lam.)	Purple sea urchin, pyramid plates	6*	26	4*	9
Paracentrotus lividus (Lam.)	Purple sea urchin, rotula	3	31*	-	5
Paracentrotus lividus (Lam.)	Purple sea urchin, teeth	3	5	-	6*
Paracentrotus lividus (Lam.)	Purple sea urchin, other jaw fragments	7	21	-	2
	MNI – based on * item	1	7	1	2

QUADRANT 5-6	COMMON NAME	US38	US39	US40	US42	US43
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	-	-	-	-	-
Acanthocardia tuberculata (L.)	Rough cockle	-	-	1	-	-
cf. *Acanthocardia tuberculata* (L.)	cf. Rough cockle	-	-	-	-	-
Aequipecten opercularis (L.)	Queen scallop	-	4	1	2	3
Arca noae (L.)	Noah's ark shell	-	-	-	-	-
Bittium reticulatum (da C.)	Needle whelk	-	-	-	-	-
Bittium sp. (*tesselatum* (Mts.))	Horn snail	-	-	-	-	-
Bolinus brandaris (L.)	Purple dye murex	-	1	3	-	-
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible or lagoon cockle	-	-	-	-	-
cf. *Cerastoderma edule* (L.) or *glaucum* (Poir.)	cf. Common/edible or lagoon cockle	-	1	-	-	-
Cerithiidae indet.	Cerith	-	-	-	-	-
cf. *Cerithium* sp.	Cerith	-	-	-	-	-
Chamelea gallina (L.)	Striped venus	-	-	1	-	-
Columbella rustica (L.)	Rustic dove-shell	-	-	1	-	-
Crustacea	Crustacean	-	-	-	-	-
Diodora italica (Def.)	Limpet	-	-	-	-	-
Donacilla cornea (Poli)	Corneous wedge clam	3	22	18	3	2
Donax trunculus (L.)	Truncate donax	-	-	1	-	-
Ensis minor (Che.)	Minor jackknife clam	-	-	-	-	-
cf. *Eriphia verrucosa*	Warty crab	-	-	-	-	-
Fusinus pulchellus (Phil.)	Spindle snail	-	-	-	-	-
Gibbula albida (Gmel.)	Whitish gibbula	-	-	-	-	-
cf. *Gibbula albida* (Gmel.)	cf. Whitish gibbula	-	-	-	-	-
Gibbula philberti (Récl.)	Top snail	-	-	-	-	-
Gibbula sp.	Top snail	-	-	-	-	-
cf. *Gibbula* sp.	cf. Top snail	-	1	-	-	-
Glycymeris sp.	Bittersweet clams	-	-	-	-	-
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	-	-	-	-	-
cf. *Gregariella* cf. *petagnae* (Sca.)	cf. Half-hairy mussel	-	-	1	-	-
Helicidae	Land snail	2	1	4	-	1
Helix pomatia or *aspersa*	Edible snail or garden snail	-	-	-	4	-
Hexaplex trunculus (L.)	Trunculus murex	-	2	-	-	-
cf. *Hexaplex trunculus* (L.)	cf. Trunculus murex	-	-	-	-	-
Lucinella divaricata (L.)	None	-	-	1	-	-
Modiolula phaseolina (Phi.)	None	-	-	-	-	-

QUADRANT 5-6	COMMON NAME	US38	US39	US40	US42	US43
Muricidae indet.	Murex family	-	-	1	-	-
Mytilaster cf. *minimus* (Poli.)	Mussel	-	-	-	1	-
Mytilidae indet.	Mussel	-	-	-	-	-
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	-	-	-	1	-
Nassarius cf. *costulatus* (Ren.)	Dog welk	-	-	1	-	-
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	-	-	-	-	-
Nassarius cf. *corniculum* (Olivi)	Horn nassa	-	-	-	-	-
Naticidae indet.	Moon shells	-	-	-	-	-
Ocenebra erinaceus (L.)	Hedgehog murex	-	1	-	-	-
Ocinebrina aciculata (Lam.)	Sea snail	-	-	1	-	-
Ocinebrina edwardsii (Pay.)	Sea snail	-	-	-	-	-
Odostomia eulimoides (Han.)	Pyram	-	-	-	-	-
cf. *Odostomia eulimoides* (Han.)	cf. Pyram	-	-	-	-	-
Ostrea edulis (L.)	Common/edible oyster	-	-	-	-	-
cf. *Ostrea edulis* (L.)	cf. Common/edible oyster	-	1	-	-	-
Patella sp.	Limpet	-	10	4	2	1
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	-	-	1	-	1
Polititapes aureus (Gmel.)	Golden carpet shell	-	-	-	-	-
Sepia sp.	Cuttlefish	-	1	-	-	-
Spatangoida	Heart urchins	-	-	-	-	-
Spondylus gaederopus (L.)	European thorny oyster	-	-	-	-	-
Timoclea ovata (Pen.)	Oval venus	-	-	1	-	-
Tonna galea (L.)	Giant tun	-	1	-	-	-
cf. *Tonna galea* (L.)	cf. Giant tun	-	-	-	-	-
Turritella communis (Riss.)	Auger shell	-	-	-	-	-
Venerupis decussata (L.)	Chequered carpet shell	-	2	-	-	-
SEA URCHIN						
Paracentrotus lividus (Lam.)	Purple sea urchin, body fragments	4	10+	10+*	10+	100+
Paracentrotus lividus (Lam.)	Purple sea urchin, spines	6	10+	10+	10+	100+
Paracentrotus lividus (Lam.)	Purple sea urchin, pyramid plates	1*	12	-	3*	52*
Paracentrotus lividus (Lam.)	Purple sea urchin, rotula	-	89*	-	1	8
Paracentrotus lividus (Lam.)	Purple sea urchin, teeth	-	10	-	-	16
Paracentrotus lividus (Lam.)	Purple sea urchin, other jaw fragments	-	42	-	-	62
	MNI – based on * item	1	18	1	1	6

QUADRANT 13-14	COMMON NAME	US38	US39	US40
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	-	-	-
Acanthocardia tuberculata (L.)	Rough cockle	1	-	-
cf. *Acanthocardia tuberculata* (L.)	cf. Rough cockle	-	-	-
Aequipecten opercularis (L.)	Queen scallop	2	1	1
Arca noae (L.)	Noah's ark shell	1	1	1
Bittium reticulatum (da C.)	Needle whelk	-	-	-
Bittium sp. (*tesselatum* (Mts.))	Horn snail	1	-	-
Bolinus brandaris (L.)	Purple dye murex	1	1	1
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible or lagoon cockle	-	-	-
cf. *Cerastoderma edule* (L.) or *glaucum* (Poir.)	cf. Common/edible or lagoon cockle	-	-	1
Cerithiidae indet.	Cerith	1	-	-
cf. *Cerithium* sp.	Cerith	1	-	-
Chamelea gallina (L.)	Striped venus	1	1	-
Columbella rustica (L.)	Rustic dove-shell	-	-	1
Crustacea	Crustacean	-	-	-
Diodora italica (Def.)	Limpet	2	-	-
Donacilla cornea (Poli.)	Corneous wedge clam	-	9	29
Donax trunculus L.	Truncate donax	-	-	1
Ensis minor (Che.)	Minor jackknife clam	1	-	-
cf. *Eriphia verrucosa*	Warty crab	-	-	-
Fusinus pulchellus (Phil.)	Spindle snail	-	-	-
Gibbula albida (Gmel.)	Whitish gibbula	-	1	-
cf. *Gibbula albida* (Gmel.)	cf. Whitish gibbula	1	-	-
Gibbula philberti (Récl.)	Top snail	-	-	-
Gibbula sp.	Top snail	-	-	-
cf. *Gibbula* sp.	cf. Top snail	-	1	-
Glycymeris sp.	Bittersweet clams	-	1	-
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	1	-	-
cf. *Gregariella* cf. *petagnae* (Sca.)	cf. Half-hairy mussel	-	-	-
Helicidae	Land snail	1	1	1
Helix pomatia or *aspersa*	Edible snail or garden snail	-	-	-
Hexaplex trunculus (L.)	Trunculus murex	-	-	-
cf. *Hexaplex trunculus* (L.)	cf. Trunculus murex	-	-	-
Lucinella divaricata (L.)	None	-	-	-
Modiolula phaseolina (Phi.)	None	-	-	-
Muricidae indet.	Murex family	-	-	-

QUADRANT 13-14	COMMON NAME	US38	US39	US40
Mytilaster cf. *minimus* (Poli.)	Mussel	-	2	-
Mytilidae indet.	Mussel	-	-	-
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	-	-	1
Nassarius cf. *costulatus* (Ren.)	Dog welk	-	-	-
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	2	-	-
Nassarius cf. c*orniculum* (Olivi)	Horn nassa	-	-	-
Naticidae indet.	Moon shells	-	-	-
Ocenebra erinaceus (L.)	Hedgehog murex	1	-	-
Ocinebrina aciculata (Lam.)	Sea snail	-	-	-
Ocinebrina edwardsii (Pay.)	Sea snail	1	-	-
Odostomia eulimoides (Han.)	Pyram	-	-	-
cf. *Odostomia eulimoides* (Han.)	cf. Pyram	1	-	-
Ostrea edulis (L.)	Common/edible oyster	-	2	-
cf. *Ostrea edulis* (L.)	cf. Common/edible oyster	1	-	-
Patella sp.	Limpet	17	-	17
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	1	-	1
Polititapes aureus (Gmel.)	Golden carpet shell	-	-	1
Sepia sp.	Cuttlefish	-	-	1
Spatangoida	Heart urchins	-	-	-
Spondylus gaederopus (L.)	European thorny oyster	-	-	-
Timoclea ovata (Pen.)	Oval venus	-	-	-
Tonna galea (L.)	Giant tun	-	-	-
cf. *Tonna galea* (L.)	cf. Giant tun	1	-	-
Turritella communis (Riss.)	Auger shell	1	-	-
Venerupis decussata (L.)	Chequered carpet shell	-	-	1
SEA URCHIN				
Paracentrotus lividus (Lam.)	Purple sea urchin, body fragments	10+	10+	10+
Paracentrotus lividus (Lam.)	Purple sea urchin, spines	100+	10+	10+
Paracentrotus lividus (Lam.)	Purple sea urchin, pyramid plates	2	-	1*
Paracentrotus lividus (Lam.)	Purple sea urchin, rotula	2*	4*	-
Paracentrotus lividus (Lam.)	Purple sea urchin, teeth	1	1	-
Paracentrotus lividus (Lam.)	Purple sea urchin, other jaw fragments	1	2	1
	MNI – based on * item	1	1	1

QUADRANT 23-24	COMMON NAME	US38	US39	US40
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	1	-	-
Acanthocardia tuberculata (L.)	Rough cockle	-	-	-
cf. *Acanthocardia tuberculata* (L.)	cf. Rough cockle	-	-	1
Aequipecten opercularis (L.)	Queen scallop	1	-	1
Arca noae (L.)	Noah's ark shell	1	-	-
Bittium reticulatum (da C.)	Needle whelk	1	-	-
Bittium sp. (*tesselatum* (Mts.))	Horn snail	-	-	-
Bolinus brandaris (L.)	Purple dye murex	1	-	1
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible or lagoon cockle	-	-	-
cf. *Cerastoderma edule* (L.) or *glaucum* (Poir.)	cf. Common/edible or lagoon cockle	-	-	-
Cerithiidae indet.	Cerith	-	-	-
cf. *Cerithium* sp.	Cerith	-	-	-
Chamelea gallina (L.)	Striped venus	-	-	-
Columbella rustica (L.)	Rustic dove-shell	-	-	-
Crustacea	Crustacean	-	-	1
Diodora italica (Def.)	Limpet	1	-	2
Donacilla cornea (Poli.)	Corneous wedge clam	13	10	58
Donax trunculus (L.)	Truncate donax	-	-	2
Ensis minor (Che.)	Minor jackknife clam	-	-	-
cf. *Eriphia verrucosa*	Warty crab	-	-	-
Fusinus pulchellus (Phil.)	Spindle snail	-	-	1
Gibbula albida (Gmel.)	Whitish gibbula	-	-	-
cf. *Gibbula albida* (Gmel.)	cf. Whitish gibbula	-	-	-
Gibbula philberti (Récl.)	Top snail	-	-	2
Gibbula sp.	Top snail	-	-	-
cf. *Gibbula* sp.	cf. Top snail	-	-	-
Glycymeris sp.	Bittersweet clams	-	-	1
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	-	-	-
cf. *Gregariella* cf. *petagnae* (Sca.)	cf. Half-hairy mussel	-	-	-
Helicidae	Land snail	3	1	5
Helix pomatia or *aspersa*	Edible snail or garden snail	-	-	-
Hexaplex trunculus (L.)	Trunculus murex	-	1	1
cf. *Hexaplex trunculus* (L.)	cf. Trunculus murex	1	-	-
Lucinella divaricata (L.)	None	-	-	-
Modiolula phaseolina (Phi.)	None	-	-	1
Muricidae indet.	Murex family	-	-	-

QUADRANT 23-24	COMMON NAME	US38	US39	US40
Mytilaster cf. *minimus* (Poli.)	Mussel	36	-	16
Mytilidae indet.	Mussel	-	-	-
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	-	-	-
Nassarius cf. *costulatus* (Ren.)	Dog welk	-	-	-
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	-	-	-
Nassarius cf. c*orniculum* (Olivi)	Horn nassa	-	-	-
Naticidae indet.	Moon shells	1	-	-
Ocenebra erinaceus (L.)	Hedgehog murex	-	-	-
Ocinebrina aciculata (Lam.)	Sea snail	-	-	-
Ocinebrina edwardsii (Pay.)	Sea snail	-	-	-
Odostomia eulimoides (Han.)	Pyram	1	-	-
cf. *Odostomia eulimoides* (Han.)	cf. Pyram	-	-	-
Ostrea edulis (L.)	Common/edible oyster	-	-	-
cf. *Ostrea edulis* (L.)	cf. Common/edible oyster	-	-	-
Patella sp.	Limpet	-	1	23
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	1	1	-
Polititapes aureus (Gmel.)	Golden carpet shell	-	-	-
Sepia sp.	Cuttlefish	-	-	-
Spatangoida	Heart urchins	-	-	-
Spondylus gaederopus (L.)	European thorny oyster	-	-	-
Timoclea ovata (Pen.)	Oval venus	-	-	-
Tonna galea (L.)	Giant tun	-	-	-
cf. *Tonna galea* (L.)	cf. Giant tun	-	-	-
Turritella communis (Riss.)	Auger shell	1	-	-
Venerupis decussata (L.)	Chequered carpet shell	-	3	-
SEA URCHIN				
Paracentrotus lividus (Lam.)	Purple sea urchin, body fragments	10+	-	8
Paracentrotus lividus (Lam.)	Purple sea urchin, spines	10+	-	10+
Paracentrotus lividus (Lam.)	Purple sea urchin, pyramid plates	2*	-	1*
Paracentrotus lividus (Lam.)	Purple sea urchin, rotula	-	-	-
Paracentrotus lividus (Lam.)	Purple sea urchin, teeth	-	-	-
Paracentrotus lividus (Lam.)	Purple sea urchin, other jaw fragments	-	-	-
	MNI – based on * item	1		1

QUADRANT 37-38	**COMMON NAME**	**US38**
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	-
Acanthocardia tuberculata (L.)	Rough cockle	-
cf. *Acanthocardia tuberculata* (L.)	cf. Rough cockle	-
Aequipecten opercularis (L.)	Queen scallop	-
Arca noae (L.)	Noah's ark shell	-
Bittium reticulatum (da C.)	Needle whelk	-
Bittium sp. (*tesselatum* (Mts.))	Horn snail	-
Bolinus brandaris (L.)	Purple dye murex	-
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible or lagoon cockle	-
cf. *Cerastoderma edule* (L.) or *glaucum* (Poir.)	cf. Common/edible or lagoon cockle	-
Cerithiidae indet.	Cerith	-
cf. *Cerithium* sp.	Cerith	-
Chamelea gallina (L.)	Striped venus	-
Columbella rustica (L.)	Rustic dove-shell	-
Crustacea	Crustacean	-
Diodora italica (Def.)	Limpet	-
Donacilla cornea (Poli)	Corneous wedge clam	-
Donax trunculus (L.)	Truncate donax	-
Ensis minor (Che.)	Minor jackknife clam	-
cf. *Eriphia verrucosa*	Warty crab	-
Fusinus pulchellus (Phil.)	Spindle snail	-
Gibbula albida (Gmel.)	Whitish gibbula	-
cf. *Gibbula albida* (Gmel.)	cf. Whitish gibbula	-
Gibbula philberti (Récl.)	Top snail	-
Gibbula sp.	Top snail	-
cf. *Gibbula* sp.	cf. Top snail	-
Glycymeris sp.	Bittersweet clams	-
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	-
cf. *Gregariella* cf. *petagnae* (Sca.)	cf. Half-hairy mussel	-
Helicidae	Land snail	-
Helix pomatia or *aspersa*	Edible snail or garden snail	-
Hexaplex trunculus (L.)	Trunculus murex	-
cf. *Hexaplex trunculus* (L.)	cf. Trunculus murex	-
Lucinella divaricata (L.)	None	-
Modiolula phaseolina (Phi.)	None	-
Muricidae indet.	Murex family	-

QUADRANT 37-38	COMMON NAME	US38
Mytilaster cf. *minimus* (Poli.)	Mussel	-
Mytilidae indet.	Mussel	-
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	-
Nassarius cf. *costulatus* (Ren.)	Dog welk	-
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	-
Nassarius cf. c*orniculum* (Olivi)	Horn nassa	-
Naticidae indet.	Moon shells	-
Ocenebra erinaceus (L.)	Hedgehog murex	-
Ocinebrina aciculata (Lam.)	Sea snail	-
Ocinebrina edwardsii (Pay.)	Sea snail	-
Odostomia eulimoides (Han.)	Pyram	-
cf. *Odostomia eulimoides* (Han.)	cf. Pyram	-
Ostrea edulis (L.)	Common/edible oyster	-
cf. *Ostrea edulis* (L.)	cf. Common/edible oyster	-
Patella sp.	Limpet	-
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	-
Polititapes aureus (Gmel.)	Golden carpet shell	-
Sepia sp.	Cuttlefish	-
Spatangoida	Heart urchins	-
Spondylus gaederopus (L.)	European thorny oyster	-
Timoclea ovata (Pen.)	Oval venus	-
Tonna galea (L.)	Giant tun	-
cf. *Tonna galea* (L.)	cf. Giant tun	-
Turritella communis (Riss.)	Auger shell	-
Venerupis decussata (L.)	Chequered carpet shell	-
SEA URCHIN		
Paracentrotus lividus (Lam.)	Purple sea urchin, body fragments	-
Paracentrotus lividus (Lam.)	Purple sea urchin, spines	3*
Paracentrotus lividus (Lam.)	Purple sea urchin, pyramid plates	-
Paracentrotus lividus (Lam.)	Purple sea urchin, rotula	-
Paracentrotus lividus (Lam.)	Purple sea urchin, teeth	-
Paracentrotus lividus (Lam.)	Purple sea urchin, other jaw fragments	-
	MNI – based on * item	1

QUADRANT 49-50	**COMMON NAME**	**US38**	**US39**	**US40**	**US42**	**US52**
Acanthocardia or *Cerastoderma* sp.	Rough or common cockle	-	-	-	-	-
Acanthocardia tuberculata (L.)	Rough cockle	-	-	-	-	-
cf. *Acanthocardia tuberculata* (L.)	cf. Rough cockle	-	-	-	-	-
Aequipecten opercularis (L.)	Queen scallop	-	1	-	-	-
Arca noae (L.)	Noah's ark shell	-	-	-	-	-
Bittium reticulatum (da C.)	Needle whelk	-	-	-	-	-
Bittium sp. (*tesselatum* (Mts.))	Horn snail	-	-	-	-	-
Bolinus brandaris (L.)	Purple dye murex	-	-	1	-	-
Cerastoderma edule (L.) or *glaucum* (Poir.)	Common/edible or lagoon cockle	-	-	-	-	-
cf. *Cerastoderma edule* (L.) or *glaucum* (Poir.)	cf. Common/edible or lagoon cockle	-	-	-	-	-
Cerithiidae indet.	Cerith	-	-	-	-	-
cf. *Cerithium* sp.	Cerith	-	-	-	-	-
Chamelea gallina (L.)	Striped venus	-	-	-	-	1
Columbella rustica (L.)	Rustic dove-shell	-	-	-	-	-
Crustacea	Crustacean	-	-	-	-	1
Diodora italica (Def.)	Limpet	-	-	-	-	-
Donacilla cornea (Poli)	Corneous wedge clam	3	8	7	28	4
Donax trunculus (L.)	Truncate donax	-	-	3	3	-
Ensis minor (Che.)	Minor jackknife clam	-	-	-	-	-
cf. *Eriphia verrucosa*	Warty crab	-	-	-	-	-
Fusinus pulchellus (Phil.)	Spindle snail	-	-	-	-	-
Gibbula albida (Gmel.)	Whitish gibbula	-	-	-	-	-
cf. *Gibbula albida* (Gmel.)	cf. Whitish gibbula	-	-	-	-	-
Gibbula philberti (Récl.)	Top snail	-	-	-	-	-
Gibbula sp.	Top snail	-	-	-	-	-
cf. *Gibbula* sp.	cf. Top snail	-	-	-	-	-
Glycymeris sp.	Bittersweet clams	-	-	-	-	-
Gregariella cf. *petagnae* (Sca.)	Half-hairy mussel	-	-	-	-	-
cf. *Gregariella* cf. *petagnae* (Sca.)	cf. Half-hairy mussel	-	-	-	-	-
Helicidae	Land snail	1	1	1	1	1
Helix pomatia or *aspersa*	Edible snail or garden snail	-	-	-	-	-
Hexaplex trunculus (L.)	Trunculus murex	1	-	1	-	-
cf. *Hexaplex trunculus* (L.)	cf. Trunculus murex	-	-	-	-	-
Lucinella divaricata (L.)	None	-	-	-	-	-
Modiolula phaseolina (Phi.)	None	-	-	-	-	-
Muricidae indet.	Murex family	-	-	-	-	-

QUADRANT 49-50	COMMON NAME	US38	US39	US40	US42	US52
Mytilaster cf. *minimus* (Poli.)	Mussel	-	-	-	-	-
Mytilidae indet.	Mussel	-	1	-	-	1
Mytilus galloprovincialis (Lam.)	Mediterranean mussel	-	-	-	-	-
Nassarius cf. *costulatus* (Ren.)	Dog welk	-	-	-	-	-
Nassarius cf. *costulatus cuvierii* (Pay.)	Dog welk	-	-	-	-	-
Nassarius cf. c*orniculum* (Olivi)	Horn nassa	-	-	-	-	-
Naticidae indet.	Moon shells	-	-	-	-	-
Ocenebra erinaceus (L.)	Hedgehog murex	-	-	-	-	-
Ocinebrina aciculata (Lam.)	Sea snail	-	-	-	-	-
Ocinebrina edwardsii (Pay.)	Sea snail	-	-	-	-	-
Odostomia eulimoides (Han.)	Pyram	-	-	-	-	-
cf. *Odostomia eulimoides* (Han.)	cf. Pyram	-	-	-	-	-
Ostrea edulis (L.)	Common/edible oyster	-	-	-	-	-
cf. *Ostrea edulis* (L.)	cf. Common/edible oyster	-	-	-	-	-
Patella sp.	Limpet	-	1	-	1	-
Pecten jacobaeus (L.)	Great scallop/pilgrim's scallop	-	1	1	1	1
Polititapes aureus (Gmel.)	Golden carpet shell	-	-	-	-	-
Sepia sp.	Cuttlefish	-	-	-	-	-
Spatangoida	Heart urchins	-	-	-	-	-
Spondylus gaederopus (L.)	European thorny oyster	-	-	-	-	-
Timoclea ovata (Pen.)	Oval venus	-	-	-	-	-
Tonna galea (L.)	Giant tun	-	-	-	-	-
cf. *Tonna galea* (L.)	cf. Giant tun	-	-	-	-	-
Turritella communis (Riss.)	Auger shell	-	-	-	-	-
Venerupis decussata (L.)	Chequered carpet shell	-	-	-	-	-
SEA URCHIN						
Paracentrotus lividus (Lam.)	Purple sea urchin, body fragments	10+	2	6	5	9
Paracentrotus lividus (Lam.)	Purple sea urchin, spines	10+	10+	10+	10+	5
Paracentrotus lividus (Lam.)	Purple sea urchin, pyramid plates	2*	-	-	2*	-
Paracentrotus lividus (Lam.)	Purple sea urchin, rotula	-	1*	-	1	-
Paracentrotus lividus (Lam.)	Purple sea urchin, teeth	-	-	-	1	-
Paracentrotus lividus (Lam.)	Purple sea urchin, other jaw fragments	-	-	-	-	-
	MNI – based on * item	1	1	1	1	1

EGGSHELL

Gallus gallus domesticus L. Chicken

QUADRANT 3-4	**US38**	**US39**	**US40**	**US41**	
	4.9	1.08	1	1.8	
QUADRANT 5-6	**US38**	**US39**	**US40**	**US42**	**US43**
	0.45	1.1	2.97	1.95	0.37
QUADRANT 13-14	**US38**	**US39**	**US40**		
	0.62	0.24	0.51		
QUADRANT 23-24	**US38**	**US39**	**US40**		
	1.36	0.01	1.7		
QUADRANT 49-50	**US38**	**US39**	**US40**	**US42**	**US52**
	0.31	0.1	0.2	0.74	0.41