**Bioarchaeological preservation and non-elite diet in the Bay of Naples: An analysis of the food remains from the Cardo V sewer at the Roman site of Herculaneum**

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**Abstract**

Due to its burial by the eruption of Vesuvius in AD79, the level of biological preservation in the Roman town of Herculaneum is very high. The recovery and analysis of large quantities of material from the city’s Cardo V sewer has provided the rare opportunity to study the diet of middle and lower class Romans living in an urban context in mid-1st century AD Italy. The sewer lacked an outflow point and instead functioned as a cesspit to collect the human and kitchen waste generated by those living in the multi-storey shop and apartment complex (*Insula Orientalis* II) situated above. In total, 220L of soil was examined for carbonized and mineralized material, seashells, eggshells, otoliths and fish bones. 194 taxa were identified, including 94 botanical, 45 fish, 53 shellfish and two bird taxa. 113 of the 194 taxa can be considered edible foodstuffs indicating a high level of dietary diversity. This article compares preservation conditions with those found in Pompeii and assess diet in relation to these findings. The level of preservation is found to be comparable between the two sites and no major taphonomic biases are observed. The diet of non-elite individuals in Herculaneum is found to consist of a few staple foods that are frequently supplemented by a wide range of other goods. Subtle differences in diet are observable in the sewer assemblage, most likely related to differences in wealth.

**Keywords:** Herculaneum, Roman, Diet, Archaeobotany, , Mineralization, Pompeii

**Introduction**

Several Roman sites situated on the Bay of Naples in Italy, including Pompeii and Herculaneum, were buried by the eruption of Mount Vesuvius in AD79. The submersion of Pompeii beneath pumice and Herculaneum beneath pyroclastic ash led to the creation of several sealed deposits of archaeobotanical and zooarchaeological material and consequently these sites are our best sources of evidence for diet in Roman Italy . To date, the majority of the bioarchaeological data from the region comes from Pompeii as it has been subject to more extensive excavation and sampling of material below the AD79 level than either Herculaneum or the nearby villas. In addition to tombs and bakeries, the gardens, kitchens, floor surfaces, and latrines of several domestic and commercial properties at Pompeii have been excavated, resulting in substantial quantities of carbonized, mineralized and zooarchaeological material (Robinson, 1999, 2002, 2007; Jashemski and Meyer2002; Ciaraldi 2007; Kockel and Flecker 2008; Matterne and Derreumaux 2008; Monteix 2009, 2010a; Monteix *et al.* 2011; Fairbairn 2012; Murphy *et al.* 2013; Rowan 2014a, 2014b). Herculaneum has lagged significantly behind with regards to bioarchaeological research and prior to the large scale cleaning of the site by the Herculaneum Conservation Project (HCP) in 2006, the site had never been properly sampled for bioarchaeological material (Wallace-Hadrill 2006). The only biological finds were those intermittently recorded during the early excavations of the 1700-1960s (Maiuri 1958; Meyer 1980, 1988; Borgongino 2006).

Although Pompeii has undergone extensive sampling, the mixed nature of many of the deposits, often from the larger houses, has made it difficult to distinguish the diets of the wealthy from those of lesser financial means (Ciaraldi 2007, 151, 155). Within a Roman household, slaves and even freedmen lived alongside their owners and their families (George 1997). Thus determining whether an assemblage represents a slave diet, the diet of the owners or both is almost impossible. Moreover, it is unclear who was permitted to utilize indoor latrines. Consequently, we are still heavily dependent on the ancient sources for understanding non-elite diet. While several ancient Roman authors discuss food and some such as Pliny the Elder do focus on food in the Bay of Naples, many authors (ie. Juvenal, Martial, Horace) utilize food as a metaphor to comment upon the dining activities of their fellow aristocrats, particularly in Rome. This article will utilize the food remains from a sewer in Herculaneum to assess the preservation of pre-AD79 Herculaneum deposits in relation to similar deposits recovered from Pompeii while simultaneously providing crucial evidence for non-elite diet in the Bay of Naples.

**Overview of the Roman town of Herculaneum**

Herculaneum was situated on a tuff terrace that slopes gently towards the sea. The site was originally founded in the 4th century BC, possibly as a Greek settlement (Wallace-Hadrill 2011, 93-94). According the ancient geographer Strabo, Herculaneum, like Pompeii was originally controlled by the Oscans and then subsequently by the Etruscans, the Greeks, the Samnites and finally the Romans (*Geog.* 5.4.8). Herculaneum was granted the status of *municipium* in 89BC (DeKind 1998: 21). During the 1st century BC the wealthy elite from Rome began building large and lavishly decorated villas, such as the Villa of Oplontis, along the nearby coastline. The influx of wealth to the region resulted in the construction of several well decorated public buildings including the central baths, the Basilica Noniana and the theatre (Monteix 2010b: 349). New buildings continued to be constructed during the 1st century AD (Monteix 2010b: 260; Wallace-Hadrill 2011: 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 2010b: 234-235). Again, the city repaired itself and the increase in the number shops and upper floor apartments created during this time suggests that the city was in a period of economic growth when the eruption of Vesuvius occurred in AD79 (Monteix 2010a: 353).

Only the southern half of the town has been excavated, approximately 4.5 hectares, although it is estimated that the entire town is between 15-20 hectares (Guidobaldi 2008: 22; Wallace-Hadrill 2011: 105) (Fig. 1). It was built on a grid plan with series of rectangular *insula* blocks enclosed by *cardines* (north-south streets) and *decumani* (east-west streets). The population at the time of the eruption is estimated to be between 4000-5000 people (Camodeca 2008: 87).

**Figure 1 here**

***Insula Orientalis* II**

The north eastern section of the town is occupied by the large multi-building complex referred to as the *palaestra* (see fig. 1). The western side of the *palestra* is occupied by *Insula Orientalis* II, a mixed commercial and residential structure whose shops and apartments face the Cardo V. The separately accessible back porticoes and rooms of *Ins. Or.* II face into the center of the complex towards the pool. Construction on *Ins. Or.* II began during the early first century AD and it was finished sometime between AD 25-35. The building had two storeys running the entirety of its length. Since it was built on a significant incline towards the north, some of the units at the southern end also had a third storey. 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; Monteix 2010: 257-263) (Fig. 2). 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 (Monteix 2010b: 288; Wallace-Hadrill 1994: 117).

**Figure 2 here**

The ground floor shops varied significantly in size and function and many contained domestic spaces in the backrooms, on the upper floors or on mezzanine levels (Figs. 3 and 4). Due to alterations over time in the original spacing of the rooms and size of the ground floor units of *Ins. Or.* II, only the activities taking place in the insula during the final phase of use are observable (Table 1). At the time of the eruption, 41% of the ground floor of the building was dedicated to commercial space (Monteix 2010b: 284-286). The unique layout of each shop and apartment reflect a range of activities and socioeconomic statuses.

**Figures 3 and 4 here**

Table 1. Total commercial and living spaces in AD79 for the units of *Ins. Or.* II situated above the Cardo V sewer

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Unit** | **Probable function** | **Domestic space** | **Identifying features** | **Ground floor (m2)** | **Upper floor**  **(m2)** | **Total space (m2)** | **Latrine location** |
| Or. II.6 | Food shop  dried foodstuffs, wine, possibly hot cooked food | Yes | Masonry counter with dolia, amphora stacked in back room | 48.1 | 49 | 97.1 | SW corner of room 1 |
| Or. II.7 | Independent upper floor domestic space(s) | Yes | Kitchen | 0 | 848 | 848 | Second floor, room 22, access by balcony only |
| Or. II.8 | Bakery | No | Oven, millstones | 110.2 | 0 | 110.2 | Room 8.3 |
| Or. II.9 | Wine shop, possibly food | Yes | Wooden wine rack | 35.8 | 22.3 | 58.1 | SW corner of room 1 |
| Or. II.10 | Turned wooden goods and gems | Yes | Gems, wood working tools | 56.2 | 19.5 | 57.7 | SW corner of room 1 |
| Or. II.11-12 | Textile production | Yes | Tiled floor, boiler | 85.3 | 15.4 | 100.7 | SW corner of room 11.1, possibly one in 12.2 |
| Or. II.13 | Cooked food | Yes | Masonry counter with dolia, water heater/ cook top | 77.3 | 7.9 (mezzanine) | 85.2 | None |
| Or. II.14 | Unknown | Yes | No surviving features | 66.5 | 2.2 (mezzanine) | 78.7 | SW corner of room 1 |

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

**Waste removal and the Cardo V sewer**

In Herculaneum, the 8% slope of the terrace towards the sea meant that the city streets were used to channel rainwater towards the beach (Camardo *et al.* 2006: 190 n.24). However, the hard and compact tuff terrace did not absorb water and thus soakaway cesspits could not be used for the collection of waste and waste water 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 (CIL. IV suppl. 3.4.10606). Consequently, large sewers were built beneath Cardo III and Cardo IV that drained waste water towards the beach (Camardo 2007: 180; 2011).

Built directly beneath *Ins. Or.* II and not under the street like the Cardo III and IV sewers, the Cardo V sewer did not empty onto the beach but was closed off by a wall to the south (Camardo 2008: 418) (see fig. 1). This tunnel functioned as a cesspit for the human and cooking waste generated by those living in *Ins. Or.* II. The main north-south and east-west branches of the sewer, which form an almost perfect L-shape, were part of the building’s initial construction. There were subsequent additions, including numerous small side branches, which resulted in a complex series of tunnels (see fig. 2). The walls and vaulted ceiling of the sewer were made of tuff with large areas built in the irregular *reticulatum* typical of Herculaenum (Camardo 2008:417).

The north-south branch was fed by eight latrine shafts and three small rain water drains (see Table 1). 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. Based on the ceramic and coin evidence, it is estimated that the sewer had not been cleaned in the 10 years prior to the eruption, and thus the whole context dates to AD69-79 (Paul Roberts May 23, 2011, pers. comm.).

The north-south branch was 85.6 m long, running from II.14 to II.1 and was 80 cm wide. At its start at II.14 the tunnel was 2 m high but rose to a height of 3.5 m at its southern end (Camardo 2008: 417, 2011: 90). The tunnel sloped gently downwards, following the slope of the terrace that was created to level this section of the town (Camardo 2011; Wallace-Hadrill 2011: 275) (Fig. 5). The larger east-west branch (20.9m x 1.7m x 3.2m) met the north-south branch at *Ins. Or.* II.2 and acted as a collection point for the organic (and often inorganic material such as pottery, glass and building debris) material that was slowly shifting down the north-south branch (Camardo 2008: 417-418, 420). The liquid contents presumably drained away through an as yet unlocated channel towards the beach (Camardo 2011).

**Figure 5 here**

During the eruption of Vesuvius, the Cardo V sewer 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 (Fig 6).

The Cardo V sewer was first uncovered and partially excavated in 1949 (Maiuri 1958: 467-469). The first 50m of material from the north-south branch, from II.1-5, was removed and the east-west branch was completely emptied. Consequently, the organic material situated between II.6 to II.14 remained untouched. In 2006 the Herculaneum Conservation Project (HCP) as part of a site wide restoration project, installed a pipe line along the roof of the sewer, designed to help drain rainwater from the site. The installation of the pipe necessitated the systematic excavation by the HCP of all the organic and inorganic remains from the Cardo V sewer (HCP 2010).

**Figure 6 here**

**Materials and Methods**

The hardened volcanic debris was removed from the north-south branch of the sewer between *Ins. Or.* II.6-14 using a power drill (Camardo 2008:419). The HCP divided this section of the sewer into 53 one-meter quadrants. 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, unità stratigrafica 40 while Q23-24, US40 refers to quadrant 23-24, stratigraphic layer 40. 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. The downwards slope of the tunnel meant that the solid contents shifted slowly towards the south and therefore, despite the division into quadrants, the sewer is considered a single archaeological context.

In total, over 11,625 L of soil containing environmental material was collected into 775 15 L sample bags. Material from alternating quadrants, starting with Q1-2, (roughly 10% of the total volume of material) was processed on-site in September 2007 by Professor Mark Robinson and a team from the University of Oxford. Thus, Q3-4 and Q5-6 were sorted while Q4-5 remains unsorted in storage. Ten litres from each 15L bag from each stratigraphic layer was processed while the other 5 L have been held in reserve should the need for further study arise. During the field season approximately 1140 L of soil or 76 samples were processed. During excavation large non-biological items such as pottery fragments were removed by hand.

Due to water constraints it was not possible to use machine assisted flotation, and instead the following bucket flotation procedures were used. Each 10 L sample was first washed through an 8.5 mm mesh into a large plastic drum in order to break up the sample and enabled larger items, including both bioarchaeological remains and artefacts to be recovered. 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) and allowed to dry. The remaining sediment in the drum, the residue, was then sieved over a 1 mm mesh. Once dry, the residue was further divided using 2 mm and 1 mm sieves. The material collected from the 8,5mm sieve 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.

All of the bioarchaeological material from six quadrants was examined in Oxford by the author as part of her DPhil thesis, representing approximately 30% of the total volume of processed material (Rowan 2014a) (see fig. 2). 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 2).

Table 2. List of quadrants and stratigraphic layers examined in this study. Blank spaces represent stratigraphic layers not present in a quadrant.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **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 identified material included the mineralized, carbonized and dried waterlogged assemblages (if present) as well as the eggshell, seashell, fish bones and otoliths. The sorting of the archaeobotanical material was conducted using a binocular microscope with a magnification range of x6 to x50. The identification of the archaeobotanical material was made by comparison with modern reference material in Professor Robinson’s personal seed collection (Oxford University Museum of Natural History) and by reference to seed guides (Jacomet 2006; Cappers *et al.* 2009; Neef *et al.* 2012; Cappers and Neef 2012).

The small numbers of seeds (other than fig pips) in each sample meant that simple counting was often sufficient. Whole and fragmentary seeds were counted based on identifiable features such as apices. If the smaller fragments of any seed were not part of an identifiable feature then the combined fragments were given an MNI of one. Olive stone assemblages with over 100 fragments were weighed. 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. For samples containing less than 100 fragments, a reconstruction method, whereby fragments equaling the size of one carbonized olive awere put together and the subsequent groups counted, was found to be sufficient. 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. Since only a quarter sample of the residue material sorted below 2mm was brought back to Oxford, any seeds smaller than 2mm, such as *Urtica dioica,* have been multiplied by four in the raw counts provided below.

The fish bones were identified by Dr. Rebecca Nicholson at Oxford Archaeology while the fish otoliths were identified by the author using the Anàlisi de Formes d’Otòlits (AFORO) online database and Dr. Nicholson’s reference collection (Lombarte *et al.* 2006). The number of left and right sagitta were counted to provide an MNI. The seashells were identified by the author and identifications were confirmed by Jenny Robinson. 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). 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. Five eggshell fragments from each eggshell sample were measured for thickness using an eyepiece graticule under x20 magnification. In total, 100 fragments were measured.

**Results**

In total, there were 194 taxa identified, included including 94 botanical, 45 fish, 53 shellfish and two bird taxa (Tables 3-6). There were 2188 mineralized remains identified (excluding the fig pips), 833 carbonized items and 31 waterlogged remains. The fish bones were scanned quickly to identify the range of species and full MNI counts were not performed. There were 170 identified whole otoliths, 134 unidentified and 183 fragments along with a MNI of 656 for the seashells. Out of the 194 taxa, 114 taxa represent edible foodstuffs including 35 taxa from the archaeobotanical assemblage, all 45 fish, 32 shellfish and both bird shell taxa.

**Figure 7 here**

*Botanical material*

There were 84 mineralized, 27 carbonized and 9 waterlogged taxa with material from 19 taxa present in both the carbonized and mineralized assemblages (Fig. 7). The subsequent filling and sealing of the sewer with pyroclastic material allowed a small quantity of waterlogged material to survive in pockets that must have been particularly wet or damp.

The mineralized assemblage was composed primarily of weed seeds, millet, and the small seeds from herbs and fruits that could be swallowed whole. Finds of *Buxus* sp. and *Cupressus sempervirens* represent the presences of ornamental plants. The carbonized assemblage was dominated by carbonized olive stones followed by grapes, other fruit seeds, weed seeds and nut shells. The waterlogged remains were composed of mostly fruit and weed seeds.

Table 3: Archaeobotanical remains from the Cardo V sewer (MNI counts)

| **Taxonomic name** | **Common name** | **Type of remain** | **Mineralized** | **Carbonized** | **Waterlogged** |
| --- | --- | --- | --- | --- | --- |
| **Cereals** |  |  |  |  |  |
| *Hordeum* sp. | Barley | caryopsis | - | 3 | - |
| *Panicum miliaceum\** | Common millet | caryopsis | 52 | - | - |
| *Panicum miliaceum\** or *Setaria italica\** | Common or foxtail millet | caryopsis | 196 | 1 | - |
| *Setaria italica\** | Foxtail millet | caryopsis | 34 | 1 | - |
| cf*. Sorghum* sp. | Sorghum | caryopsis | 7 | - | - |
| *Triticum aestivum* | Bread wheat | rachis node | - | 1 | - |
| *Triticum dicoccum* | Emmer wheat | caryopsis | 1 | 1 | - |
| *Triticum dicoccum* or *Triticum monococcum* | Emmer or einkorn wheat | caryopsis | - | 2 | - |
| *Triticum monococcum* | Einkorn wheat | caryopsis | - | 1 | - |
| *Triticum* sp. | Wheat | caryopsis | - | 1 | - |
| Cereal grain | Cereal grain | caryopsis | 3 | 3 | - |
|  |  |  |  |  |  |
| **Legumes and pulses** |  |  |  |  |  |
| *Lens culinaris* | Lentil | seed | 16 | 2 | - |
| *Vicia faba* var. *minuta* | Broad bean | seed | 3 | - | - |
| *Vicia* or *Lathyrus* sp. | Vetch or pea | seed | 1 | 3 | - |
| *Vicia* sp. | Vetch | hilum | 1 | - | - |
|  |  |  |  |  |  |
| **Fruit** |  |  |  |  |  |
| cf. *Celtis australis* | Mediterranean hackberry | berry | 1 | - | - |
| *Cucumis melo* or *sativus* | Melon or cucumber | seed | 4 | - | - |
| *Ficus carica* | Fig | achene | thousands | 12 | - |
| *Malus* or *Pyrus* sp. | Apple or pear | Seed | 33 | 3 | 3 |
| *Malus* sp. | Apple | Seed | 1 | - | - |
| *Morus nigra* | Black mulberry | endocarp | 11 | - | - |
| *Olea europaea* | Olive | endocarp | - | 666 | - |
| *Olea europaea* | Olive | seed | 19 |  |  |
| *Phoenix dactylifera* | Date | endocarp | 1 | 1 | - |
| *Prunus avium* or *cerasus* | Wild or dwarf cherry | stone | 3 | - | - |
| *Prunus domestica* | Wild plum | stone | 4 | - | - |
| *Prunus* sp. | Stone fruit | stone | 9 | - | - |
| *Pyrus* sp. | Pear | seed | - | 1 | - |
| *Rubus fruticosus* (agg.) | Blackberry | endocarp | 12 | - | 2 |
| *Rubus fruticosus* (agg) | Blackberry | thorn | - | - | 2 |
| *Vitis vinifera* | Grape | pip | 149 | 49 | 8 |
| *Vitis vinifera* | Grape | stalk | 1 | 10 | - |
|  |  |  |  |  |  |
| **Nuts** |  |  |  |  |  |
| *Corylus avellana* | Hazelnut | shell frag. | 2 | 1 | - |
| *Juglans regia* | Walnut | shell frag. | - | 6 | - |
| *Pinus pinea* | Stone pine | bract |  | 3 |  |
| *Pinus pinea* | Stone pine | husk | 1 | - | - |
| *Pinus pinea* | Stone pine | nut | - | 2 |  |
| *Pinus pinea* | Stone pine | seed |  | 3 | - |
|  |  |  |  |  |  |
| **Herbs and Seasonings** |  |  |  |  |  |
| cf. *Anethum graveolens* | Dill | mericarp | 5 | - | - |
| *Apium graveolens\** | Wild celery | mericarp | 47 | - | 1 |
| *Brassica* sp.\* | Cabbage or mustard | seed | 41 | - | - |
| *Coriandrum sativum* | Coriander | mericarp | 3 | - | - |
| *Foeniculum vulgare* | Fennel | mericarp | 20 | - | - |
| *Linum usitatissimum* | Flax/linseed | seed | 4 | - | - |
| *Mentha* sp. | Mint | mericarp | 11 | - | - |
| *Papaver somniferum\** | Opium poppy | seed | 83 | - | - |
| *Piper nigrum* | Black pepper | berry | 2 | - | - |
|  |  |  |  |  |  |
| **Possible foodstuffs** |  |  |  |  |  |
| *Ceratonia silique* | Carob | seed | 1 | - | - |
| *Daucus carota* | Wild carrot | seed | - | - | 5 |
| *Malva* sp. | Mallow | seed | 26 | - | - |
| *Medicago* sp. | Medick | seed | 10 | - | - |
|  |  |  |  |  |  |
| **Weeds, ruderals and other taxa** |  |  |  |  |  |
| Amaranthaceae | Amaranth family | seed | 36 | 0 | 0 |
| *Anagallis* sp. | Pimpernel | seed | 2 | - | - |
| *Anthemis arvensis* | Corn chamomile | achene | 12 | - | - |
| *Aphanes* sp. | Parsley-piert | seed | 1 | - | - |
| Apiaceae | Parsley family | mericarp | 138 | 1 | 7 |
| Asteraceae | Daisy family | achene | 4 | - | - |
| cf. *Avena* sp. | Wild oat | caryopsis | - | 1 | - |
| Boraginaceae | Borage family | seed | 2 | - | - |
| Brassicaceae | Cabbage family | seed | 2 | - | - |
| *Carduus* sp. | Thistle | seed | 2 | - | - |
| *Carex* sp. | Sedge | utricle | 21 | - | - |
| Caryophyllaceae | Carnation family | seed | 99 | - | - |
| cf. *Centaurea* sp. | Knapweed | achene | 1 | - | - |
| *Chara* sp. | Green algae | seed | 1 | - | - |
| *Chenopodium album\** | Fat-hen | achene | 4 | - | - |
| *Chenopodium* sp.\* | Goosefoot | achene | 53 | 2 | - |
| Cyperaceae | Sedge family | seed | 2 | - | - |
| Fabaceae | Legume family | seed | 3 | - | - |
| *Fumaria* sp. | Fumitory | seed | - | - | 1 |
| Lamiaceae\* | Mint | achene | 42 | - | 1 |
| *Linum* sp. | Flax | seed | 2 | - | - |
| *Lithospermum arvense* | Field gromwell | seed | 1 | - | - |
| cf. *Medicago* sp. or *Melilotus* sp. | Medick or melilot | seed | 1 | - | - |
| *Ornithopus* sp. | Bird’s foot | seed | 7 | 1 | - |
| *Papaver* sp. | Poppy | Seed | 22 | - | - |
| *Papaveraceae* | Poppy family | Seed | 1 | - | - |
| cf. *Plantago* sp. | Plantain | Seed | 1 | - | - |
| Poaceae | Wild grass | caryposis | 11 | 6 | - |
| Poaceae | Wild grass | rachis frag. | - | 5 | - |
| Polygonaceae\* | Knotweed family | achene | 35 | - | - |
| *Polygonum aviculare* (agg)\* | Knotgrass | achene | 14 | - | - |
| *Polygonum* sp.\* | Knotweed | achene | 25 | - | - |
| *Pteridium aquilinum* | Bracken | frond frag. | 3 | - | - |
| cf. *Ranunculus parviflorus* | Small-flowered buttercup | achene | 2 | - | - |
| *Ranunculus* sp.\* | Buttercup | achene | 16 | - | - |
| *Ranunculus* subgens. *Ranunculus* | Buttercup | achene | 4 | - | - |
| *Reseda* sp. | Mignonette | seed | 52 | - | - |
| cf. *Rubus* sp. | Bramble | endocarp | 2 | - | - |
| *Rumex acetosella* agg. | Sheep's sorrel | achene | 3 | - | - |
| *Rumex* sp. | Dock | achene | 8 | 1 | - |
| *Sambucus* sp. | Elder | endocarp | 1 | - | - |
| Scrophulariaceae | Figwort family | seed | 2 | - | - |
| *Sherardia arvensis\** | Field madder | seed | 21 | - | - |
| *Silene gallica* | Small-flowered catchfly | seed | 10 | - | - |
| *Silene* sp. | Campion | seed | 2 | - | - |
| *Stellaria media\** | Common chickweed | seed | 30 | 1 | 2 |
| *Stellaria* sp. | Chickweed | seed | 2 | - | - |
| *Urtica dioica\** | Common stinging nettle | achene | 79 | - | - |
| *Urtica* sp.\* | Nettle | achene | 56 | - | - |
| *Vicia ervilia* | Bitter vetch | seed | - | 1 | - |
| *Viola* sp. (subgen.) *Melanium* | Pansy | seed | 1 | - | - |
|  |  |  |  |  |  |
| **Ornamental plants** |  |  |  |  |  |
| *Buxus* sp. | Box | stem | 1 | - |  |
| *Cupressus sempervirens* | Mediterranean cypress | twig | 7 | 5 |  |
| **Totals** |  |  | **1629** | **800** | **32** |

\* Sum has been multiplied by 4 when item in the residue samples was smaller than 2mm

*Cereals and legumes*

A wide range of cereals were recovered, but, with the exception of *Panicum miliaceum* and *Setaria italica*, all were present in very small quantities. The millets were often mineralized while all but one of the *Triticum* sp. were carbonized. The paucity of wheat and barley, and especially chaff, is probably due to the practice of processing cereals outside Herculaneum as well as the tendency for grain to be ground into flour in the bakery at *Ins. Or.* II.8. The diversity of grains, however, does indicate varied cereal consumption.

Three varieties of pulses and legumes were identified and usually present in a mineralized form. The *Vicia sp*. may represent intentional consumption but seeds from this genus can also appear as grain contaminants or be used as a fodder crop. Again, the small quantities of legumes and pulses are probably due to their softening and destruction during the cooking process.

*Fruits and Nuts*

The fruits were taxonomically the most diverse and abundant category of foodstuffs found in the archaeobotanical assemblage. All of the fruit had been preserved through mineralization except for a *Pyrus* sp. seed which was recovered only in carbonized form. *Ficus carica* and *Vitis vinifera* were the most abundant mineralized food items recovered from the sewer attesting both to their frequency of preservation and consumption. Apples, pears, mulberries and blackberries were also relatively common in the samples. The remaining eight fruits were found only intermittently. *Olea europaea* dominated the carbonized assemblage. While some of the endocarps represent food waste, the majority indicate the use of olive oil pressing waste (pomace) as a fuel source (Rowan 2015: 473-5).

Fragments from three nut taxa were recovered. *Corylus avellana* and *Pinus pinea* were found mineralized and carbonized while *Juglans regia* 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 *Pinus pinea* bracts and nutswere found, suggesting a possible use in ritual burnt offerings.

*Herbs and Seasonings*

All nine taxa in this category were preserved through mineralization. The small quantitiy of *Linum usitatissimum* seeds suggest consumption rather than fiber extraction. *Papaver somniferum* was the most commonly recovered herb followed by *Apium graveolens, Brassica* sp. and *Foeniculum vulgare*. The identification of *Piper nigrum*, which would have been imported from India during this period (Cappers 2006: 111), was probably one of the most expensive items recovered from the entire sewer assemblage and was certainly the most expensive seasoning.

*Eggshell*

All but two of the measured fragments had a thickness range between 0.25 mm and 0.35 mm, which falls into the range of domestic chicken or duck. Chicken bones were found in the sewer, making it the more probable species. The two thicker fragments ranged from 0.52 mm and 0.6 mm and may have come from domestic goose as their shells are between 0.525-0.65 mm thick (Siddell 1993: 13).

*Fish*

The identifications from the otoliths and fish bones from six strata and five quadrants produced a total of 45 taxa. *Spondyliosoma cantharus* and *Chromis chromis* were found in the highest quantities followed by the seven other identified Sparidae species (see Rowan 2014b for a detailed discussion of the particular fish species). The survival of 338 whole and 183 fragmentary otoliths is an incredibly rare occurrence and their recovery suggests very particular preservation conditions present in the sewer. Very few fish scales were recovered.

Table 4. Identified fish taxa from the Cardo V sewer

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

\*Based on otolith raw counts (not MNI)

*Shellfish*

Land snails, have been grouped with the shellfish and were found in large enough quantities to suggest human consumption. All 52 shellfish taxa can be found in the littoral zone, which ranges from the beach to approximately 60 m into the sea (Abbott and Dance 1991; Palomares and Pauly 2013). 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). Out of the 31 edible taxa, the only species recovered in extremely large quantities were *Donacilla cornea,* *Patella, Paracentrotus lividus* (Fig. 8). The 20 small inedible taxa were mostly predatory species, where even the maximum size of the shell or creature was still too small to be considered a human foodstuff. *Sepia* sp. was also found.

Table 5. Identified shellfish taxa from the Cardo V sewer

| **Taxonomic name** | **Common name** | **Edible**  **(Y/N)** | **MNI** | **Max/sample** |
| --- | --- | --- | --- | --- |
| *Acanthocardia* or *Cerastoderma* sp. | Rough or common cockle | Y | 1 | 1 |
| *Acanthocardia tuberculata* (L.) | Rough cockle | Y | 4 | 1 |
| *Aequipecten opercularis* (L.) | Queen scallop | Y | 21 | 4 |
| *Arca noae* (L.) | Noah’s ark shell | Y | 7 | 1 |
| *Bittium reticulatum* (da C.) | Needle whelk | N | 1 | 1 |
| *Bittium* sp. (*tesselatum* (Mts.)) | Horn snail | N | 2 | 1 |
| *Bolinus brandaris* (L.) | Purple dye murex | Y | 14 | 3 |
| *Cerastoderma edule* (L.) or *glaucum* (Poir.) | Common/edible cockle | Y | 6 | 2 |
| Cerithiidae indet. | Cerith | N | 1 | 1 |
| cf. *Cerithium* sp. | Cerith | N | 1 | 1 |
| *Chamelea gallina* (L.) | Striped venus | Y | 4 | 1 |
| *Columbella rustica* (L.) | Rustic dove-shell | N | 2 | 1 |
| Crustacea | Crustacean | Y | 3 | 1 |
| *Diodora italica* (Def.) | Limpet | Y | 5 | 2 |
| *Donacilla cornea* (Poli) | Corneous wedge clam | Y | 255 | 58 |
| *Donax trunculus* (L.) | Truncate donax | Y | 12 | 3 |
| *Ensis minor* (Che.) | Minor jackknife clam | Y | 1 | 1 |
| cf*. Eobania* or *Helix* sp. | Land snail | Y | 39 | 5 |
| *Eriphia verrucosa* (Forsk.) | Warty crab | Y | 1 | 1 |
| *Fusinus pulchellus* (Phil.) | Spindle snail | N | 1 | 1 |
| *Gibbula albida* (Gmel.) | Whitish gibbula | N | 3 | 2 |
| *Gibbula philberti* (Récl.) | Top snail | N | 2 | 2 |
| *Gibbula* sp. | Top snail | Y/N? | 3 | 1 |
| *Glycymeris* sp. | Bittersweet clams | Y | 5 | 1 |
| *Gregariella* cf. *petagnae* (Sca.) | Half-hairy mussel | Y/N? | 2 | 1 |
| *Helix aspersa* (Müller) | Garden snail | Y | 4 | 4 |
| *Hexaplex trunculus* (L.) | Trunculus murex | Y | 8 | 2 |
| *Lucinella divaricata* (L.) | None | N | 1 | 1 |
| *Modiolula phaseolina* (Phi.) | None | N | 1 | 1 |
| Muricidae indet. | Murex family | Y | 2 | 1 |
| *Mytilaster* cf. *minimus* (Poli.) | Mussel | N | 57 | 36 |
| Mytilidae indet. | Mussel | Y | 4 | 1 |
| *Mytilus galloprovincialis* (Lam.) | Mediterranean mussel | Y | 2 | 1 |
| *Nassarius* cf. *costulatus* (Ren.) | Dog welk | N | 1 | 1 |
| *Nassarius* cf. *costulatus cuvierii* (Pay.) | Dog welk | N | 2 | 2 |
| *Nassarius* cf. c*orniculum* (Olivi) | Horn nassa | N | 1 | 1 |
| Naticidae indet. | Moon shells | N | 1 | 1 |
| *Ocenebra erinaceus* (L.) | Hedgehog murex | Y | 2 | 1 |
| *Ocinebrina aciculata* (Lam.) | Sea snail | N | 1 | 1 |
| *Ocinebrina edwardsii* (Pay.) | Sea snail | N | 1 | 1 |
| *Odostomia eulimoides* (Han.) | Pyram | N | 2 | 1 |
| *Ostrea edulis* (L.) | Common/edible oyster | Y | 4 | 2 |
| *Paracentrotus lividus* (Lam.) | Purple sea urchin | Y | 49 | 18 |
| *Patella* sp. | Limpet | Y | 86 | 23 |
| *Pecten jacobaeus* (L.) | Great scallop/pilgrim's scallop | Y | 12 | 1 |
| *Polititapes aureus* (Gmel.) | Golden carpet shell | Y | 1 | 1 |
| *Sepia* sp. | Cuttlefish | Y | 1 | 1 |
| Spatangoida | Heart urchins | Y | 1 | 1 |
| *Spondylus gaederopus* (L.) | European thorny oyster | Y | 1 | 1 |
| *Timoclea ovata* (Pen.) | Oval venus | N | 1 | 1 |
| *Tonna galea* (L.) | Giant tun | Y | 2 | 1 |
| *Turritella communis* (Riss.) | Auger shell | N | 2 | 1 |
| *Venerupis decussata* (L.) | Chequered carpet shell | Y | 10 | 3 |

**Figure 8 here**

**Movement of the material**

For each type of material, density, ubiquity scores were generated and taxa were ranked according to three scales of abundance. Density ratios confirmed a downward shift in all forms of bioarchaeological material towards the south (Fig 9). There were specific areas of buildup particularly at Q5-6 and Q23-24. The decrease slope of the tunnel from 7.9% to 6.5%, just prior to Q23-24, made it one of the flattest portions of the tunnel thereby facilitating material accumulation (see fig. 5). Similarly, Q5-6 is situated at the end of the longest interval without a latrine shaft and therefore lacked any additional water to help push material downstream.

Taking these areas of build up into account, it is clear that not all the material moved down the sewer at the same rate. Entering the sewer as loose material produced during cooking and heating, the light and buoyant carbonized material moved the farthest, floating downstream whenever there was a sufficient amount of water. 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 larger and heavier fish and shellfish material underwent the least amount of movement. 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.

**Figure 9 here**

Despite this downwards movement and the subsequent variation in density, the identified taxa have displayed a remarkable level of consistency in terms of diversity, abundance and ubiquity. Each quadrant displayed a wide range of taxonomic diversity and although the abundance levels were moderate to low, the ratio between abundance levels did not vary considerable by either preservation type or quadrant (Fig. 10). There was no spike in abundance levels in either the mineralized, carbonized or shell material, nor in a particular quadrant. These results suggest that preservation conditions within the sewer were consistent across its entire length. For example, 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 diversity and abundance levels, particularly when looking at the quadrants.

There was also a very high degree of overlap for the taxa falling into the two highest categories of abundance (red and green bars in figure 10). For example, while the number of taxa falling into the 10-100 abundance category for mineralized material ranges from twenty to zero, the entirety of that category consists of only 25 taxa. Thus all the taxa in Q13-14 and Q49-50 with high abundance levels can also be found in Q5-6. Half of these mineralized taxa are edible items. Similarly, grapes and olives are the only two carbonized taxa to have more than 10 items per quadrant.

**Figure 10 here**

Taking the relationship between preservation and consumption practices into account, it is also interesting to note that that the most abundant food items also have high ubiquity scores and are dispersed across multiple quadrants and samples (Fig. 11). These findings suggest that preservation conditions, and the diets of those living in *Ins. Or.* II, were stable across both space and time. The items in figure 11 reflect some of the most frequently consumed foodstuffs, but also items that tend to preserve well such as grape pips and poppy seeds. If the diet had changed or if the preservation conditions within the sewer, particularly with respect to the mineralized material, had been altered then those items found in the greatest abundance would not also be the most ubiquitous.

**Figure 11 here**

**Discussion**

*Preservation conditions*

The range of identified items from the Cardo V sewer provides important information regarding bioarchaeological preservation at Herculaneum, which in turn enable comparison with preservation conditions at Pompeii. Moreover, as a closed and sealed context, the material allows for a nuanced discussion regarding the diets of those living above the sewer in *Ins. Or.* II.

Overall, the level of preservation, for all forms of bioarchaeological material, was very high. While fish bone preservation was excellent, the large faunal remains have yet to be analyzed and thus are not included here. Mineralization of the botanical material occurred through calcium-phosphate replacement in a manner similar to that described by Green (1979), Robinson (2006, 2011) and Marshall (2008). Within the sewer, the human faecal matter provided the necessary phosphate ions while calcium carbonate was derived from the wide variety of faunal material. Mammal and fish bones acted as additional sources of both phosphate and calcium (Green 1979: 281). Small fragments of mortar and lime, which were used in construction and wall plaster respectively, were frequently found in the sewer samples and would have provided additional calcium (Robinson 2006: 214). Water came from cooking, urine, the flushing of the latrines and the three small rooftop rainwater drains (Hobson 2009: 25). The downward slope of the channel and multiple entry shafts guaranteed the movement of waste water which facilitated the deposition of the phosphate and calcium ions 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 in the decade before the eruption, the material was kept in a stable environment and its burial during the eruption made certain that it remained in an undisturbed state. (Camardo 2007: 181).

The diversity of the mineralized assemblage, the high degree of overlap between the carbonized and mineralized assemblages (n=19), and the presence of rarely mineralized items such as emmer, olive seeds and hazelnut shell, indicate that the sewer contained the ideal chemical conditions required for mineralization. Similarly diverse mineralized assemblages, including a latrine from the House of the Vestals, have been recovered from Pompeii but with some notable differences (examined Pompeii assemblages include: The House of Amarantus I.9.12 (Robinson 1999), House of Hercules’ Wedding and the House of the Vestals (Ciaraldi 2007), Research on the Forum of Pompeii project (Kockel and Flecker, 2008),PARP:PS (Fairbairn 2012), Insula VI.I (AAPP) (Murphy *et al.* 2013).The Pompeii assemblages lack celery, dill and flax, inexpensive and easily accessible items. The quantity of mineralized material present in the sewer may explain the recovery of these items. It is unlikely to be due to a superior level of preservation in relation to Pompeii as there are some notable absences from the Cardo V assemblage as well. Moreover, not all the mineralized remains from Pompeii were recovered from latrines or cesspits; contexts that are the most suitable for mineralized preservation. Although black pepper was found at Herculaneum, there were no peach pits, seeds of citrus or sesame as there are at Pompeii (Ciaraldi 2007). These absences, despite the significantly larger quantity of available material, probably reflect the moderate to low socioeconomic standing of the majority of the inhabitants of *Ins. Or.* II. All three items would have been expensive in Italy during the 1st century AD, especially sesame as it was imported either from Egypt or India (Pliny *HN* 15.39-45; Cappers 2006: 111, 125). Similarly, large quantities of millet were recovered from the sewer. At Pompeii, *Panicum miliaceum* dominated the cereal assemblage at the modest House of the Wedding of Hercules while a minimal quantity was recovered from the more elite House of the Vestals. These findings led Ciaraldi and Richardson (2000: 75-76) to suggest that less wealthy individuals ate more millet. Thus while the preservation conditions within the sewer were excellent, they were not exceptional, and differences between the Pompeian and Cardo V mineralized assemblages do not reflect issues of taphonomy but instead variations in wealth. The defining feature of the Herculaneum assemblage, compared to the Pompeii assemblages, is therefore its scale (Ciaraldi and Richardson 2000: 81).

The presence of mineralized material in the sewer meant that the carbonized assemblage was formed through the deposition of fuel and cooking waste down the latrine shafts prior to the eruption. Carbonization during the eruption would have resulted in the destruction of the mineralized material. Minor differences between the Cardo V carbonized assemblage and those from Pompeii include the absence of pomegranate, chickpea and pea from the sewer (same assemblages looked at as above, but also now including: House of the Greek Epigrams (Robinson 2007), Vesonii tomb, Porta Nocera (Matterne and Derreumaux 2008), Pompeii Pistrina project ( Monteix 2009, 2010b; Monteix *et al.* 2011)). Moreover, a greater variety of weed seeds and nuts, including almond and hazelnut, have been found at Pompeii. These differences however, can be explained by the fact that a wide range of context types, including ritual burnt offering pits, tombs, garden soils and kitchen hearths, covering a much broader time period (4th century BC – AD79) have been excavated from Pompeii. While all the Cardo V material was deposited down the latrine shafts as cooking and heating waste, the deposition of the Pompeian material varied. At Pompeii, in addition to similar waste removal activities, material was also deposited due to the re-use of soil and the ritual placement and burning of material. Due to the durability of carbonized material, the wider range of contexts should not have effected preservation and in fact, preservation seems to have varied little between the two sites. Moreover, all the contexts discussed above come from pre-AD 79 levels where the material was similarly carbonized prior to the eruption.

The calcium carbonate and calcium phosphate within the sewer’s large faunal assemblage contributed to its own preservation by ensuring that the sewer maintained a slightly alkaline pH (unfortunately no pH measurements were taken at the time of excavation), preventing biogenic degradation. 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 eggshell, seashell and fish bones helped to maintain the alkalinity of the material by counteracting any acidity in the urine and acidity produced by the decay of faecal material. It is this alkaline pH that also helped ensure the survival of the delicate otoliths as they are very susceptible to degradation in acidic conditions.

It is interesting that the conditions were still too harsh for the preservation of fish scales as very few were recovered. This situation is the opposite from the Pompeian AAPP assemblages where fish scales were present but otoliths were absent (Andrew Jones March 23, 2011, pers. comm.). However, the AAPP excavated very few latrines. The PARP:PS project has collected samples from industrial and latrine contexts and has found that while some industrial contexts contained large quantities of extremely well preserved fish scales, the latrines contained few very (Ellis and Devore 2010, Ellis et al. 2011). These early results seem to suggest that environments suitable to the preservation of mineralized material do not favour the preservation of fish scales (Robinson and Nicholson, pers. comm. Nov. 26, 2015).

*Diet*

The high and consistent level of preservation throughout the sewer means that differences in the ubiquity and abundance of the material represent true differences in the consumption and use/deposition of material. As a result, some of the dietary patterns of those living in *Ins. Or.* II are observable. As stated above, items with high abundance scores generally had high ubiquity scores by both quadrant and sample. Taking preservation frequencies into account, such as the grinding of grain into flour, which leaves it largely unrepresented in the record, foodstuffs with high ubiquity and abundance scores in the quadrants and strata were probably the most widely consumed goods. Such foods include grapes, olives, figs, apples, poppy seeds, millet, fennel, eggs, limpets, clams and sea urchins. This pattern is most clearly seen in the shellfish. While there are 32 edible shellfish taxa, there were only six taxa recovered in quantities of 10 or more per sample and quantitatively, these six taxa make up 77% of the entire shellfish assemblage (including edible and inedible material). The ubiquity and abundance of the weed seeds, often recovered as mineralized material, does suggest frequent, although unintentional consumption as well as a lack of fine sieving with respect to flour. Foodstuffs found in fewer quadrants, strata or samples were probably consumed less frequently (hazelnuts, walnuts, stone fruit, coriander) while those with extremely ubiquity low scores represent rare items (black pepper). The abundance scores for the archaeobotanical remains is similar to that recovered from the AAPP excavations (Ciaraldi 2007; Murphy *et al.* 2013: 415). As figure 11 shows, despite the movement of the sewer material, the limited number of taxa with high ubiquity and abundance levels were well dispersed throughout the tunnel, indicating that the diet for all of those living in *Ins. Or.* II consisted of a few staple foods. The high levels of diversity in each quadrant suggest that these staple foods were frequently supplemented by a wide range of other ingredients. Based on the consistency within both the ubiquity and abundance scores, across the length and depth of the sewer, there do not appear to be any significant dietary changes taking place in the decade prior to the eruption.

Although the unidirectional movement of the sewer material allow for the detection of differences in diet, the inability to connect a particular quadrant with a particular latrine shaft does mean that differences cannot be attributed to a specific apartment or shop. Nevertheless, subtle differences are observable and the distribution of the more expensive foodstuffs represent varying levels of wealth of the inhabitants of *Ins. Or.* II. Except for a single peppercorn, recovered from Q49-50, all of the most expensive foodstuffs are recovered from the more southerly quadrants, and in particular Q13-14. Sea bass, for example, was an expensive fish according to Pliny the Elder (*HN* 9.61). It is a migratory species that must be caught with a single line and hook rather than a net and thus more effort is required to catch it than, for example sea bream (Gallant 1985: 67; Whitehead 1986, vol 2; Foese and Pauly 2013; Rowan 2014b: 68). Sea bass was recovered only from Q13-14 and Q3-4. Moreover, the two fragments of goose eggshell, rare items purchased to display wealth and social status, were found in Q23-24 and again, Q13-14. The second of the two peppercorns was recovered from Q5-6. The variation in preservation type of these more expensive goods (mineralized, bones, otolith, shell) counteracts the notion that the downwards shift of material is responsible for the collection of these items at the southern end of the sewer. Moreover, Q49-50 has a range of mineralized and shell taxa only slightly lower than 23-24 and an identical range of carbonized taxa to both Q23-24 and Q13-14. Consequently, it appears that those living at the southern end of the sewer and those living in the upper floor apartments, as Q13-14 is downstream of the upper floor latrine shaft, were somewhat wealthier than those living in the northern end of the building. This being said, the vastly differing locations of the two recovered peppercorns, from Q5-6 and Q49-50 respectively, which indicates that two separate units had the financial means to purchase this expensive good, does also suggest an overall level of wealth somewhat higher than would be expected based on the size of the domestic spaces in *Ins. Or.* II.

**Conclusions**

As a single archaeological context, the contents of the Cardo V sewer represent the single largest collection of bioarchaeological material so far recovered from Roman Italy. Mineralization was the primary form of botanical preservation, followed by carbonized material and the occasional presence of waterlogged remains. The combination of items within the sewer, including faecal matter, bone and water ensured that mineralization took place throughout the length of the tunnel while at the same time maintaining a relatively neutral pH, leading to the preservation of rare items such as fish otoliths. Overall, the preservation conditions were extremely good as evidenced by the recovery of rarely mineralized material such as olive seeds. Except for the otoliths, neither the archaeobotanical, zooarchaeological nor shell material, for the most part, contained many rare or unusually preserved finds, suggesting that the preservation conditions were excellent but not atypical.

The compositions of the botanical assemblages did not deviate significantly from those found at Pompeii and differences reflect the lower socioeconomic standing of the inhabitants of *Ins. Or.* II and the wider range of excavated contexts at Pompeii. Since taphonomic bias was not a significant factor in the Cardo V assemblage, 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. Taking the usual absences associated with food preservation into account (ie. the absence of completely degradable items such as cheese, meat and the fleshy portions of vegetables) the Cardo V assemblage can be considered a reliable representation of the diets of those who lived in the shops and apartments above.

The most notable aspect of the *Ins. Or.* II diet was its diversity. In addition to cereals and legumes, the inhabitants of *Ins. Or.* II ate a diet based on a limited number of staple foods such as millet, grapes and figs, but supplemented on a frequent basis by over 100 different types of fruits, herbs, fish and shellfish. The similarity in the levels of ubiquity and abundance across all the quadrants indicate that the diet was relatively similar for all individuals and changed little over the 10 years of accumulation. The concentration of more expensive such as black pepper and sea bass at the southern end of the sewer suggests that the domestic spaces between *Ins. Or.* 11.8-6 were inhabited by slightly wealthier individuals than units II.9-14. However, the overall diversity of the diet was still unexpected high for those living in a densely populated urban apartment block.

The Cardo V finds clearly contradict the theories that in the Roman world, most foodstuffs were unavailable or too expensive for those living in modest domestic dwellings (Fidanza 1979: 88-89; Sippel 1987: 49-50; Garnsey 1999: 37, 43-44). 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 the Vesuvian soil and the Bay of Naples played an important role in ensuring that a varied and local supply of foodstuffs could be brought into the city with few additional transport costs. In Herculaneum, even small shop owners could afford fish and seafood on a consistent basis. 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 arriving into the large and nearby port city of Puteoli, may in fact have made it a privileged place relative to other towns in Roman Italy and the Empire. Ongoing bioarchaeological sampling from Italy will help to reveal the extent to which Herculaneum was distinctive in the availability and cost of foodstuffs.

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**Captions**

**Figure 1:** Plan of the excavated section of Herculaneum showing the location of Insula Orientalis II and the palaestra. The Cardo III, IV and V sewers are highlighted in blue.

**Figure 2:** The *palaestra*, ground floor and upper floors of *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 represents a channel that drained the pool (adapted from pl. V, Monteix 2010). The arrows point to the location of the quadrants (Q) where samples were taken. Rooms in each individual unit have been numbered, thus II.6.2 refers to room 2 in unit 6. M = mezzanine level. (Permission to reproduce plan granted by N. Monteix)

**Figure 3:** *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 4:** Bed niche in *Ins. Or.* II.11 room 3. (Author’s photograph)

**Figure 5:** 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. Quadrant locations in bold. 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 6:** The N-S branch of the Cardo V prior to excavation. The upper layer is composed of volcanic fill while the bottom layer below the gap is the organic remains. 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 Domenico Camardo/HCP)

**Figure 7:** Selected carbonized and mineralized remains from left to right: top - carbonized *Juglans regia* shell, mineralized *vitis vinifera*, carbonized *Vitis vinifera*, mineralized *Foeniculum vulgare, Papaver somniferum,* bottom – mineralized *Olea europaea* seed, *Piper nigrum, Lens culinaris, Urtica dioica.*

**Figure 8:** Selected fish and shellfish remains from left to right: top - *Paracentrotus lividus* spine, body fragment, jaw fragment, rotula, tooth, bottom – left sagittal otolith of *Spondyliosoma cantharus*, *Donacilla cornea,* eggshell fragments of differing thickness.

**Figure 9.** Density ratios of the archaeobotanical, shell and otolith data by quadrant. Otolith counts include whole and fragmentary items.

**Figure 10.** Abundance of the mineralized, carbonized and shell assemblages by quadrant. Non-food items with abundance levels greater than 10 items per quadrant - mineralized items: Amaranthaceae, Apiaceae, Caryophyllaceae, *Chenopodium* sp., Lamiaceae, *Papaver* sp., Polygonaceae, *Polygonum aviculare, Polygonum* sp., *Reseda* sp., *Sherardia arvensis, Stellaria media, Urtica dioica, Urtica* sp. Carbonized items: none. Shell: Mytilaster cf. minimus.

**Figure 11**. Ubiquity of only the food items shown in figure 10 that had abundance levels greater than 10 items per quadrant. From left to right with increasing ubiquity by quadrant - mineralized items: *Rubus fruticosus, Olea europaea, Foeniculum vulgare, Panicum miliaceum, Apium graveolens, Brassica sp., Setaria italic,* *Panicum miliaceum or Setaria italic, Malus or Pyrus sp., Papaver somniferum, Vitis vinifera, Ficus carica.* Carbonized items: *Olea europaea, Vitis vinifera.* Shell:*, Aequipecten opercularis, Patella* sp., *Donacilla cornea*, Helicidae, *Paracentrotus lividus.*