**[Supplementary material]**

**Living and dying at the *Portus Romae***

Tamsin C. O'Connell[1,*], Rachel M. Ballantyne[2], Sheila Hamilton-Dyer[3], Evi Margaritis[4], Samantha Oxford[1,5], Walter Pantano[6], Martin Millett[7] & Simon 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 Street, Chelmsford CM2 9AQ, UK*

[6] *Collaboratore Soprintendenza Speciale per il Colosseo, il Museo Nazionale Romano e l'Area Archeologica di Roma, Piazza dei Cinquecento, 67, 00185 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*

[*] *Author for correspondence (Email: tco21@cam.ac.uk)*

## 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, first to third century AD features were targeted due to their relatively low occurrence compared to fifth/sixth century 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 per cent of grain

abundance values within each site period (Table S3). Since 80 per cent 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 (Table S6 and Figure S2). Bone specimens of probable food taxa were selected for isotopic analysis with the aim of ensuring samples from across the three analytical periods (early second to early third century AD, late fourth to early fifth century AD, mid fifth to early/mid sixth 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 in main article). 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 approximately 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 per cent) 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 per cent aq. sodium hypochlorite was added per mg of tooth enamel powder, and left for 24 hours at 4°C before being rinsed five times with distilled water to remove the sodium hypochlorite. 0.1ml of acetic acid was then added per mg of sample, left for 4 hours 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 aq. hydrochloric acid for 20 minutes, 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 analyser coupled in continuous-flow mode to an isotope-ratio-monitoring mass-

spectrometer (Costech elemental analyser 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 $\delta^{15}N$), where $\delta^{15}N_{AIR} = [(^{15/14}N_{sample} / {}^{15/14}N_{AIR}) - 1]$. 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 and 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 generalisation of the well known boxplot, as proposed by Rousseeuw *et al.* (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‰ (see Table S4b for summary statistics).

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.

**Statistical results: 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.
Unstandardised 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.
Unstandardised 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‰.

**References**

AMBROSE, S.H. 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. *Journal of Archaeological Science* 17: 431–51. https://doi.org/10.1016/0305-4403(90)90007-R

– 1993. Isotopic analysis of paleodiets: methodological and interpretive considerations, in M.K. Sandford (ed.) *Investigations of ancient human tissue*: 59–130. Langhorne (PA): Gordon & Breach Science Publishers.

BALASSE, M., S. AMBROSE, A. SMITH & T. PRICE. 2002. The seasonal mobility model for prehistoric herders in the south-western cape of South Africa assessed by isotopic analysis of sheep tooth enamel. *Journal of Archaeological Science* 29: 917–32. https://doi.org/10.1006/jasc.2001.0787

BOESSNECK, J. 1969. Osteological differences between sheep (*Ovis aries* Linné) and goat (*Capra hircus* Linné), in D. Brothwell & E.S. Higgs. (ed.) *Science in Archaeology*: 331–58. London: Thames & Hudson.

CROWE, F., A. SPERDUTI, T.C. O'CONNELL, O.E. CRAIG, K. KIRSANOW, P. GERMONI, R. MACCHIARELLI, P. GARNSEY & L. BONDIOLI. 2010. Water-related occupations and diet in two Roman coastal communities (Italy, first to third century AD): correlation between stable carbon and nitrogen isotope values and auricular exostosis prevalence. *American Journal of Physical Anthropology* 142: 355–66. https://doi.org/10.1002/ajpa.21229

DENIRO, M.J. 1985. Postmortem preservation and alteration of *in vivo* bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317: 806–809. https://doi.org/10.1038/317806a0

FARQUHAR, G.D., H.T. HUBICK, A.G. CONDON & R.A. RICHARDS. 1988. Carbon isotope fractionation and water use efficiency, in P.W. Rundel, J.R. Ehleringer & K.A. Nagy (ed.)

*Stable isotopes in ecological research*: 22–40. New York: Springer.
HALSTEAD, P. & P. COLLINS. 2002. Sorting the sheep from the goats: morphological distinctions between the mandibles and mandibular teeth of adult *Ovis* and *Capra*. *Journal of Archaeological Science* 29: 545–53. https://doi.org/10.1006/jasc.2001.0777
HOEFS, J. 1997. *Stable isotope geochemistry.* Berlin: Springer.
NITSCH, E.K., M. CHARLES & A. BOGAARD. 2015. Calculating a statistically robust $\delta^{13}C$ and $\delta^{15}N$ offset for charred cereal and pulse seeds. *STAR: Science & Technology of Archaeological Research* 1: 1–8. https://doi.org/10.1179/2054892315Y.0000000001
PAYNE, S. 1985. Morphological distinctions between the mandibular teeth of young sheep, *Ovis*, and goats, *Capra*. *Journal of Archaeological Science* 12(2): 139–47. https://doi.org/10.1016/0305-4403(85)90058-5
PRIVAT, K.L., T.C. O'CONNELL & M.P. RICHARDS. 2002. Stable isotope analysis of human and faunal remains from the Anglo-Saxon cemetery at Berinsfield, Oxfordshire: dietary and social implications. *Journal of Archaeological Science* 29: 779–90. https://doi.org/10.1006/jasc.2001.0785
ROUSSEEUW, P.J., I. RUTS & J.W. TUKEY. 1999. The bagplot: a bivariate boxplot. *American Statistician* 53: 382–87.
WALLACE, M., G. JONES, M. CHARLES, R. FRASER, P. HALSTEAD, T.H.E. HEATON & A. BOGAARD. 2013. Stable carbon isotope analysis as a direct means of inferring crop water status and water management practices. *World Archaeology* 45: 388–409. https://doi.org/10.1080/00438243.2013.821671
WILLIAMS, D. 1973. Flotation at Sīrāf. *Antiquity* 47: 288–92. https://doi.org/10.1017/S0003598X00039132

**Table S1. Charred macrofossil counts of plants probably consumed, by period.**

| **Common name** | **Taxonomic name** | **Periods 2, 3, 4**<br>Early second to early third centuries AD<br>41 contexts (586 litres) | **Period 5**<br>Late fourth to early fifth centuries AD<br>17 contexts (222.5 litres) | **Period 6**<br>Mid fifth to mid sixth centuries AD<br>122 contexts (2498.5 litres) | **Total macro-fossil counts** | **Number of contexts with macro-fossils** |
|---|---|---|---|---|---|---|
| **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 animals probably consumed, by period.**

| Common name | Taxonomic name | Periods 2, 3 and 4<br>Early second to early third centuries AD<br>35 contexts | Period 5<br>Late fourth to early fifth centuries AD<br>7 contexts | Period 6<br>Mid fifth to mid sixth centuries AD<br>117 contexts | Total NISP |
|---|---|---|---|---|---|
| **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** |

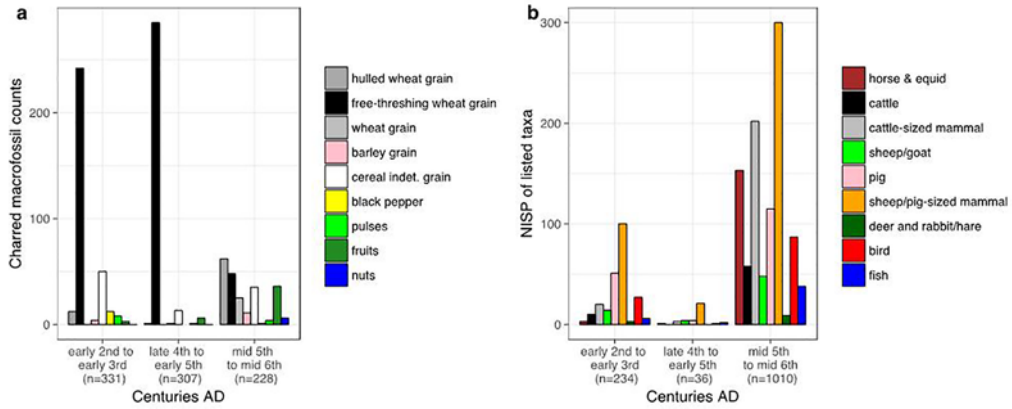


*Figure S1. Plant and animal assemblages at Portus: a) count of charred macrofossils of plants probably consumed, by period; b) NISP count of animals probably consumed, by period.*

**Table S3. Isotopic sample distribution by charred grain abundance.**

| Period | Number of flotation sieved contexts | | | | | | Number of grains analysed isotopically |
|---|---|---|---|---|---|---|---|
| | **Overall** | **No grains** | **1-2 grains** | **< 10 grains** | **10–50 grains** | **> 50 grains** | |
| **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** |

* Stable isotopic analysis of charred grain within that context category

**Table S4a. 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) | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | N (mg) | Atom C/N ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16F | 0.9 | -22.5 | 9.1 | 0.031 | 19.5 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16E | 0.8 | -23.0 | 10.1 | 0.030 | 17.6 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16B | 0.9 | -22.0 | | 0.027 | 24.6 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16D | 0.8 | -22.4 | | 0.025 | 21.4 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16E | 0.8 | -23.2 | | 0.021 | 25.6 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16I&J | 0.8 | -22.1 | | 0.021 | 27.9 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16I | 0.8 | -23.9 | | 0.020 | 31.2 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16H | 0.8 | -23.4 | | 0.018 | 34.3 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16F | 0.9 | -24.2 | | 0.018 | 32.1 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16J | 0.7 | -22.8 | | 0.018 | 30.4 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16A | 0.8 | -23.7 | | 0.017 | 32.0 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16C | 0.8 | -23.3 | | 0.017 | 28.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16C | 0.8 | -24.2 | 0.017 | 34.7 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16B | 0.8 | -24.1 | 0.016 | 36.5 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16G | 0.9 | -24.2 | 0.016 | 39.8 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD16A | 0.8 | -24.6 | 0.016 | 35.2 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16H | 0.7 | -24.7 | 0.015 | 32.7 |
| 2 | Early second | 1061 | 0016 | Macaroni wheat grain | FT | LBCFD016D | 0.7 | -22.5 | 0.014 | 33.5 |
| 2 | Early second | 1061 | 0016 | Free-threshing wheat grain | FT | LBCFA16G | 0.7 | -24.7 | 0.013 | 38.6 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008I&J | 0.7 | -22.4 | 0.027 | 18.1 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008G | 0.7 | -20.5 | 0.027 | 18.3 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008F | 0.9 | -21.6 | 0.023 | 26.4 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008C | 0.9 | -22.8 | 0.022 | 27.8 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008A | 0.8 | -24.1 | 0.021 | 28.0 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008C | 0.9 | -23.0 | 0.021 | 28.9 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008G | 0.9 | -22.5 | 0.020 | 30.3 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008B | 0.9 | -24.0 | 0.020 | 31.7 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008D | 0.7 | -22.6 | 0.019 | 28.4 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008E | 0.7 | -23.2 | 0.019 | 29.9 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008K | 0.8 | -22.9 | 0.019 | 30.9 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008D | 0.9 | -22.9 | 0.018 | 34.3 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008F | 0.8 | -24.2 | 0.018 | 30.0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008E | 0.8 | -23.0 | | 0.018 | 33.8 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1008H | 0.9 | -23.6 | | 0.017 | 34.1 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008H | 0.9 | -24.3 | | 0.017 | 37.3 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008A | 0.8 | -23.2 | | 0.017 | 33.0 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008I | 0.8 | -23.5 | | 0.017 | 35.8 |
| 2 | Early second | 1061 | 1008 | Macaroni wheat grain | FT | LBCFD1088B | 0.7 | -23.7 | | 0.015 | 35.1 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008J | 0.9 | -23.5 | | 0.015 | 36.8 |
| 2 | Early second | 1061 | 1008 | Bread wheat grain | FT | LBTA1008L | 0.8 | -23.8 | | 0.014 | 36.6 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012I | 0.8 | -23.4 | 4.0 | 0.032 | 18.0 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012H&I | 0.8 | -23.0 | 10.9 | 0.032 | 18.3 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012F | 0.8 | -21.8 | | 0.029 | 20.1 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012D | 0.8 | -22.2 | | 0.026 | 22.8 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012E | 0.9 | -22.9 | | 0.026 | 24.6 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012E | 0.9 | -23.5 | | 0.023 | 25.5 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012B | 0.9 | -21.9 | | 0.023 | 25.9 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012A | 0.9 | -22.3 | | 0.023 | 27.8 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012J | 0.7 | -23.8 | | 0.022 | 22.5 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012C | 0.8 | -23.0 | | 0.021 | 27.0 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012G | 0.8 | -24.4 | | 0.020 | 27.7 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012B | 0.8 | -22.2 | | 0.020 | 26.7 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012F | 0.9 | -24.3 | | 0.019 | 31.6 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012H | 0.9 | -22.6 | | 0.018 | 33.5 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012J | 0.7 | -22.7 | | 0.018 | 27.4 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012G | 0.7 | -24.1 | | 0.018 | 29.8 |
| 2 | Early second | 1123-1124 | 1012 | Bread wheat grain | FT | LBTA1012C | 0.7 | -23.9 | | 0.017 | 30.5 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012A | 0.9 | -22.8 | | 0.016 | 35.2 |
| 2 | Early second | 1123-1124 | 1012 | Macaroni wheat grain | FT | LBTD1012D | 0.8 | -22.6 | | 0.015 | 24.3 |
| 4 | Early third | 2315 | 2021 | Free-threshing wheat grain | FT | BMW2021 | 0.7 | -22.5 | | 0.024 | 17.8 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013B | 0.9 | -21.1 | 5.8 | 0.042 | 15.3 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013A | 0.9 | -21.5 | 8.0 | 0.038 | 16.5 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013G | 0.9 | -20.4 | 8.9 | 0.032 | 17.9 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013F | 0.9 | -21.1 | 9.4 | 0.042 | 15.1 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013A | 0.9 | -20.6 | 9.8 | 0.037 | 16.6 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013H | 0.8 | -21.2 | 10.1 | 0.032 | 16.4 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013I | 0.9 | -21.2 | | 0.029 | 23.0 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBCFD4013I | 0.8 | -20.7 | | 0.029 | 20.0 |
| 5 | Late fourth–early | 4031 | 4013 | Bread wheat grain | FT | LBTA4013F | 0.8 | -23.0 | | 0.027 | 21.8 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | fifth | | | | | | | | | |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013JK | 0.7 | -21.3 | 0.027 | 19.6 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013G | 0.8 | -21.2 | 0.027 | 22.2 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013D | 0.7 | -21.3 | 0.025 | 19.5 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013E | 0.8 | -23.4 | 0.024 | 22.8 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013C | 0.9 | -22.3 | 0.024 | 26.3 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013E | 0.8 | -22.8 | 0.024 | 24.8 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013B | 0.9 | -24.1 | 0.023 | 30.6 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013C | 0.8 | -22.1 | 0.022 | 25.5 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Bread wheat grain | FT | LBTA4013D | 0.8 | -21.9 | 0.021 | 24.3 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBTCFD4013H | 0.7 | -22.6 | 0.020 | 25.6 |
| 5 | Late fourth–early fifth | 4031 | 4013 | Macaroni wheat grain | FT | LBCFD4013J | 0.8 | -22.1 | 0.020 | 28.4 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Late fourth–early fifth | 4049 | 4018 | Free-threshing wheat grain | FT | MW4018 | 0.9 | -22.6 | | 0.030 | 20.5 |
| 5 | Late fourth–early fifth | 4049 | 4018 | Indeterminate cereal grain fragments | | CFR4018 | 0.9 | -21.8 | | 0.029 | 20.6 |
| 6A | Mid fifth–early sixth | 1113 | 0053 | Bread wheat grain | FT | LB53A | 0.8 | -23.1 | | 0.026 | 21.9 |
| 6A | Mid fifth–early sixth | 2314 | 2013 | Macaroni wheat grain | FT | LBTCFD2015 | 0.9 | -22.2 | 2.4 | 0.030 | 18.1 |
| 6A | Mid fifth–early sixth | 2314 | 2013 | Hulled barley grain | | LBHB2013A | 0.9 | -22.0 | 6.9 | 0.037 | 16.9 |
| 6A | Mid fifth–early sixth | 3013 | 0042 | Einkorn/Emmer wheat grain | H | CPGW0042 | 0.8 | -22.5 | | 0.028 | 20.0 |
| 6A | Mid fifth–early sixth | 5054 | 5019 | Free-threshing wheat grain | FT | BMW5019 | 0.8 | -23.0 | | 0.029 | 17.1 |
| 6A | Mid fifth–early sixth | 5055 | 5022 | Einkorn grain | H | LBTM5022B | 0.7 | -23.3 | | 0.025 | 20.3 |
| 6A | Mid fifth–early sixth | 5055 | 5022 | Einkorn grain | H | LBTM5022A | 0.7 | -22.5 | | 0.015 | 23.2 |
| 6A | Mid fifth–early sixth | 5055 | 5022 | Indeterminate large-seeded legume | | LL5022 | 0.9 | -26.5 | | 0.004 | 156.7 |
| 6A | Mid fifth–early sixth | 5062 | 5027 | Free-threshing wheat grain | FT | LBTAD5027AB | 0.8 | -22.8 | -0.3 | 0.033 | 18.6 |

**Table S4b. Summary of wheat carbon isotopic values by period.**

| | | $\delta^{13}C$ (‰) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Centuries AD** | **N** | **Mean** | **SD** | **Median** | **IQR** | **Max** | **Min** | **Range** |
| Early second–early third | 6<br>0 | -23.2 | 0.9 | -23.1 | 1.3 | -20.5 | -24.7 | 4.2 |
| Late fourth–early fifth | 2<br>1 | -21.8 | 1.0 | -21.5 | 1.4 | -20.4 | -24.1 | 3.7 |
| Mid fifth–mid sixth | 4 | -22.8 | 0.4 | -22.9 | 0.4 | -22.2 | -23.1 | 0.8 |

**Table S5. Provenance of animal bone specimens for isotopic sampling.**

| Taxon | Area | Number of sampled specimens | | | Number of contexts | | | Additional comments |
|---|---|---|---|---|---|---|---|---|
| | | **Periods 2, 3, 4** early second to early third centuries AD | **Period 5** late fourth to early fifth centuries AD | **Period 6** mid fifth to early sixth centuries AD | **Periods 2, 3, 4** early second to early third centuries AD | **Period 5** late fourth to early fifth centuries AD | **Period 6** mid fifth to early sixth centuries AD | |
| | Area A | 3 | | | 3 | | | |
| **Cattle** | Area B | | | 6 | | | 6 | |
| 11 samples | Area C | 1 | | | 1 | | | |
| | Area E | | | 1 | | | 1 | |
| | Area A | 1 | | | 1 | | | |
| | Area B | 3 | | 1 | 3 | | 1 | |
| **Pig** | Area C | 1 | | | 1 | | | |
| 8 samples | Area D | | | 1 | | | 1 | |
| | Area E | | | 1 | | | 1 | |
| | Area B | | | 3 | | | 3 | |
| **Sheep** | Area C | | 1 | | | 1 | | |
| 8 samples | Area D | 1 | | 2 | 1 | | 2 | |
| | Area E | | | 1 | | | 1 | |
| | Area A | | | 1 | | | 1 | |
| | Area B | 1 | | 1 | 1 | | 1 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sheep/goat** 7 samples | Area C | 1 | 1 | | 1 | 1 | | |
| | Area D | | | 1 | | | 1 | |
| | Area E | | | 1 | | | 1 | |
| | Area A | | | 1 | | | 1 | |
| **Horse** 4 samples | 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** |

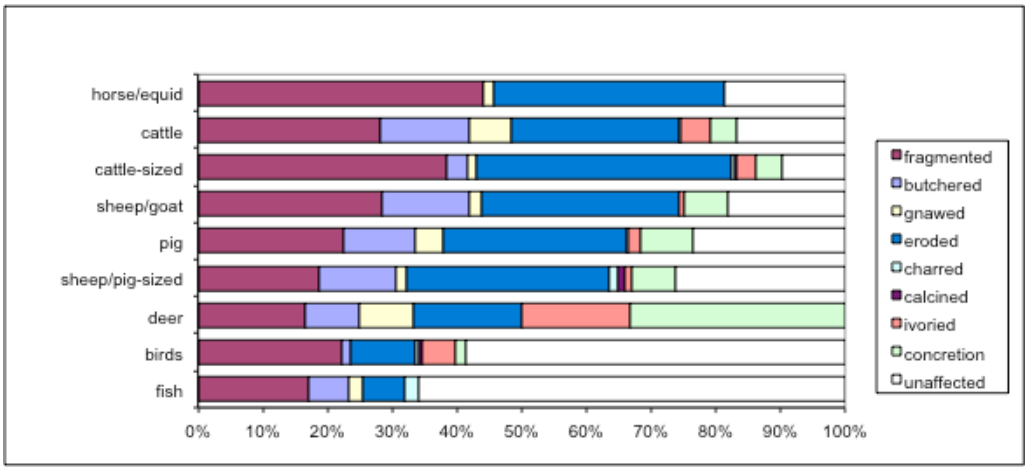


*Figure S2. Occurrence of bone condition records by taxonomic group*

**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 |

| Species | Element | Context | Period | Chronology | Lab_ID | Collagen % yield | Atom C/N ratio | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | Rep nos. |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |

| Species | Element | Context | Period | Chronology | Lab_ID | Collagen % yield | Atom C/N ratio | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | Rep nos. |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

| Species | Element | Context | Period | Chronology | Lab_ID | Collagen % yield | Atom C/N ratio | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | Rep nos. |
|---|---|---|---|---|---|---|---|---|---|---|
| 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) | 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 $\delta^{18}O$ (‰) | Enamel $\delta^{13}C$ (‰) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 3.2 | 3 | -19.3 | 0.2 | 11.7 | 0.1 | | -6.0 | -12.8 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R | | | | | | | | | |
| 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 L | MX | 3.2 | 3 | -18.0 | 0.1 | 12.1 | 0.0 | +0.7<br>+0.6 | -11.8<br>-11.6 |
| PTXI4156 | M | 20–30 | 6A | | M2 R | MD | 3.2 | 3 | -18.6 | 0.0 | 9.7 | 0.1 | -3.5 | -12.3 |
| PTXI4209 | M | 30–40 | 6A | Amphora burial | M2 R | MD | 3.3 | 3 | -18.9 | 0.1 | 11.1 | 0.0 | -3.5 | -12.0 |
| PTXI4211 | M | >50 | 6A | Ditch burial | M2 L | MD | | | | | | | fail | -5.0 | -11.6 |
| PTXI4235 | M | 20–30 | 6A | | M2 R | MD | 3.2 | 3 | -19.3 | 0.1 | 10.3 | 0.1 | -6.8 | -13.1 |
| PTXI4269 | M | 35–45 | 6A | | M2 L | MD | 3.2 | 3 | -19.7 | 0.1 | 8.0 | 0.0 | -7.4 | -12.8 |
| PTXI4287 | M | 25–30 | 6A | | M2 R | MD | 3.2 | 3 | -19.5 | 0.1 | 9.1 | 0.0 | -5.6 | -12.5 |
| PTXI4288 | ND | 16–20 | 6A | | M2 L | MX | | | | | | | -5.3 | -12.3 |
| PTXI4300 | ND | 20–30 | 6A | | - | | | | | | | | fail | | |
| PTXI4302 | M | 20–30 | 6A | | M2 | MD | 3.1 | 3 | -19.0 | 0.1 | 10.6 | 0.1 | -6.1 | -11.4 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R | | | | | | | | | |
| 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<br>-1.7 | -12.6<br>-12.7 |
| PTXI4452 | ND | 6–10 | 6A | | - | 3.2 | 3 | -19.4 | 0.1 | 9.7 | 0.1 | | | |
| PTXI4478 | M | 20–25 | 6A | | M2 MD R | | | | | | | no ribs | -4.5 | -10.7 |
| PTXI4493 | F | 40–50 | 6A | | M2 MD | 3.2 | 3 | -19.1 | 0.1 | 11.1 | 0.0 | | -7.5 | -12.5 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R | | | | | | | | |
| 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 faunal bone collagen carbon and nitrogen isotopic values from Portus.**

| | | $\delta^{13}C$ (‰) | | | | | | | $\delta^{15}N$ (‰) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **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. Data from Isola Sacra individuals were used where age and sex data were available, which are the 91 individuals from Crowe *et al.* (2010).**

| | | $\delta^{13}C$ (‰) | | | | | | | $\delta^{15}N$ (‰) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **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 |

**Table S12. Summary of human tooth enamel carbonate oxygen isotopic values. Data from Isola Sacra individuals were taken from Prowse *et al.* (2007).**

| | $\delta^{18}O$ (‰) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Median** | **IQR** | **Max** | **Min** | **Mean** |
| 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 |