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Complete List of Authors:	O'Connell, Tamsin; University of Cambridge, Department of Archaeology Ballantyne, Rachel; University of Cambridge, McDonald Institute for Archaeological Research Hamilton-Dyer, Sheila; SH-D ArchaeoZoology, Shirley Margaritis, Evi; The Cyprus Institute, STARC Oxford, Sammy; University of Cambridge, Department of Archaeology; Chelmsford Museum, Oaklands Park Pantano, Walter; il Museo Nazionale Romano e l'Area Archeologica di Roma, Collaboratore Soprintendenza Speciale per il Colosseo Millett, Martin; University of Cambridge Faculty of Human Social and Political Science, Faculty of Classics Keay, Simon; University of Southampton, Department of Archaeology
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Living and Dying at the *Portus Romae*

T.C. O'Connell[1*], R.M. Ballantyne[2], S. Hamilton-Dyer[3], E. Margaritis[4], S. Oxford[1,5], W. Pantano[6], M. Millett[7] and S. J. Keay[8]

[1] Department of Archaeology, University of Cambridge, Downing Street, Cambridge, CB2 3DZ, UK.

[2] McDonald Institute of Archaeological Research, University of Cambridge, Downing Street, Cambridge, CB2 3ER, UK.

[3] SH-D ArchaeoZoology, 5 Suffolk Avenue, Shirley, Southampton SO15 5EF, UK.

[4] STARC, The Cyprus Institute, Athalassa Campus, 20 Constantinou Kavafi Street, 2121 Nicosia, Cyprus.

[5] Chelmsford Museum, Oaklands Park, Moulsham St, Chelmsford, CM2 9AQ, UK

[6] Collaboratore Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologica di Roma, Rome, Italy.

[7] Faculty of Classics, University of Cambridge, Sidgwick Avenue, Cambridge, CB3 9DA, UK.

[8] Department of Archaeology, University of Southampton, Southampton, SO17 1BF, UK.

* Corresponding author email: tco21@cam.ac.uk

Abstract

This paper presents the first results of research into plant, animal, and human remains from Portus, the maritime port of Imperial Rome, in order to examine the diet and geographical origins of its inhabitants between the second and sixth century AD. Comparisons with evidence from the excavation and ceramic analysis show clear changes throughout the period, with shifts in diet and patterns of foods import that can be related to the commercial and political changes following the breakdown of Roman of the Mediterranean.

Introduction

Portus, the maritime port of Imperial Rome was established near Ostia by the mouth of the Tiber under Claudius (after AD 42), and substantially enlarged under Trajan *c.* 112–17 (Keay *et al.* 2005: 11-14; 298-309). For over 400 years, it funnelled imports from across the Mediterranean to Rome, acting as a hub for exporting products from the Tiber valley, and for redistribution across the Mediterranean. The extent of the port and its commerce during the periods of Ostrogothic and Byzantine control is less well understood (Keay et al. 2005: 13; 291-5).

Since 2007 the Portus Project (www.portusproject.org) has been analysing the site in its broader economic and social context. The excavated evidence has transformed understanding of the nature and development of two key buildings at its centre, and the port's broader commercial connections with Ostia, Rome and Mediterranean communities through the second to sixth century. (Keay 2012). This paper presents the first results of research into animal bone, plant remains, and stable isotopic analyses of these plus human remains in order to assess the diet and geographical origins of its inhabitants.

Archaeological Context

Excavation focused upon the Palazzo Imperiale and Building 5 situated at the heart of the port (Fig. 1), established *c.* 115–20, the former as an imperial villa with residential and administrative functions, the latter most likely as a monumental shelter for ships. Both underwent six periods of use until the mid-sixth century AD. The character and taphonomy of the studied contexts means that sample size varied greatly through time. Most plant and animal remains derived from rubbish dumps, with earlier periods under-represented in terms of excavated volumes. (Fig. 2).

Biological Evidence

Plant and animal remains provide direct evidence of food, traded goods, building materials, fuels and the local environment. Imported staples and exotic goods were perhaps consumed alongside local products. The small quantities of exotics provide clear biogeographical evidence for maritime trade, notably early third century charred black pepper seeds from India via Egypt (van der Veen and Morales 2015), late fifth century African ostrich eggshell containers, as well as two metapodials of bear and the probable dorsal thoracic rib of crocodile. Both crocodiles and bears were likely for use in the games at Rome, the former imported live from Egypt (MacKinnon 2006), and the latter either from Europe or possibly a now extinct subspecies from the Atlas Mountains of North Africa (Hamdine *et al.* 1998). Such exotics could only have been minor dietary components, consumed infrequently, if at all, and therefore would have contributed little to the dietary and isotopic signatures of the inhabitants. Our main focus here is thus the main dietary staples represented by charred cereal grain and faunal remains, predominantly domestic ungulate bones.

Distribution of samples

A sampling strategy obtained representation of all phases, excavation areas and feature types (Fig. 2 and Table S1), although the resultant assemblages are somewhat limited. As the excavations examined administrative and commercial areas, with households situated elsewhere (Keay *et al.* 2005: 311-2; Keay 2012:

46), the food refuse assemblages primarily derive from the daily lives of the port workers.

Charred plant remains

The 789 macrofossils represent 25 charred plant types, of which 20 are of food plants with cooking or meal refuse the most likely sources (Fig. 3; see Table S1 for binomial nomenclature). Cereal grain is ubiquitous and occasionally abundant whilst pulses are very infrequent, perhaps as a result of boiling or stewing rather than baking. Cereals and pulses both have durable, distinctive seeds that are routinely exposed to fire during processing or cooking, so they are often recovered archaeologically (Boardman and Jones 1990; van der Veen 2007).

The grain is primarily of free-threshing wheats, with examples comparable to both bread wheat (183 grains) and macaroni wheat (191 grains). Hulled wheats are represented by einkorn 10 grains) and emmer (31 grains). A complete absence of cereal chaff means that identifications are cautious due to limited morphological distinctiveness of different wheat grain types; many grains are identified to wheat groups not species (Jones 1998). Barley (16 grains) is less frequent, with both hulled and naked forms occasionally identifiable. The absence of chaff and rarity of arable weed seeds further emphasises that consumption at the port was divorced from agricultural production and primary crop processing.

When examined by period, the free-threshing wheats are predominant during the second to early fifth century, whilst hulled wheats predominate in dump deposits of the mid-fifth century onwards (Fig. 3). This temporal shift related to the character of associated activities, shifts in maritime trade networks, or consumers' cultural preferences.

Hulled wheats are still cultivated on a small scale across Mediterranean (Nesbitt and Samuel 1996; Peña-Chocarro and Zapata Peña 1998). Roman texts indicate that emmer wheat was a staple with a central role in ritual and festivals (Papa 1996, 156). As mid-fifth and sixth century contexts at Portus include numerous inhumations and a more diverse range of food plants, the presence of votive, funerary, or at least non-routine, food refuse is likely alongside any shifts in the trans-Mediterranean grain trade (Margaritis 2014).

There are no clear temporal trends for the few identifiable macrofossils of lentil, pea and broad bean. By the mid-fifth to mid-sixth century, the charred seeds include multiple examples of grape, fig, blackberry, elderberry and olive in addition to occasional pulses (Table S1), suggesting that different activities may be represented in the macrofossil record compared to earlier periods. Possibilities are fruit drying, cooking, votive offerings linked to funerary rites, or meal-refuse thrown into fires. Oil-rich olive stones are also a known fuel source (Margaritis and Jones 2008). Meal-refuse appears most plausible as different fruits co-occur in several contexts alongside occasional nutshell fragments of stone pine, oak acorn, walnut and terebinth.

Animal bones

The animal bone assemblage comprises 2570 identified bone specimens (NISP), with likely consumed taxa accounting for 234 in the earlier second to early third century, 36 in the late fourth to the beginning of the 5th century AD, and 1010 in the mid-fifth to the mid-sixth century AD (Fig. 3; see Table S2 for binomial nomenclature). No shifts are inferred in the proportions of species through time due to the low NISP and poor preservation such that, within in each period, over half of the large mammal specimens are identified as 'cattle/horse-sized' and 'sheep/pig-sized'.

At least 33 animal taxa are present, but most bones are of sheep/goat, pig and cattle and horse/equid likely representing refuse discarded at or near places of work. Whilst the activities that generated this small assemblage are ambiguous, the bones are likely to represent wider animal populations available as food at the port.

Other likely consumed animals are fallow deer, rabbit/hare, domestic/greylag goose and domestic fowl. The fallow deer and rabbit/hare include traces of butchery. The rare fish bones include both freshwater and marine types, such as Carp Family, sardine/sardinella, seabream and eel.

Butchery traces are rare due to surface erosion linked to the chemically harsh, sandy burial environment. Although relatively small with high levels of fragmentation and surface erosion (Table S5, Figure S1), this is still an important assemblage as it is the first to be analysed from the port.

Isotopic analysis

Carbon and nitrogen stable isotopic analysis allows characterisation of isotopic foodweb, with sampling limited to those entities preserved following cultural and natural taphonomy. It also offers the potential of distinguishing imported plants and animals from the same species produced locally. Such a differentiation is crucial given Portus' role in pan-Mediterranean commerce, since classical sources indicate that cereals were traded widely (Erdkamp 2005; Foxhall and Forbes 1982).

Isotopic analyses of the human remains can elucidate the habitual diet of individuals living and working at Portus, and where individuals may (or may not) have been raised. Comparison of isotopic data within burial groups and across time can reveal the degree of homogeneity within a group in diet and origin and show diachronic shifts in population structure and food habits.

Plant samples

91 charred plant macrofossils were analysed, based on grain abundance and context type. 88 grains were identified as wheat; the others identified as barley, a large legume, and unidentified cereal fragments. Of the wheat samples, 85 were securely identified by morphological criteria as free-threshing, and three as hulled wheat.

We analysed each grain individually (single-entity analyses), rather than grouping them (Kanstrup *et al.* 2012). As a result, for all 91 samples, we only have valid $\delta^{13}C$ results, due to low nitrogen content of the samples (Table S4 contains all isotopic results for plant samples, with details of archaeological context and species identification).

The overall carbon isotopic range in wheat is 4.2‰, between -24.7 and -20.4‰, similar to values observed in Mediterranean archaeological samples, but larger than are expected for crops grown in a single year or site (Wallace *et al.* 2013), as expected for traded cereals coming into Portus.

The carbon isotopic values of the free-threshing wheat show an interesting temporal pattern (Fig 4a). Whilst the overall range changes little, the 60 samples from the early second to early third century have significantly lower $\delta^{13}C$ than the 21 from the late fourth–early fifth century whilst the few from the contexts dating to the mid-fifth to mid-sixth century have intermediate values (Figure 4a, see SI for statistical tests).

The $\delta^{13}C$ change over time in the free-threshing wheat indicates a change in wheat growing conditions (Flohr *et al.* 2011, Wallace *et al.* 2013), which could relate to changes in origin, management, irrigation patterns or climate in the growing region. Within a single population, the increase seen between the early third and late fourth century would be indicative of greater plant stress (such as less water availability: Wallace *et al.* 2013). What is more likely in this case is a change in grain origin. There is some evidence for a wetter east Mediterranean in the fourth and fifth centuries, including a higher proportion of deficient floods of the Nile at this time (McCormick *et al.* 2012: 195–9). However, the lack of evidence from key grain supplying areas in the more western parts of north Africa, as well as broader methodological and evidential issues (Manning 2013) suggests caution.

Animal samples

A total of 57 animal bone samples were analysed from a range of species (Tables S5 and S7). Twelve are from the earlier second and earlier third century and the remaining 45 from the late fourth/early fifth to sixth century, limiting our assessment of diachronic change. Due to the low NISP and poor preservation limiting the representativeness of our sample, statistical comparisons are unlikely to be valid, but a graphical comparison of the four species present in the early and late samples (birds, cattle, sheep/goat and pig) shows no clear shift in either carbon or nitrogen isotopic values (Fig. 4). Therefore, discussion of the animal isotopic data combines samples from all periods.

The animal carbon and nitrogen isotopic values (Fig. 5 and Tables S7 and S10) are consistent with those across Europe in this period, and similar to other published Roman sites in this region (Prowse *et al.* 2004, Craig *et al.* 2009). Herbivore carbon isotopic values (-22.3 to -18.8‰) reflect a diet predominantly based on C_3 vegetation (no notable indication of consumption of millet or other C_4 plants). The domesticated herbivores have a greater nitrogen isotopic range than expected for animals kept in single groupings, as expected for goods traded into Portus. Pigs have similar carbon and nitrogen isotopic values to other herbivores, in absolute and relative terms, so there is no isotopic evidence that they were fed a different diet to the domesticated herbivores, such an omnivorous diet (as often seen in household-kept pigs: Hamilton *et al.* 2009). The birds, both wild and domestic, have higher nitrogen isotopic values than the other animals (mean of 8.9‰) but similar $\delta^{13}C$ values, as found elsewhere (Müldner and Richards, 2005, 2007; Hakenbeck *et al.* 2010).

Despite the extensive flotation sieving with heavy residues collected over 1mm mesh, very few fish remains were recovered, of which few had sufficient bone mass for collagen extraction and analysis. Four samples were successfully analysed (one seabream and three unidentified to species). The carbon and nitrogen isotopic values are varied, but consistent with Mediterranean fish (Blasi *et al.* 2018), fish from Velia (n=5: Craig *et al.* 2009) and garum from Africa, Sardinia and Italy (Prowse *et al.* 2004).

Human skeletons

Human skeletal remains were sampled from the mid-fifth and early sixth century burials from Building 5 and the late second/early third and late fourth/early fifth century burials from Tenuta del Duca, a site *c.* 1 km to the north-east of the Palazzo Imperiale (Pantano n.d.). Bone collagen from 28 Building 5 individuals, and 32 Tenuta del Duca individuals, plus 22 tooth enamel samples from Building 5 individuals were successfully analysed.

The isotopic results of all samples with relevant details of archaeological context, osteological information, sex and bone elements sampled are given in Tables S8 and S9. These data were compared to previously published results from the adjacent Isola Sacra cemetery, dating to the first to third century AD (Prowse *et al.* 2007, Crowe *et al.* 2010).

Diet at Portus

Humans from the three sites had carbon isotope values from -20.3 to -17.3‰, and nitrogen isotopic values between 7.5 and 13.7‰. We have not attempted any modelling of human dietary isotopic composition because of the paucity of data for some potential food sources (e.g. fish), and the lack of data for others (e.g. plant nitrogen isotopic data). Instead, we can use our animal and plant isotopic data to assess the foodweb, and to constrain potential interpretations of the human diet.

Overall, the isotopic data indicate that people were eating predominantly C_3 plants and animals with some input from marine foods, with variable consumption patterns across all individuals. There is little evidence of marine fish intake for most individuals due to the small offset between terrestrial animal and human carbon isotopic values (Bocherens and Drucker, 2003). The humans have nitrogen isotopic values that are close to or above the upper end of the typical human-animal range for terrestrial consumers (c. 13‰: Bocherens and Drucker, 2003; Hedges and Reynard, 2007), suggesting some input of food sources with higher nitrogen isotopic values – potential candidates include birds, both domestic and wild, and freshwater fish.

Variation with time and place

The isotopic data show substantial variability within each group of people, and some patterning between the three. The isotopic data are difficult to interpret in a clear-cut fashion, since they result from multiple influences, but can indicate dietary trends between the three groups.

From the archaeological, osteological and demographic data, Isola Sacra is a cemetery for relatively well-off residents from Portus and Ostia (Baldassare 1978; Helttula 1995), whereas the Tenuta del Duca and Building 5 burials are predominantly male individuals in early to middle age, who undertook arduous physical labour and are likely to have been port workers. The anthropological data of Tenuta del Duca and Building 5 show similarities with those found at cemeteries closer to Rome, including Castel Malnome and Casal Bertone where most of the skeletons are male exhibiting signs of physical stress generated through heavy manual activity similar to those at Portus (Musco *et al.* 2008; Catalano *et al.* 2010).

Yet there is little difference between the isotopic composition of the diets of those buried at Tenuta del Duca and Isola Sacra, and a significant difference between two earlier groups and Building 5 in nitrogen isotopic values, a mean difference of more than 1‰ (Fig. 6, Table S11, see SI for statistical tests). This indicates that the diet of the Building 5 individuals was isotopically different to that of people from Isola Sacra and Tenuta Del Duca – an intriguing finding, given the demographic similarity of Tenuta del Duca and Building 5. This could either result from eating the same foods that have a different isotopic value, or from eating a diet of a different composition that therefore differs isotopically. The lack of any obvious isotopic shift in the animals with time (Fig. 4) suggests that it was the people's diet that had changed. In the absence of valid comparative plant nitrogen isotopic data, we cannot draw firm conclusions, but a dietary shift to a greater reliance on plant protein, including more legumes, and less intake of animal protein (either marine or terrestrial) is a likely explanation for the observed isotopic change with time. That this correlates with a shift in wheat type (increased prevalence of hulled wheats) at the site is noteworthy.

Human origins and mobility

The oxygen isotopic values of the tooth enamel of Building 5 and the Isola Sacra individuals are very similar, suggesting they could be of similar origin (Fig. 6b and Table S12). Thus, it is unlikely that the carbon and nitrogen isotopic difference between those buried at Building 5 and the earlier groups results from long-term movement or migration – we are not seeing the residual dietary signature of immigrants coming to work in the docks.

There are, however, two Building 5 individuals whose $\delta^{18}O$ values stand out as notably higher than the rest, at -1.5‰ and +0.7‰. These individuals (PTXI4425 and PTXI4054) were analysed in duplicate, with close agreement between measurements. Their absolute values, and difference to the rest of the group, suggest that they were not raised locally, but likely moved from a warmer environment to Portus after childhood (Evans *et al.* 2012). One of them, PTXI4054, a male of 40-50 years, is the only individual from period 6B, dating to sometime after 530. This is interesting in view of the downturn in commercial activity at the port after the mid-fifth century and the likely fall in the number of foreign traders as a consequence.

Ceramic Analysis

Transport amphorae provide additional evidence for the range and volume of imports to Portus. The origins and content of most types have been established through kiln excavation, analyses of organic residues and typological comparisons over the last 40 years. Our excavations yielded *c.* 52,000 ceramic fragments, of which just under half were amphorae (Keay *et al.* 2015). As with the environmental evidence, early–mid second century material was scarce. The early third century sample was much larger, while that of the mid-fifth century was even greater. These variations are taphonomic, rather than resulting from changing volumes of importation, since the later deposits derived from large dumps and the earlier from thin occupation levels. The early third century material was represented almost exclusively by olive oil imported from Tripolitania (modern Libya). The Period 6A material represents foodstuffs in circulation prior to the contraction in commercial activity in the mid-fifth century – a mixture of olive oil, fish sauce and wine primarily from what is now Tunisia and western Libya (57%), with local Italian wine (16%) and imports from the eastern Mediterranean (c. 14%) far fewer than at neighbouring Ostia and Rome. Imports are far rarer in sixth century contexts.

Conclusions: Living and dying at Portus

Our results are best considered in terms of two consecutive time horizons. Between the earlier second and mid-fifth century (Periods 2–5), the human evidence from Tenuta del Duca indicates a local population involved in heavy manual labour, perhaps the *saccarri* (porters) attested on inscriptions from both

Portus and Ostia (Martelli 2013). We suggest that in the early third century, they were predominately consuming free-threshing wheat and olive oil from North Africa, and a broad range of common food plants and animals. Their dietary profile might be expected to have been different to that of the higher status individuals buried in the Isola Sacra cemetery just south of Portus, but there is little isotopic evidence for such dietary differences (Fig. 6a). Towards the end of this time horizon, there was a change of origin of imported free-threshing wheat which is best explained by a shift away from north African imports.

Between the mid-fifth – early mid-sixth century, as represented by the Building 5 burials (Period 6), the population had a similar demographic profile to that of the earlier Tenuta del Duca. The dead were largely male and had been involved in heavy physical labour, a profile paralleled by cemeteries closer to Rome (Caldarini et al. 2015). While most were likely of local origin, two non-locals could be overseas traders, even though port activity had contracted sharply by this time. In terms of diet, there was a shift away from animal to plant protein, while marine intake was low. As far as foodstuffs are concerned, there were three significant changes. By the mid-fifth century, imports were dominated by olive oil, fish sauce and wine from North Africa, with lesser amounts of wine from the east Mediterranean; subsequently, these had disappeared. Second, there is equivocal evidence for a change of origin of imported free-threshing wheat. Third, hulled wheat became more abundant and ubiquitous than the free-threshing varieties, for reasons that are unclear. Otherwise, a broad range of common food plants and some exotica were present.

This evidence provides a unique glimpse of the people at the port and the goods consumed immediately prior to the commercial downturn that followed the Vandal sack of Rome in 455, and during the Gothic Wars (536-552). It suggests the former marked a significant rupture in long-standing commercial connections between Rome and north African. Subsequently, Rome was increasingly supplied by food sources closer to home, such as the Italian peninsula. This is symptomatic of the contraction of her political influence in the post-Roman Mediterranean.

This is a rare study that integrates a broad range of evidence to examine the lives of people at a major site across time. Furthermore, by examining the evidence from the port of Imperial Rome, we have provided new insights into the lives of those at the centre of one of the World's largest early empires. We have documented a major shift in the commercial relationship between Rome and the Mediterranean in the period of flux between the dissolution of the western Empire in 476 and the establishment of Byzantine control in the mid-sixth century.

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Figure Captions

Figure 1. Map showing the topography of Portus. The area of the 2007-2012 excavations is defined by the box (after Keay *et al.* 2005: Pull-Out 1)

Figure 2. Multi-Period plan of the 2007-2012 excavations showing the spatial and chronological distribution of the contexts from which the environmental material discussed in this paper was derived (Portus Project).

Figure 3: Plant and animal assemblages at Portus: (a) Charred macrofossils of likely consumed plants by period; (b) NISP of likely consumed animals by period

Figure 4: Isotopic values of (a) free-threshing wheat and (b&c) animals by period. See Tables S4 and S7 for full information.

Figure 5: Carbon and nitrogen isotopic values of animals analysed from Portus, together with those from the site of Velia, compared to the humans from Isola Sacra, Tenuta del Duca and Building 5.
Velia data taken from Craig *et al.* 2009.

Figure 6: Isotopic values of humans from the sites of Isola Sacra, Tenuta del Duca and Imperial Navalia Building 5: (a) scatter plots of bone collagen carbon and nitrogen isotopic values of humans from Isola Sacra, Tenuta del Duca and Building 5, with the coloured polygons representing the 'bag' that encloses 50% of the points around the depth median, marked with a cross; (b) histograms of human tooth enamel carbonate oxygen isotopic values of individuals from the two cemeteries of Isola Sacra and Building 5
For (a): Building 5 and Tenuta del Duca data given in Tables S8 and S9. Data from Isola Sacra individuals were used where age and sex data were available, which are the 91 individuals from Crowe *et al.* 2010.
For (b): Building 5 data given in Table S8, and data from Isola Sacra individuals were taken from Prowse *et al.* 2007.

Supplementary Information

Tables & Figures

Methodologies, Statistics & Results

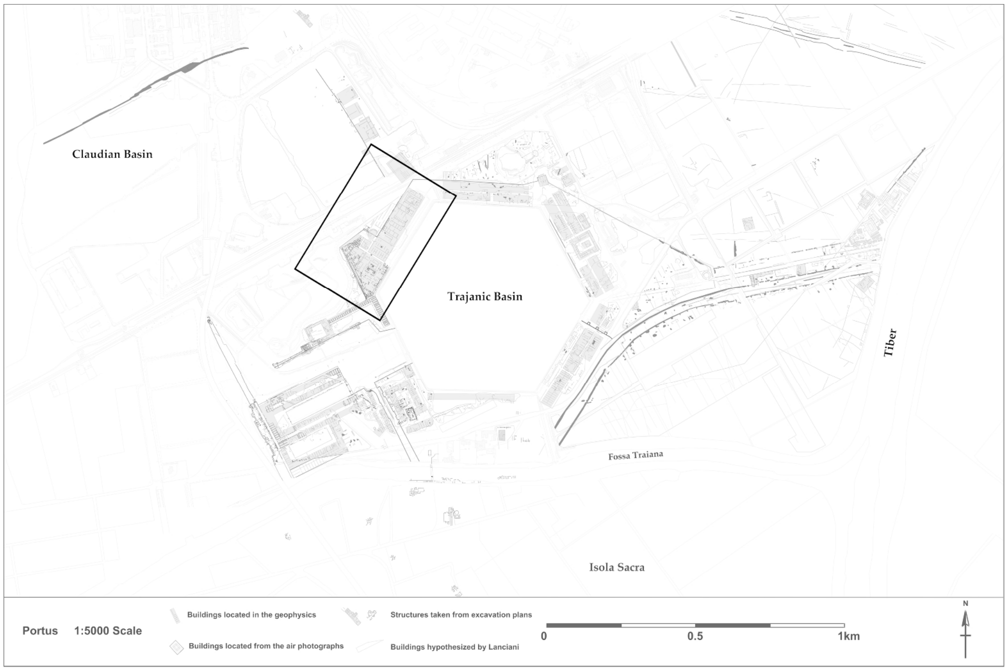

Figure 1. Map showing the topography of Portus. The area of the 2007-2012 excavations is defined by the box (after Keay et al. 2005: Pull-Out 1)

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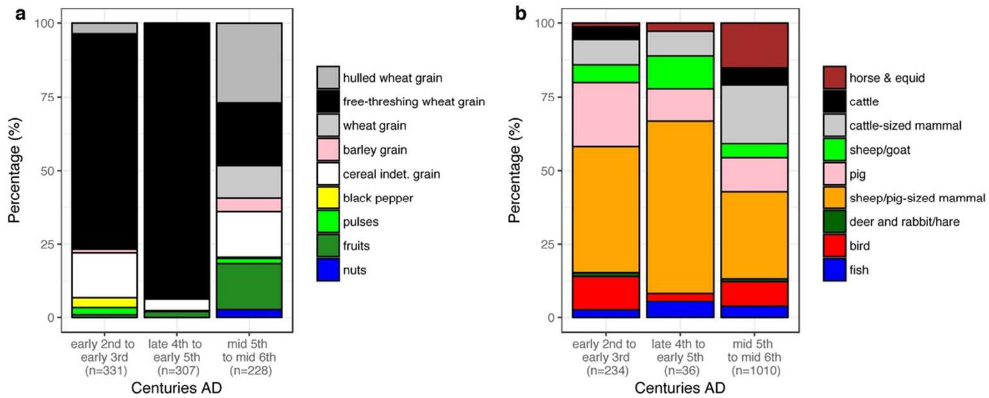

Figure 3: Plant and animal assemblages at Portus: (a) Charred macrofossils of likely consumed plants by period; (b) NISP of likely consumed animals by period

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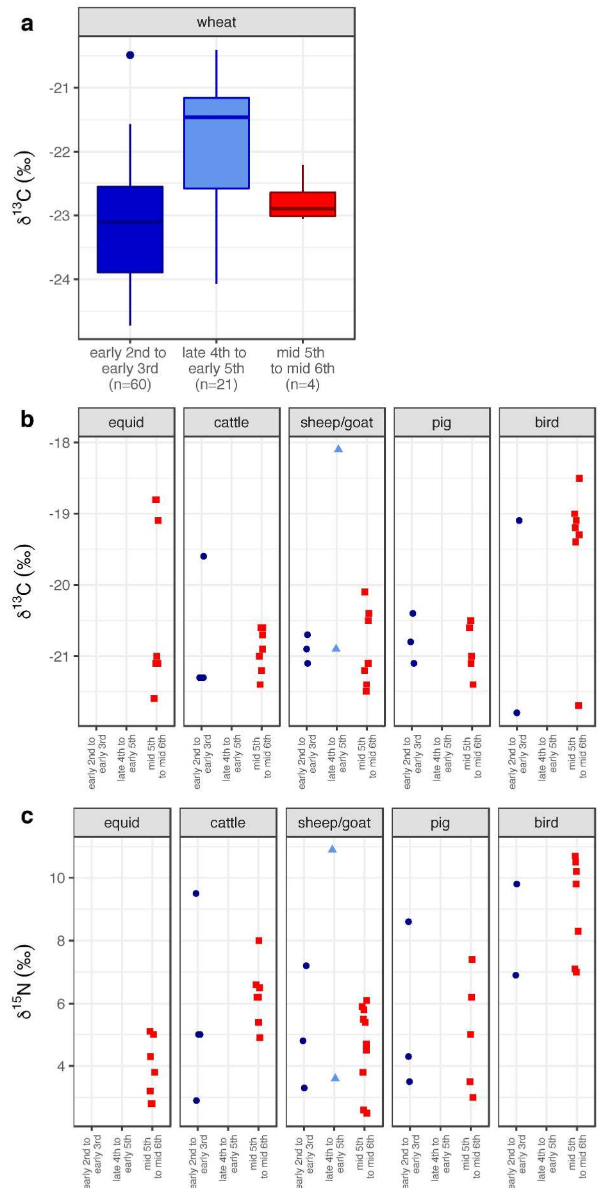

Figure 4: Isotopic values of (a) free-threshing wheat and (b&c) animals by period. See Tables S4 and S7 for full information.

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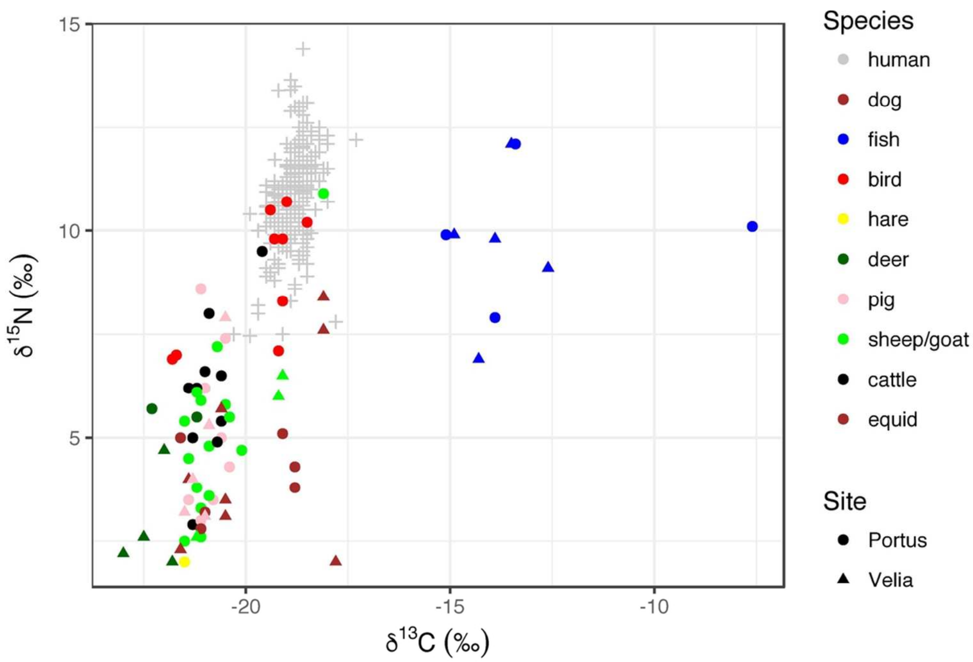

Figure 5: Carbon and nitrogen isotopic values of animals analysed from Portus, together with those from the site of Velia, compared to the humans from Isola Sacra, Tenuta del Duca and Building 5. Velia data taken from Craig et al. 2009.

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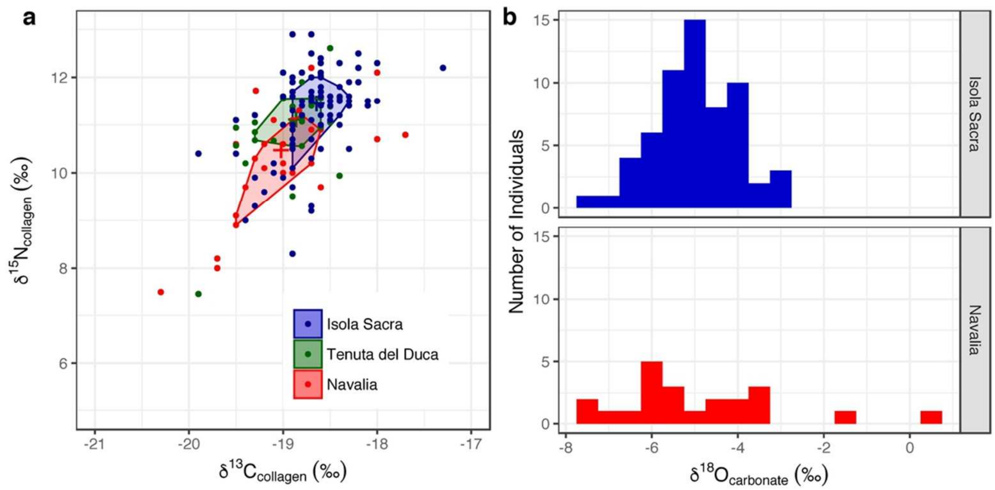

Figure 6: Isotopic values of humans from the sites of Isola Sacra, Tenuta del Duca and Imperial Navalia Building 5: (a) scatter plots of bone collagen carbon and nitrogen isotopic values of humans from Isola Sacra, Tenuta del Duca and Building 5, with the coloured polygons representing the 'bag' that encloses 50% of the points around the depth median, marked with a cross; (b) histograms of human tooth enamel carbonate oxygen isotopic values of individuals from the two cemeteries of Isola Sacra and Building 5. For (a): Building 5 and Tenuta del Duca data given in Tables S8 and S9. Data from Isola Sacra individuals were used where age and sex data were available, which are the 91 individuals from Crowe et al. 2010. For (b): Building 5 data given in Table S8, and data from Isola Sacra individuals were taken from Prowse et al. 2007.

101x50mm (300 x 300 DPI)

Tables & Figures

Methodologies, Statistics & Results

Living and Dying at the Portus Romae
Supplementary Information

O'Connell et al.

Table S1: Charred macrofossil counts of likely consumed plants by period

Common name	Taxonomic name	Periods 2, 3, 4	Period 5	Period 6	Total macro-fossil counts	Number of contexts with macro-fossils
		early 2nd to early 3rd cent AD	late 4th to early 5th cent AD	mid 5th to mid 6th cent AD		
		41 contexts (586 litres)	17 contexts (222.5 litres)	122 contexts (2498.5 litres)		
Cereals						
Barley, grain	*Hordeum vulgare L.*	4	1	11	16	8
Einkorn, grain	*Triticum cf. monococcum L.*			10	10	3
Emmer wheat, grain	*Triticum cf. dicoccum Schübl*	3	1	27	31	13
Einkorn/Emmer wheat, grain	*Triticum monococcum/dicoccum*	9		25	34	15
Macaroni wheat, grain	*Triticum durum sensu lato*	122	64	5	191	9
Bread wheat, grain	*Triticum aestivum sensu lato*	100	76	7	183	10
Free-threshing wheat, grain	*Triticum durum/aestivum*	20	145	36	201	8
Wheat, grain	*Triticum* spp.			25	25	6
Indeterminate cereal, grain		50	13	35	98	12
Pulses						
Lentil, seed	*Lens culinaris* Medikus	5		1	**6**	**3**
?Pea, seed	cf. *Pisum sativum* L.	1	1	1	**3**	**3**
?Broad bean, seed	cf. *Vicia faba* L.			1	**1**	**1**
Legume indet., seed		2		1	**3**	**3**
Spices						
Black pepper, seed	*Piper nigrum* L.	12		1	13	2
Fruits						
Grape, seed	*Vitis vinifera* L.	2		11	13	7
Olive, stone	*Olea europaea* L.		2	2	4	4
Elder, seed	*Sambucus* sp.	1		9	10	3
Blackberry-type, seed	*Rubus* sp.			4	4	3
Fig, seed	*Ficus carica* L.		3 + 1 fruit frag	7 + 1 fruit frag	10 + 2 fruit frags	4
Fruit, pulp fragment				2	2	1
Nuts						
Stone pine, seed	*Pinus pinea* L.			2	**2**	**2**
Terebinth, seed	*Pistacia* sp.			1	**1**	**1**
Oak, acorn	*Quercus* sp.			2	**2**	**2**
Walnut, nutshell	*Juglans regia* L.			1	**1**	**1**

Overall total			**331**	**307**	**228**	**866**	**48**

Table S2: Bone counts of likely consumed animals by period

Common name	Taxonomic name	Periods 2, 3 and 4	Period 5	Period 6	Total NISP
		early 2nd to early 3rd cent AD	late 4th to early 5th cent AD	mid 5th to mid 6th cent AD	
		35 contexts	7 contexts	117 contexts	
Mammals		198	33	879	
Horse	*Equus caballus* L.	2		79	**81**
Equid	Equidae	1	1	74	**76**
Cattle	*Bos taurus* L.	10		58	**68**
Cattle/horse-sized mammal		20	3	202	**225**
Sheep	*Ovis aries* L.	2		4	**6**
Sheep/goat	*Ovis/Capra*	12	4	44	**60**
Pig	*Sus domesticus* Erxleben	51	4	115	**170**
Sheep/pig-sized mammal		100	21	300	**421**
Fallow deer	*Dama dama* Frisch			3	**3**
Hare	*Lepus europaeus* Pallas	3		3	**6**
Rabbit	*Cuniculus oryctolagus* L.			1	**1**
Hare/rabbit	*Lepus/Oryctolagus*			2	**2**
Birds					
Goose, domestic/greylag	*Anser anser* (L.)	1		2	**3**
Duck, mallard/domestic	*Anas platyrhynchos* L.	1		1	**2**
Teal	*Anas crecca* L.	1		1	**2**
Domestic fowl	*Gallus gallus* (L.)	7		10	**17**
Pheasant	*Phasianus colchicus* L.			2	**2**
Pigeon	*Columba* sp.			1	**1**
Coot	*Fulica atra* L.			2	**2**
Small passerine, songbirds	Passeriformes	3	1	6	**10**
cf. Partridge	cf. *Perdix perdix* (L.)	1			**1**
Bird, indeterminate		13		62	**75**
Fish					
Eel	*Anguilla anguilla* (L.)			1	**1**
Sardine/sardinella	Clupeidae			1	**1**
Carp Family	Cyprindae			1	**1**
Seabream	Sparidae			2	**2**
Fish, indeterminate		6	2	33	41

Total NISP		**234**	**36**	**1010**	**1280**

Figure S1: Plant and animal assemblages at Portus: (a) Count of charred macrofossils of likely consumed plants by period; (b) NISP count of likely consumed animals by period

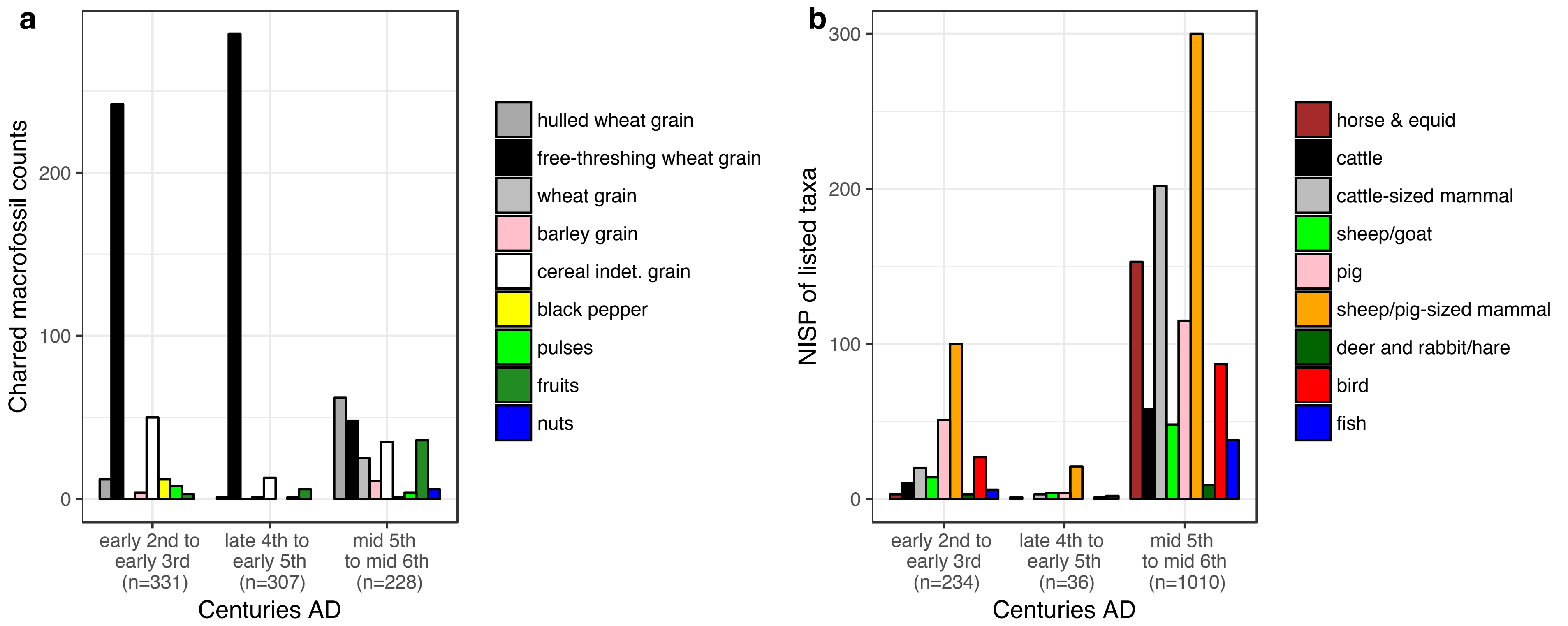

Table S3: Isotopic sample distribution by charred grain abundance
* stable isotopic analysis of charred grain within that context category

	Number of flotation sieved contexts						**Number of grains analysed isotopically**
Period	Overall	No grain	1-2 grain	< 10 grain	10-50 grain	> 50 grain	
1	1	1	0	0	0	0	0
2	20	17	1	0	0	2 *	59
3	3	3	0	0	0	0	0
4	18	13	3	2 *	0	0	1
5	17	14	0	1	1 *	1 *	22
6	122	90	9	19 *	4 *	0	9
Total	**181**	**138**	**13**	**22**	**5**	**3**	**91**

Table S4: Isotopic results of all plant samples with relevant details of archaeological context, and species identification
Nitrogen isotopic values are only reported for those samples with sufficient nitrogen for a valid measurement
FT = free-threshing wheat, H = hulled wheat

Period	**Chronology** (centuries AD)	**Context**	**Sample**	**Species**	**Type**	**Lab code**	**Sample size (mg)**	**δ13C (‰)**	**δ15N (‰)**	**N (mg)**	**Atom C/N ratio**
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16F	0.9	-22.5	9.1	0.031	19.5
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16E	0.8	-23.0	10.1	0.030	17.6
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16B	0.9	-22.0		0.027	24.6
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16D	0.8	-22.4		0.025	21.4
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16E	0.8	-23.2		0.021	25.6
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16I&J	0.8	-22.1		0.021	27.9
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16I	0.8	-23.9		0.020	31.2
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16H	0.8	-23.4		0.018	34.3
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16F	0.9	-24.2		0.018	32.1
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16J	0.7	-22.8		0.018	30.4
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16A	0.8	-23.7		0.017	32.0
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16C	0.8	-23.3		0.017	28.9
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16C	0.8	-24.2		0.017	34.7
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16B	0.8	-24.1		0.016	36.5
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16G	0.9	-24.2		0.016	39.8
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD16A	0.8	-24.6		0.016	35.2
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16H	0.7	-24.7		0.015	32.7
2	early 2nd	1061	0016	Macaroni wheat grain	FT	LBCFD016D	0.7	-22.5		0.014	33.5
2	early 2nd	1061	0016	Free-threshing wheat grain	FT	LBCFA16G	0.7	-24.7		0.013	38.6
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008I&J	0.7	-22.4		0.027	18.1
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008G	0.7	-20.5		0.027	18.3
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008F	0.9	-21.6		0.023	26.4
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008C	0.9	-22.8		0.022	27.8
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008A	0.8	-24.1		0.021	28.0
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008C	0.9	-23.0		0.021	28.9
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008G	0.9	-22.5		0.020	30.3
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008B	0.9	-24.0		0.020	31.7
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008D	0.7	-22.6		0.019	28.4
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008E	0.7	-23.2		0.019	29.9
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008K	0.8	-22.9		0.019	30.9
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008D	0.9	-22.9		0.018	34.3

Living and Dying at the Portus Romae
Supplementary Information **O'Connell et al.**

Period	Chronology (centuries AD)	Context	Sample	Species	Type	Lab code	Sample size (mg)	δ^{13}C (‰)	δ^{15}N (‰)	N (mg)	Atom C/N ratio
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008F	0.8	-24.2		0.018	30.0
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008E	0.8	-23.0		0.018	33.8
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1008H	0.9	-23.6		0.017	34.1
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008H	0.9	-24.3		0.017	37.3
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008A	0.8	-23.2		0.017	33.0
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008I	0.8	-23.5		0.017	35.8
2	early 2nd	1061	1008	Macaroni wheat grain	FT	LBCFD1088B	0.7	-23.7		0.015	35.1
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008J	0.9	-23.5		0.015	36.8
2	early 2nd	1061	1008	Bread wheat grain	FT	LBTA1008L	0.8	-23.8		0.014	36.6
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012I	0.8	-23.4	4.0	0.032	18.0
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012H&I	0.8	-23.0	10.9	0.032	18.3
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012F	0.8	-21.8		0.029	20.1
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012D	0.8	-22.2		0.026	22.8
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012E	0.9	-22.9		0.026	24.6
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012E	0.9	-23.5		0.023	25.5
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012B	0.9	-21.9		0.023	25.9
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012A	0.9	-22.3		0.023	27.8
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012J	0.7	-23.8		0.022	22.5
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012C	0.8	-23.0		0.021	27.0
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012G	0.8	-24.4		0.020	27.7
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012B	0.8	-22.2		0.020	26.7
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012F	0.9	-24.3		0.019	31.6
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012H	0.9	-22.6		0.018	33.5
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012J	0.7	-22.7		0.018	27.4
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012G	0.7	-24.1		0.018	29.8
2	early 2nd	1123-1124	1012	Bread wheat grain	FT	LBTA1012C	0.7	-23.9		0.017	30.5
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012A	0.9	-22.8		0.016	35.2
2	early 2nd	1123-1124	1012	Macaroni wheat grain	FT	LBTD1012D	0.8	-22.6		0.015	24.3
4	early 3rd	2315	2021	Free-threshing wheat grain	FT	BMW2021	0.7	-22.5		0.024	17.8
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013B	0.9	-21.1	5.8	0.042	15.3
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013A	0.9	-21.5	8.0	0.038	16.5
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013G	0.9	-20.4	8.9	0.032	17.9
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013F	0.9	-21.1	9.4	0.042	15.1
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013A	0.9	-20.6	9.8	0.037	16.6
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013H	0.8	-21.2	10.1	0.032	16.4

Period	**Chronology** (centuries AD)	**Context**	**Sample**	**Species**	**Type**	**Lab code**	**Sample size (mg)**	**δ13C (‰)**	**δ15N (‰)**	**N (mg)**	**Atom C/N ratio**
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013I	0.9	-21.2		0.029	23.0
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBCFD4013I	0.8	-20.7		0.029	20.0
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013F	0.8	-23.0		0.027	21.8
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013JK	0.7	-21.3		0.027	19.6
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013G	0.8	-21.2		0.027	22.2
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013D	0.7	-21.3		0.025	19.5
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013E	0.8	-23.4		0.024	22.8
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013C	0.9	-22.3		0.024	26.3
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013E	0.8	-22.8		0.024	24.8
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013B	0.9	-24.1		0.023	30.6
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013C	0.8	-22.1		0.022	25.5
5	late 4th-early 5th	4031	4013	Bread wheat grain	FT	LBTA4013D	0.8	-21.9		0.021	24.3
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBTCFD4013H	0.7	-22.6		0.020	25.6
5	late 4th-early 5th	4031	4013	Macaroni wheat grain	FT	LBCFD4013J	0.8	-22.1		0.020	28.4
5	late 4th-early 5th	4049	4018	Free-threshing wheat grain	FT	MW4018	0.9	-22.6		0.030	20.5
5	late 4th-early 5th	4049	4018	Indeterminate cereal grain fragments		CFR4018	0.9	-21.8		0.029	20.6
6A	mid 5th-early 6th	1113	0053	Bread wheat grain	FT	LB53A	0.8	-23.1		0.026	21.9
6A	mid 5th-early 6th	2314	2013	Macaroni wheat grain	FT	LBTCFD2015	0.9	-22.2	2.4	0.030	18.1
6A	mid 5th-early 6th	2314	2013	Hulled barley grain		LBHB2013A	0.9	-22.0	6.9	0.037	16.9
6A	mid 5th-early 6th	3013	0042	Einkorn/Emmer wheat grain	H	CPGW0042	0.8	-22.5		0.028	20.0
6A	mid 5th-early 6th	5054	5019	Free-threshing wheat grain	FT	BMW5019	0.8	-23.0		0.029	17.1
6A	mid 5th-early 6th	5055	5022	Einkorn grain	H	LBTM5022B	0.7	-23.3		0.025	20.3
6A	mid 5th-early 6th	5055	5022	Einkorn grain	H	LBTM5022A	0.7	-22.5		0.015	23.2
6A	mid 5th-early 6th	5055	5022	Indeterminate large-seeded legume		LL5022	0.9	-26.5		0.004	156.7
6A	mid 5th-early 6th	5062	5027	Free-threshing wheat grain	FT	LBTAD5027AB	0.8	-22.8	-0.3	0.033	18.6

Table S5: Provenance of animal bone specimens for isotopic sampling

Taxon	Area	Number of sampled specimens: Periods 2, 3, 4 early 2nd to early 3rd cent AD	Number of sampled specimens: Period 5 late 4th to early 5th cent AD	Number of sampled specimens: Period 6 mid 5th-early 6th cent AD	Number of contexts: Periods 2, 3, 4 early 2nd to early 3rd cent AD	Number of contexts: Period 5 late 4th to early 5th cent AD	Number of contexts: Period 6 mid 5th-early 6th cent AD	Additional comments
Cattle 11 samples	Area A	3			3			
	Area B			6			6	
	Area C	1			1			
	Area E			1			1	
Pig 8 samples	Area A	1			1			
	Area B	3		1	3		1	
	Area C	1			1			
	Area D			1			1	
	Area E			1			1	
Sheep 8 samples	Area B			3			3	
	Area C		1			1		
	Area D	1		2	1		2	
	Area E			1			1	
Sheep/goat 7 samples	Area A			1			1	
	Area B	1		1	1		1	
	Area C	1	1		1	1		
	Area D			1			1	
	Area E			1			1	
Horse 4 samples	Area A			1			1	
	Area C			2			2	
	Area D			1			1	
Equid 3 samples	Area C			1			1	Two left ulna from Period 6A context 4277
	Area D			2			1	

Bird **9 samples**	Area B	2		6	1		3	Fowl and duck both from Period 4 context 2315. Pigeon, pigeon/duck, domestic fowl and pheasant from Period 6A context 2282.
Fallow deer **2 samples**	Area B			1			1	
	Area E			1			1	
Hare **1 sample**	Area B			1			1	
Fish **4 samples**	Area B			1			1	
	Area E			3			3	
Totals		**14**	**2**	**40**	**13**	**2**	**36**	

Table S6: Occurrence of bone condition records by taxonomic group

Taxonomic group	fragmented	butchered	gnawed	eroded	charred	calcined	ivoried	concretion	unaffected	total excl. teeth	total records
fish	8	3	1	3	1				31	**48**	48
birds	40	2		18	1	1	9	3	105	**160**	160
deer	2	1	1	2			2	4		**7**	7
sheep/pig-sized	108	69	9	181	8	6	7	38	152	**453**	453
pig	57	28	11	72	1		5	20	60	**153**	190
sheep/goat	30	14	2	32			1	7	19	**56**	76
cattle-sized	165	13	6	169	2	1	13	17	42	**262**	262
cattle	56	27	13	51	1		9	8	33	**116**	127
horse/equid	95		4	77					40	**116**	172
Total	**561**	**157**	**47**	**605**	**14**	**8**	**46**	**97**	**482**	**1371**	**1495**

Figure S2: Occurrence of bone condition records by taxonomic group

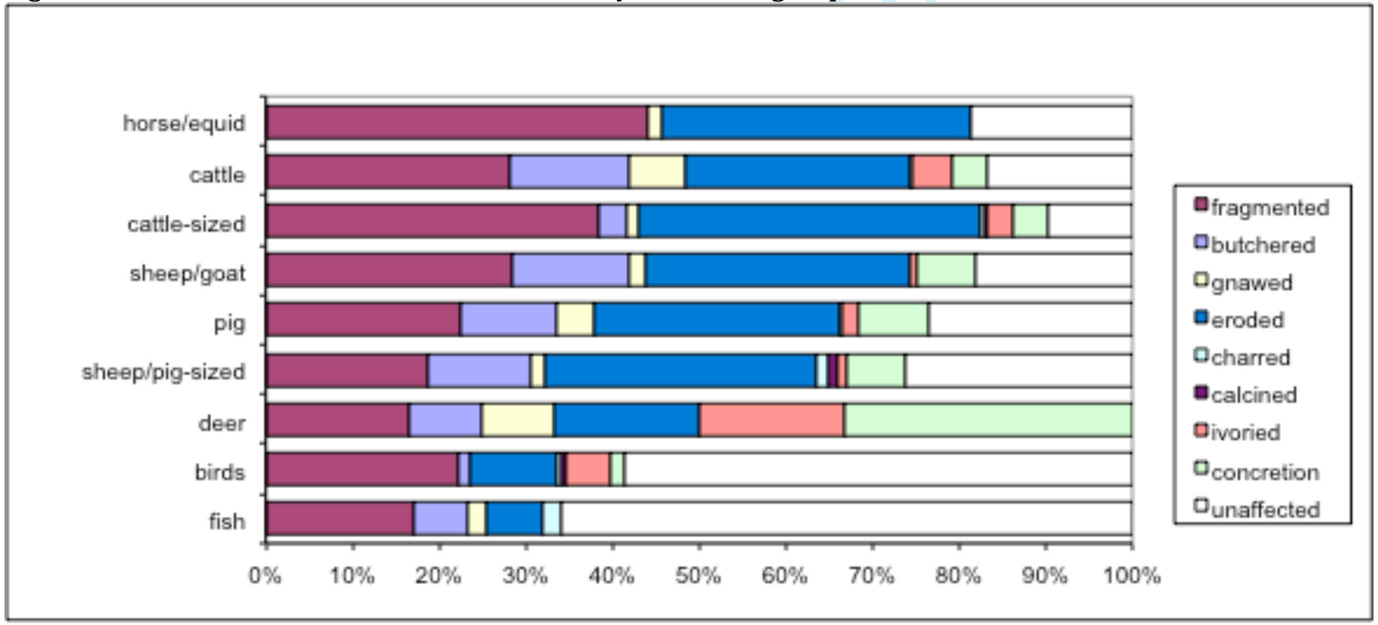

Table S7: Isotopic results of bone collagen from all animal samples with relevant excavation data

Species	Element	Context	Period	Chronology	Lab_ID	Collagen % yield	Atom C/N ratio	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Rep nos.
Cattle	scapula	1047	4	early 3rd	PTXI001	5.3	3.24	-21.3	5.0	3
Cattle	metacarpus	1045	4	early 3rd	PTXI007	3.9	3.17	-21.3	2.9	3
Cattle	phalanx	1056	4	early 3rd	PTXI016	3.3	3.20	-21.3	5.0	3
Cattle	skull frag	3125	4	early 3rd	PTXI071	5.7	3.17	-19.6	9.5	3
Cattle	left radius	2247	6A	mid 5th-early 6th	PTXI012	1.8	3.29	-20.6	6.5	3
Cattle	radius	2217	6A	mid 5th-early 6th	PTXI013	4.9	3.27	-21.2	6.2	3
Cattle	radius	5017	6A	mid 5th-early 6th	PTXI020	3.5	3.26	-20.7	4.9	3
Cattle	metacarpus	2158	6A	mid 5th-early 6th	PTXI030	13.3	3.20	-21.0	6.6	3
Cattle	phalanx 2	2172	6A	mid 5th-early 6th	PTXI032	15.5	3.17	-21.4	6.2	3
Cattle	phalanx 3	2207	6A	mid 5th-early 6th	PTXI034	8.6	3.20	-20.9	8.0	3
Cattle	astragalus	2034	6B	mid 5th-early 6th	PTXI028	4.8	3.19	-20.6	5.4	2
Sheep	mandible	4364	2	early 2nd	PTXI004	5.6	3.22	-20.9	4.8	3
Sheep	mandible	3124	5	late 4th-early 5th	PTXI009	4.9	3.22	-18.1	10.9	3
Sheep	humerus	2310	6A	mid 5th-early 6th	PTXI011	5.0	3.25	-21.1	5.9	3
Sheep	metatarsus	5017	6A	mid 5th-early 6th	PTXI021	4.9	3.23	-21.2	6.1	3
Sheep	metatarsus	2158	6A	mid 5th-early 6th	PTXI051	2.6	3.22	-21.4	4.5	3
Sheep	pelvis	2282	6A	mid 5th-early 6th	PTXI059	4.1	3.18	-21.5	2.5	3
Sheep	mandible	4126	6A	mid 5th-early 6th	PTXI073	5.4	3.19	-21.1	2.6	3
Sheep	humerus	4048	6B	mid 5th-early 6th	PTXI035	5.7	3.26	-20.4	5.5	3
Sheep/goat	tibia	2315	4	early 3rd	PTXI067	3.6	3.17	-21.1	3.3	3
Sheep/goat	tibia	3125	4	early 3rd	PTXI070	6.4	3.15	-20.7	7.2	3
Sheep/goat	femur	3004	5	late 4th-early 5th	PTXI068	4.7	3.20	-20.9	3.6	3
Sheep/goat	calcaneum	1079	6A	mid 5th-early 6th	PTXI048	5.1	3.21	-21.2	3.8	3
Sheep/goat	tibia	2217	6A	mid 5th-early 6th	PTXI056	5.9	3.17	-20.1	4.7	3
Sheep/goat	tibia	4277	6A	mid 5th-early 6th	PTXI077	6.1	3.15	-21.5	5.4	3
Sheep/goat	tibia	5019	6A	mid 5th-early 6th	PTXI081	6.9	3.17	-20.5	5.8	3
Pig	pig fibula	1045	4	early 3rd	PTXI008	4.9	3.18	-21.1	8.6	3
Pig	metatarsus	2315	4	early 3rd	PTXI065		3.24	-20.4	4.3	2
Pig	phalanx 3	3125	4	early 3rd	PTXI072	2.8	3.17	-20.8	3.5	2
Pig	maxilla	4356	6A	mid 5th-early 6th	PTXI005	3.6	3.25	-20.5	7.4	3
Pig	scapula	2158	6A	mid 5th-early 6th	PTXI052	8.4	3.18	-21.4	3.5	3
Pig	calcaneum	2217	6A	mid 5th-early 6th	PTXI053	2.9	3.27	-21.0	6.2	3
Pig	phalanx 1	2282	6A	mid 5th-early 6th	PTXI060	3.4	3.25	-21.1	3.0	3

Species	Element	Context	Period	Chronology	Lab_ID	Collagen % yield	Atom C/N ratio	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Rep nos.
Pig	astragalus	5019	6A	mid 5th-early 6th	PTXI079	4.7	3.18	-20.6	5.0	3
Fowl	tarsometatarsus	2315	4	early 3rd	PTXI064	1.8	3.24	-19.1	9.8	3
Duck	humerus	2315	4	early 3rd	PTXI066	1.5	3.20	-21.8	6.9	3
Duck	scapula	2158	6A	mid 5th-early 6th	PTXI050	18.1	3.19	-18.5	10.2	3
Pigeon	right humerus	2282	6A	mid 5th-early 6th	PTXI061	7.6	3.19	-21.7	7.0	3
Pigeon / Duck	ulna	2282	6A	mid 5th-early 6th	PTXI063	10.2	3.20	-19.1	8.3	3
Domestic fowl	tarsometatarsus	2282	6A	mid 5th-early 6th	PTXI062	2.0	3.23	-19.3	9.8	3
Domestic fowl	tarsometatarsus	5019	6A	mid 5th-early 6th	PTXI080	8.8	3.20	-19.4	10.5	3
Domestic fowl / Pheasant	tibiotarsus	2217	6A	mid 5th-early 6th	PTXI055	5.2	3.30	-19.0	10.7	3
Pheasant	tarsometatarsus	2282	6A	mid 5th-early 6th	PTXI057	3.4	3.29	-19.2	7.1	3
Horse	tibia	3032	6A	mid 5th-early 6th	PTXI002	4.0	3.23	-21.1	2.8	3
Horse	metatarsus	1089	6A	mid 5th-early 6th	PTXI003	2.7	3.27	-21.6	5.0	3
Horse	mandible	4357	6A	mid 5th-early 6th	PTXI006	3.8	3.29	-19.1	5.1	3
Horse		3041	6A	mid 5th-early 6th	PTXI039	8.2	3.21	-21.1	2.8	3
Equid	metacarpus 4	3033	6A	mid 5th-early 6th	PTXI069	3.5	3.24	-21.0	3.2	3
Equid	ulna	4277	6A	mid 5th-early 6th	PTXI075	4.7	3.15	-18.8	3.8	3
Equid	ulna	4277	6A	mid 5th-early 6th	PTXI076	9.8	3.17	-18.8	4.3	3
Fallow deer	femur	2320	6A	mid 5th-early 6th	PTXI010	6.6	3.25	-21.2	5.5	3
Fallow deer	radius	5019	6A	mid 5th-early 6th	PTXI078	4.2	3.19	-22.3	5.7	3
Hare	calcaneum	2282	6A	mid 5th-early 6th	PTXI058	2.3	3.24	-21.5	2.0	3
Fish		5105	6A	mid 5th-early 6th	PTXI083	13.4	3.16	-13.9	7.9	3
Fish		5055	6A	mid 5th-early 6th	PTXI084	6.9	3.24	-15.1	9.9	3
Fish		2373 <2047> (SK2170)	6A	mid 5th-early 6th	PTXI085	38.7	3.12	-13.4	12.1	3
Seabream		5019	6A	mid 5th-early 6th	PTXI082	7.0	3.14	-7.6	10.1	3

Table S8: Isotopic results of Imperiale Navalia Building 5 human samples with relevant details of archaeological context, osteological information, sex and bone elements sampled

Skel code	Sex	Age (yr)	Peri od	Burial type	Tooth taken	Atom C/N ratio	Rep nos	Collagen δ¹³C (‰)	SD	Collagen δ¹⁵N (‰)	SD	Comme nt on collagen	Enamel δ¹³C (‰)	Enamel δ¹³C (‰)
PTXI1030					-	3.3	3	-18.0	0.1	10.7	0.1			
PTXI1119	M	35-40	6A	Brick cist	M3 MD R	3.2	3	-18.8	0.1	11.2	0.0		-6.0	-12.4
PTXI2170	M	20-25	6A	Brick cist	-	3.2	3	-19.5	0.1	8.9	0.0			
PTXI2377	M	40-50	6A	Brick cist	M1 MD R	3.2	3	-19.3	0.2	11.7	0.1		-6.0	-12.8
PTXI3098	M	20-40	6A	Amphora burial	-							fail		
PTXI3146	M	20-30	6A	Tiles burial	-	3.0	2	-18.8		11.3				
PTXI4054	M	40-50	6B		M2 MX L	3.2	3	-18.0	0.1	12.1	0.0		+0.7 +0.6	-11.8 -11.6
PTXI4156	M	20-30	6A		M2 MD R	3.2	3	-18.6	0.0	9.7	0.1		-3.5	-12.3
PTXI4209	M	30-40	6A	Amphora burial	M2 MD R	3.3	3	-18.9	0.1	11.1	0.0		-3.5	-12.0
PTXI4211	M	>50	6A	Ditch burial	M2 MD L							fail	-5.0	-11.6
PTXI4235	M	20-30	6A		M2 MD R	3.2	3	-19.3	0.1	10.3	0.1		-6.8	-13.1
PTXI4269	M	35-45	6A		M2 MD L	3.2	3	-19.7	0.1	8.0	0.0		-7.4	-12.8
PTXI4287	M	25-30	6A		M2 MD R	3.2	3	-19.5	0.1	9.1	0.0		-5.6	-12.5
PTXI4288	ND	16-20	6A		M2 MX L								-5.3	-12.3
PTXI4300	ND	20-30	6A		-							fail		
PTXI4302	M	20-30	6A		M2 MD R	3.1	3	-19.0	0.1	10.6	0.1		-6.1	-11.4
PTXI4329	M	40-50	6A		-	3.2	3	-20.3	0.1	7.5	0.0			
PTXI4337	M	30-40	6A		M3 MX L	3.2	3	-18.7	0.1	10.2	0.1		-6.4	-12.2
PTXI4348	M	20-30	6A		M2 MD L	3.2	3	-18.9	0.1	10.0	0.0		-4.1	-12.6
PTXI4353	F	30-40	6A		M3 MD R	3.2	3	-18.7	0.1	12.2	0.0		-4.6	-12.4
PTXI4377	M	30-40	6A		M3 MD R	3.3	3	-19.7	0.1	8.2	0.1		-3.5	-12.2
PTXI4388	M	35-45	6A		-	3.2	3	-18.6	0.1	10.9	0.1			
PTXI4404	ND	8-10	6A		M2 MD L							fail	-6.0	-11.7
PTXI4413	M	30-40	6A		M3 MD L	3.0	2	-18.7		10.9		?	-3.8	-12.3
PTXI4416	ND	5-7	6A		-	3.1	3	-19.0	0.1	10.0	0.1			
PTXI4425	F	30-40	6A	Amphora burial	M2 MD R	3.2	3	-18.9	0.1	11.0	0.1		-1.4 -1.7	-12.6 -12.7
PTXI4452	ND	6-10	6A		-	3.2	3	-19.4	0.1	9.7	0.1			

Skel code	Sex	Age (yr)	Period	Burial type	Tooth taken	Atom C/N ratio	Rep nos	Collagen $\delta^{13}C$ (‰)	SD	Collagen $\delta^{15}N$ (‰)	SD	Comment on collagen	Enamel $\delta^{13}C$ (‰)	Enamel $\delta^{13}C$ (‰)
PTXI4478	M	20-25	6A		M2 MD R							no ribs	-4.5	-10.7
PTXI4493	F	40-50	6A		M2 MD R	3.2	3	-19.1	0.1	11.1	0.0		-7.5	-12.5
PTXI4494	ND	>20	6A		-	3.2	3	-19.2	0.1	10.6	0.0			
PTXI4515	F	30-35	6A		-	3.2	3	-19.2	0.1	10.1	0.1			
PTXI5113	M	25-35	6A	Tiles and amphora burial	M3 MX L	3.2	3	-19.5	0.1	10.6	0.0		-5.5	-13.5
PTXI5134	ND	6-9	6A	Tiles and amphora burial	-	3.2	3	-19.0	0.1	10.2	0.1			
PTXI7030	M	35-45	6A	Ditch burial	-	3.0	2	-17.7		10.8				

Table S9: Isotopic results of Tenuta del Duca human samples with relevant details of archaeological context, osteological information, sex and bone elements sampled

Sample code	Sex	Age (yr)	Tomb	Trench	Area	Element	Collagen yield %	Mean C/N	Rep nos.	Collagen $\delta^{13}C$ (‰)	SD	Collagen $\delta^{15}N$ (‰)	SD
TNT2	M	30-40	2	1	A	Ribs	9.8	3.2	3	-18.8	0.1	11.9	0.0
TNT3	M	20-40	3	1	A	Ribs	3.6	3.3	3	-19.4	0.1	10.2	0.0
TNT4	M	Adult	4	1	A	Ribs	6.8	3.2	3	-18.7	0.1	11.4	0.0
TNT5	M	35-40	5	1	A	Ribs	5.3	3.2	3	-18.8	0.3	11.1	0.0
TNT6	M	25-35	6	1	A	Ribs	5.1	3.2	3	-18.9	0.1	11.4	0.0
TNT7	M	20-25	7	1	A	Ribs	3.3	3.2	3	-19.3	0.2	10.9	0.0
TNT8	M	18-24	8	1	A	Ribs	2.6	3.3	3	-18.6	0.1	11.6	0.0
TNT9	M	40-45	9	1	A	Ribs	2.9	3.2	3	-18.6	0.1	11.0	0.0
TNT10	M	35-45	10	1	A	Ribs	2.4	3.2	3	-18.5	0.1	11.4	0.0
TNT11	M	25-35	11	1	A	Ribs	4.3	3.2	3	-18.9	0.1	13.7	0.0
TNT12	F	Adult	12	1	A	Ribs	3.3	3.2	3	-18.7	0.1	11.5	0.0
TNT14	F	20-25	14	1	A	Ribs	2.5	3.2	3	-18.9	0.1	9.5	0.0
TNT15	F	25-35	15	1	A	Ribs	3.4	3.2	3	-18.8	0.2	11.1	0.0
TNT16	M	Adult	16	1	A	Ribs	3.9	3.3	3	-19.1	0.1	10.7	0.0
TNT17	-	40-50	17	1	A	Scapula	5.3	3.2	3	-18.4	0.0	11.6	0.0
TNT18	M	Adult	18	1	A	Femur	4.6	3.2	3	-18.4	0.0	9.9	0.0
TNT19	M	Adult	20	1	A	Ribs	4.9	3.2	3	-18.8	0.1	13.5	0.0
TNT20	M	22-24	21	1	A	Ribs	4.4	3.2	3	-18.5	0.1	11.1	0.0
TNT21	-	20-30	22	1	A	Ribs	3.5	3.3	3	-19.3	0.0	11.1	0.1
TNT22	M	25-35	23	1	A	Ribs	4.4	3.2	3	-18.9	0.1	10.6	0.0
TNT24	M	18-22	25	1	A	Ribs	3.9	3.2	3	-18.9	0.0	11.1	0.0
TNT25	M	20-30	26	1	A	Ribs	3.7	3.2	3	-18.9	0.1	13.4	0.0
TNT26	M	18-23	27	1	A	Ribs	2.8	3.2	3	-19.0	0.1	11.6	0.0
TNT28	M	40-50	32	1	A	Ribs	4.9	3.2	3	-18.9	0.1	11.4	0.0
TNT29	F	16-21	33	1	D	Ribs	5.9	3.2	3	-18.6	0.1	12.0	0.1
TNT30	M	38-48	34	1	D	Ribs	10.3	3.2	3	-18.8	0.1	11.2	0.0
TNT31	F	35-45	35	1	D	Ribs	10.3	3.2	3	-18.8	0.1	10.6	0.1
TNT32	M	35-45	36	1	D	Ribs	3.5	3.2	3	-19.3	0.0	10.7	0.1
TNT33	-	Adult	37	1	D	Ribs	2.9	3.2	3	-19.5	0.0	10.6	0.0
TNT34	F	18-23	38	1	D	Ribs	10.0	3.2	3	-18.5	0.1	12.6	0.0
TNT36	-	Adult	2	3	B	Tibia	9.2	3.2	3	-19.5	0.1	10.9	0.1
TNT38	-	14-16	1	3	C	Ribs	8.4	3.1	3	-19.9	0.0	7.5	0.0

Table S10: Summary statistics for the faunal bone collagen carbon and nitrogen isotopic values from Portus

		δ13C (‰)							δ15N (‰)						
	N	**mean**	**SD**	**median**	**IQR**	**Max**	**Min**	**range**	**mean**	**SD**	**median**	**IQR**	**Max**	**Min**	**range**
bird	9	-19.7	1.2	-19.2	0.3	-18.5	-21.8	3.3	8.9	1.6	9.8	3.1	10.7	6.9	3.8
cattle	11	-20.9	0.5	-21.0	0.7	-19.6	-21.4	1.8	6.0	1.7	6.2	1.6	9.5	2.9	6.6
deer	2	-21.8		-21.8		-21.2	-22.3	1.1	5.6		5.6	0.1	5.7	5.5	0.2
equid	7	-20.2	1.2	-21.0	2.2	-18.8	-21.6	2.8	3.9	1.0	3.8	1.7	5.1	2.8	2.3
fish	4	-12.5	3.3	-13.7	2.3	-7.6	-15.1	7.5	10.0	1.7	10.0	1.2	12.1	7.9	4.2
hare	1	-21.5		-21.5		-21.5	-21.5	0.0	2.0		2.0		2.0	2.0	0.0
pig	8	-20.9	0.3	-20.9	0.5	-20.4	-21.4	1.0	5.2	2.0	4.7	3.0	8.6	3.0	5.6
sheep/goat	15	-20.8	0.8	-21.1	0.6	-18.1	-21.5	3.4	5.1	2.1	4.8	2.2	10.9	2.5	8.4

Table S11: Summary of human bone collagen carbon and nitrogen isotopic values.

		δ13C (‰)							**δ15N (‰)**						
	N	**mean**	**SD**	**median**	**IQR**	**Max**	**Min**	**range**	**mean**	**SD**	**median**	**IQR**	**Max**	**Min**	**range**
Isola Sacra	91	-18.7	0.4	-18.7	0.4	-17.3	-19.9	2.6	11.3	0.9	11.5	0.8	12.9	8.3	4.6
Tenuta del Duca	32	-18.9	0.4	-18.9	0.4	-18.4	-19.9	1.5	11.2	1.2	11.1	0.9	13.7	7.5	6.2
Building 5	28	-19.0	0.6	-19.0	0.6	-17.7	-20.3	2.6	10.3	1.2	10.6	1.1	12.2	7.5	4.7

Isola Sacra data from Crowe *et al.* 2010

Table S12: Summary of human tooth enamel carbonate oxygen isotopic values.

	$\delta^{18}O$ (‰)						
	N	**Mean**	**SD**	**Median**	**IQR**	**Max**	**Min**
Isola Sacra	61	-5.0	1.0	-4.9	1.2	-2.8	-7.6
Building 5	22	-4.9	1.9	-5.4	2.2	0.7	-7.5

Plant and animal bone sampling methodology

During the 2007 to 2009 excavation seasons, sediment samples of 10–20 litres were collected from all well-stratified deposits. From 2010 onwards, 1st to 3rd c. AD features were targeted due to their relatively low occurrence compared to 5th/6th c. AD features. Overall 236 flotation samples were processed, totalling 3324 litres of sediment from 181 contexts.

All samples were sieved on-site by flotation using a modified version of the Sīraf tank (Williams 1973). Flots were collected in 300 micron nylon mesh and residues in 1mm nylon mesh, with both fractions dried prior to sorting. Most of the animal bone was recovered by hand collection, with flotation residues greater than 2mm also scanned for bone. Charred plant remains were collected solely by flotation, and almost all of the fish and small vertebrates were recovered from the flotation residues.

Charred grain selection for isotopic analysis

Grain isotope samples were selected from contexts with the highest 10% of grain abundance values within each site period (Table S3). Since 80% or more of flotation sieved contexts contained zero or 1–2 charred grains, residuality is thought to be low in contexts with multiple grains, including Period 6 where a greater proportion of sampled contexts have low quantities of grain.

The Period 2 isotope samples derive from two grain-rich deposits *1061* and *1123–1124* from the late Trajanic quayside (207 and 83 grains, respectively), no Period 4 deposits were grain-rich and so floor deposit *2315* with multiple free-threshing wheat grain was used (5 grains overall), Period 5 sand dump *4031* was grain-rich and another *4049* had moderate grain (266 and 31 grains, respectively). Period 6 had one silty dump *3013* with moderate grain, and several further dumps *1113*, *2314*, *5054*, *5055*, *5062* with low grain (30, 6, 6, 4, 9 grains, respectively).

Animal bone recording and selection for isotopic analysis

All bone fragments were counted and identified to taxon and element where possible with the following exceptions: ribs and vertebrae of the ungulates (other than axis, atlas, and sacrum) were identified only to the level of cattle/horse-sized and sheep/pig-sized. This restriction did not apply to burials and other associated bones where ribs and vertebrae were assigned to species. Undiagnostic shaft and other fragments were similarly divided. Any fragments that could not be assigned even to this level were recorded as mammalian only.

Where possible sheep and goat were separated using the methods of Boessneck (1969), Payne (1985) and Halstead & Collins (2002). Recently broken fragments were joined where possible and counted as single specimens. Individual bone records were made of the condition of each specimen, including erosion, gnawing, burning and other aspects of appearance such as flaking and staining.

Bone specimens of likely food taxa were selected for isotopic analysis with the aim of ensuring samples from across the three analytical periods (early 2nd to early 3rd century AD, late 4th to early 5th century AD, mid 5th to early/mid 6th century AD). The isotopic samples are summarised by site area and period in Table S5.

No more than one specimen of a taxon was selected from any archaeological context to reduce the potential of sampling multiple specimens from individual animals. The one exception was Period 6A context 4277, where two left horse ulna were sampled as they clearly derived from different individuals. The sampled contexts were also widely distributed across Areas A, B, C, D and E, overall spanning c. 115m east–west and 70m north–south (see Figure 2). All the bones are well enough preserved to identify to species, so are also more likely to be in or near their original burial context given the attritive environment.

Sample preparation for isotopic analysis

Bone collagen samples were prepared following the method described in Privat *et al.* (2002) with a few modifications. Bone samples of approx. 0.5g were cleaned by sand-blasting, then the bones were demineralised in 0.5M aq. hydrochloric acid at 4°C until all the mineral phase was dissolved, then gelatinised at 75°C in water at pH3. The supernate was filtered off by use of an "Ezee" 100μm filter, and then lyophilised. Collagen samples were then weighed into tin capsules for isotopic analysis.

Collagen was successfully extracted and analysed from 57 out of 62 faunal samples, and from 28 out of 33 *Imperiale Navalia* human individuals, and from 32 of the 38 *Tenuta del Duca* human individuals, producing a sufficient yield (1.1%) to be analysed in triplicate (Ambrose 1993). The atomic C/N ratios calculated for all collagen samples are 3.1–3.3, well within the 2.9–3.6 range indicative of well-preserved collagen (DeNiro 1985, Ambrose 1990).

Tooth enamel samples were prepared following a similar protocol to that of Balasse *et al.* (2002). Enamel powder was collected using a Dremel hand-held drill with a diamond drill attachment. 0.1 ml of 2–3% aq. sodium hypochlorite was added per mg of tooth enamel powder, and left for 24 h at 4°C before being rinsed five times with distilled water to remove the sodium hypochlorite. 0.1 ml of acetic acid was then added per mg of sample, left for 4 h at room temperature, before the acetic acid was removed and the samples rinsed. Samples were then freeze-dried to remove any remaining liquid.

Tooth enamel samples were typically analysed once, with 2 samples repeated (PTXI4054 and 4425) to check on anomalous results, and all 22 samples produced a successful isotopic analysis.

Plant remains were rinsed in distilled water, then in 0.5M HCl for 20mins, rinsed in distilled water, lyophilised, ground and then weighed into tin capsules for isotopic analysis. For all 91 plant samples, there was sufficient carbon in each sample for a valid $\delta^{13}C$ isotopic analysis, but only 12 contained sufficient nitrogen for a valid $\delta^{15}N$ analysis (at least 0.03mg of nitrogen, range in atomic C/N ratio of 15.1–19.5)

Isotopic Analysis

All samples were isotopically analysed at the Godwin Laboratory, University of Cambridge. Samples of bone collagen and charred plant macrofossils were analysed using an automated elemental analyzer coupled in continuous-flow mode to an isotope-ratio-monitoring mass-spectrometer (Costech elemental analyzer coupled to a Thermo Finnigan Delta V mass spectrometer). Samples of tooth enamel carbonate were analysed using a Thermo Finnnigan Gas Bench Preparation System coupled to a Thermo Finnnigan MAT 253 mass spectrometer for isotopic analysis. Stable isotope concentrations are measured as the ratio of the heavier isotope to the lighter isotope relative to an internationally defined scale, VPDB for carbon, and AIR for nitrogen (Hoefs, 1997). Isotopic results are reported as δ values ($\delta^{13}C$ and $\delta^{15}N$) in parts per 1000 or 'permil' (‰) values, where $d^{15}N_{AIR} = [(^{15/14}N_{sample} / ^{15/14}N_{AIR}) - 1] \times 1000$. Based on replicate analyses of international and laboratory standards, measurement errors for organic (collagen and plant) $\delta^{13}C$ and $\delta^{15}N$ are less than ±0.2‰, and for inorganic carbon and oxygen, the measurement precision is ±0.08‰ for $\delta^{13}C$ and ±0.10‰ for $\delta^{18}O$. Unless stated, all values used for data comparison are the arithmetical mean of three isotopic measurements obtained per sample.

Statistical Tests & Graphics

Figure plotting and statistical comparisons were carried using RStudio Version 1.1.442 for Macintosh and R 3.4.4. The coloured polygons, or 'bags' in Figure 6a are taken from a bagplot calculation, where a bagplot is a bivariate generalization of the well known boxplot, as proposed by Rousseeuw, Ruts, and Tukey (1999).

Statistical Results

Wheat samples

A Student's t-test shows that the wheat from different time periods is significantly different in carbon isotopic values.

Mean of Periods 2&4 samples =-23.2±0.9‰, mean of Period 5 samples = -21.8±1.0‰, mean of Period 6A samples = -22.8‰.

Comparison of early second to early third century AD samples to late fourth–early fifth century AD samples: Student's t-test t_{79}= -5.9367, P <0.001, 95%CI = -1.81 to -0.90‰; variances judged equal based on Levene's test, F=0.3569, P=0.5519.

Comparison of early second to early third century century AD samples to late fourth to sixth century AD samples: Student's t-test t_{83}= -5.618, P <0.001, 95%CI = -1.63 to -0.78‰; variances judged equal based on Levene's test, F=0.771, P=0.3825

Human samples

An ANOVA test shows that the three groups of humans are not equal in either carbon or nitrogen isotopic values. Post-hoc Tukey tests indicate that Building 5 is different to both Isola Sacra and Tenuta del Duca in $\delta^{15}N$, and Isola Sacra is different to both Tenuta del Duca and Building 5 in $\delta^{13}C$.

For $\delta^{13}C$: $F_{2,148}$=8.055, P<0.001.

Unstandardized effect size (estimated difference between the populations).

Building 5 cf Isola Sacra: -0.319 (95% C.I.= [-0.530, -0.109], p_{adj} =0.001)

Tenuta del Duca cf Isola Sacra: -0.222 (95% C.I.= [-0.422, -0.022] , p_{adj} =0.026)

Tenuta del Duca cf Building 5: 0.098 (95% C.I.= [-0.154, 0.350] , p_{adj} =0.630)

For $\delta^{15}N$: $F_{2,148}$=9.988, P<0.001.

Unstandardized effect size (estimated difference between the populations).

Building 5 cf Isola Sacra: -0.945 (95% C.I.= [-1.454, -0.436], p_{adj} <0.001)

Tenuta del Duca cf Isola Sacra: -0.062 (95% C.I.= [-0.546, 0.422] , p_{adj} =0.950)

Tenuta del Duca cf Building 5: 0.883 (95% C.I.= [0.273, 1.492] , p_{adj} =0.002)

Plant Carbon Isotopic Results

The direction of shift between the earlier second/earlier third century AD to the late fourth–early fifth century AD (from lower $\delta^{13}C$ to higher $\delta^{13}C$) within a single population or region is indicative of greater plant stress (such as less water availability: Wallace *et al.* 2013). We can convert the plant $\delta^{13}C$ values to $\Delta^{13}C_{plant}$ values, indicating the isotopic discrimination of plants in the uptake of atmospheric CO_2 (as per Farquhar *et al.* 1988, taking a value of -6.5 to -7‰ for $\delta^{13}C$ of atmospheric CO_2 at the time). The overall wheat $\Delta^{13}C_{plant}$ values range between *c.* 14 and 19‰, spanning the range of well-watered to poorly watered values for wheat, as defined by Wallace *et al.* (2013). The mean wheat $\Delta^{13}C_{plant}$ decreases by 1.5‰ between the samples from Periods 2 and 4 and those of Period 5 (mean free-threshing wheat $\Delta^{13}C_{plant}$ is 16.6 to 17.2‰ for Periods 2 and 4, and 15.2 to 15.7‰ for Period 5, depending on value of atmospheric CO_2 assumed). Values of wheat $\Delta^{13}C_{plant}$ below 16‰ are suggested to be indicative of poorly watered crops (Wallace *et al.*2013). Whilst there are some untested assumptions underlying our conversion to $\Delta^{13}C_{plant}$, including a lack of correction for charring (Nitsch *et al.*2015), and the exact atmospheric CO_2 $\delta^{13}C$ at the time, it illustrates that the variation we observe in the wheat $\delta^{13}C$ is very significant as regards cultivation regime.

Plant Nitrogen Isotopic Results

There were 13 plant samples with valid carbon and nitrogen isotopic measurements are from six contexts. There are four macaroni wheat grains from two earlier second century contexts (two from 1061 and two from 1123-4). The late fourth to fifth century context 4031 has six samples, three of bread wheat and three of macaroni wheat. Two mid fifth century contexts are represented by a hulled barley grain and a macaroni wheat grain from 2314 and free-threshing wheat grain from 5062. The carbon isotopic values range from -23.4 to -20.4‰, less than that seen in the full set of samples, and the nitrogen isotopic values have a very wide range from 0 to 10.9‰, with 10 of the 13 samples having $\delta^{15}N$ values above 4‰.

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