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Diet and collapse: A stable isotope study of Imperial-era Gabii (1st–3rd centuries AD)

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ABSTRACT

The city of Gabii arose just east of Rome around the 8th century BC. By the Imperial period, it had all but collapsed, its habitation areas either abandoned or repurposed for industrial production. Burials within the city, however, may speak to the urbanization and collapse of Gabii. Twenty-one skeletons from the Imperial era (1st–3rd centuries AD) were analyzed for stable carbon and nitrogen isotopes in an effort to understand palaeodiet. Adults' diets are relatively homogeneous, particularly in comparison with samples from nearby sites dating to the same period, and reflect consumption of terrestrial meats and C_3 plants. Subadult diets do not reflect breastfeeding at the time of death. One individual with anomalous isotopes may have been an immigrant to Gabii.

1. Introduction

Throughout the Imperial period (1st–5th centuries AD), Rome was the largest city in the world, with an estimated one million or more people living within the urban center and the suburban area that sprawled outward in all directions (Scheidel, 2001; Wiseman, 1969; Champlin, 1982; Storey, 1997). Within the hinterland, however, formerly independent cities now under Roman rule such as Gabii saw a contraction of their population and eventual abandonment (Becker et al., 2009). While previous palaeodietary analyses have focused on skeletons from Imperial cemeteries associated with the active cities of Rome and Portus Romae (Prowse et al., 2008; Rutgers et al., 2009; Killgrove and Tykot, 2013), recently excavated graves from Gabii offer the opportunity to investigate the foodways of individuals buried in a collapsed former city.

The present study focuses on 21 skeletons from burials made at Gabii during the Imperial period. While the socioeconomic composition of the burial population is not known, most burials were simple in nature with few artifacts. It is also unclear whether these individuals were living at Gabii or were living somewhere else; that is, because of the general proscription against burial within city walls, these individuals could have been living anywhere in Rome or its suburbs. Some evidence for contemporaneous architecture exists, but largely in the form of public baths and *tabernae* or shops (D'Agostini and Musco, 2016; Farr and Hasani, 2017). This continued use of Gabii implies the presence of a local population to staff these public places, but it is unknown if those buried at Gabii were affiliated with these businesses or if they lived in the surrounding area. In antiquity, Gabii was flanked by numerous cemeteries (Bietti Sestieri, 1992a,b), making it plausible that the defunct parts of the city were seen as a natural burial place. We aim to explore with this study the variation in the Imperial Roman diet by focusing on a skeletal sample from an area of urban collapse that is not well known historically.

Textual evidence of the ancient Roman diet comes from authors like Cato the Elder, who suggests in *de Agricultura* that slaveholders should feed their farmhands wheat, olive oil, salt, fish pickle, and wine. Wheat was by far the most popular grain eaten (Garnsey, 1999), particularly considering it formed the majority of the food dole for poor male citizens (Garnsey and Rathbone, 1985; Garnsey, 1988, 1991). Millet was also grown easily and cheaply, but tended to be seen as a famine food (Evans, 1980; Spurr, 1983, 1986; Nenci, 1999) even as growing evidence points to its regular consumption (Killgrove and Tykot, 2013). Most Romans also had access to vegetables, fruits, and nuts, either grown locally or purchased at market (Garnsey, 1988).

The protein component of the Roman diet is still somewhat unknown, as it varied with socioeconomic status. In rural areas, historians like Pliny comment on the use of legumes, consumed on their own or mixed with grains like millet and wheat (Faas, 1994; Garnsey, 1999; Evans, 1980; Spurr, 1983). The extent to which legumes formed the basis of the lower-class diet, however, is still unclear (Garnsey, 1991, 1999). Given the livestock trade, Romans certainly ate meat from goats, sheep, fowl, and pigs (Kron, 2002; MacKinnon, 2004). Beef was not

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commonly eaten, and fish consumption outside of the ubiquitous sauce garum is also much lower than expected considering how many people lived near sources of freshwater fish and seafood (Purcell, 1995; Beer, 2010; Craig et al., 2009).

Because the ancient Roman diet is not well characterized through textual sources, particularly for lower class people, human skeletal remains provide an ideal opportunity to investigate dietary resources at the level of the individual. Stable carbon and nitrogen isotope analyses are frequently used to provide an overview of pre-mortem diet from the last several years of a person's life. The protein component of the diet can be gleaned from carbon isotope ratios measured from the collagen component of bone (written as $\delta^{13}C$ or $\delta^{13}C_{co}$), while carbohydrates and lipids as part of dietary energy can be seen in the isotopes from bone apatite ($\delta^{13}C_{ap}$) (Katzenberg, 2008; Krueger and Sullivan, 1984). Stable carbon isotopes can distinguish between C_3 and C_4 plants as well, indicating whether the dietary energy source was composed primarily of temperate grasses such as wheat, tropical grasses such as millet, or a mixture (Kellner and Schoeninger, 2007). For populations consuming both C_4 and aquatic resources, though, analysis of nitrogen isotopes is necessary to discriminate between them (Larsen et al., 1992; Schoeninger et al., 1983; Katzenberg, 2008). Nitrogen isotopes suggest an individual's position in the food chain, with higher $\delta^{15}N$ values correlating with an increase in trophic level (Schoeninger and DeNiro, 1984; Hedges and Reynard, 2007). Measuring $\delta^{13}C_{co}$, $\delta^{13}C_{ap}$, and $\delta^{15}N$ from human bones therefore provides an understanding of the protein and energy sources in the ancient diet. Additionally, these isotopes can be used as a proxy for understanding breastfeeding and weaning practices, as nursing infants tend to be at a higher trophic level than older children and adults (Katzenberg et al., 1996; Fuller et al., 2006; Katzenberg, 2008), with a 2–3‰ ^{15}N enrichment and a 1‰ ^{13}C enrichment (Fogel et al., 1989; Fuller et al., 2006).

Palaeodietary analysis is growing in popularity as a method for understanding the ancient Roman diet in the Imperial period. Our previous study of two cemeteries from Rome, Casal Bertone and Castellaccio Europarco, found heterogeneity in dietary resources (Killgrove and Tykot, 2013). At Isola Sacra, the cemetery associated with Portus Romae, researchers found that people living along the Tyrrhenian Sea 25 km from Rome were eating a varied diet, including aquatic resources (Prowse, 2001; Prowse et al., 2004, 2005; Prowse et al., 2008). St. Callixtus, an early Christian necropolis in the Roman suburbs, produced surprisingly low carbon isotope values, which researchers concluded could reflect a freshwater fish-based diet (Rutgers et al., 2009). Another early Christian necropolis in Rome, that of Sts. Peter and Marcellinus, has produced palaeodietary data, but those are as yet unpublished (Salesse, 2015). At Velia, far south of Rome on the Tyrrhenian coast, researchers characterized the diet as low in aquatic resources and terrestrial meat (Craig et al., 2009) (see Fig. 1).

While the dietary practices at these sites are quite varied, researchers have found preliminary differences within the samples based on age, sex, and social status. Older individuals at Isola Sacra were more likely to be consuming aquatic resources than were younger individuals (Prowse et al., 2005), while males at Velia appear to have consumed more aquatic resources than did females (Craig et al., 2009). People living closer to Rome were more likely to eat a wheat-based diet than were those in the suburbs, unless they were buried in a low-status manner (Killgrove and Tykot, 2013). A change from a millet- to a wheat-based diet can also be seen in those individuals who immigrated to Rome after childhood (Killgrove and Montgomery, 2016). These studies therefore reveal a variegated and heterogeneous Roman diet that can be dissected in order to learn more about historically underrepresented groups such as children, women, the lower classes, and immigrants. More specifically, engaging in palaeodietary research at Gabii during the period in which it declined and collapsed allows us to investigate whether the isotopic pattern is more similar to that of urban sites like Casal Bertone or to that of suburban sites like Castellaccio Europarco. This line of evidence can then be added to historical and archaeological context to more fully understand the effects of this urban transition on average Romans.

2. Materials and methods

Samples in this study come from skeletons buried at Gabii (Fig. 1). Along with Rome, just 18 km to its west, Gabii urbanized in the Early Iron Age (c. 8th century BC). Situated between two lakes, and apparently an important religious site, Gabii is mentioned in later texts as the place where Romulus and Remus were educated (Plutarch VI *Life of Romulus*). Gabii is named by the historian Livy (6.21–7) in the 4th century BC as Rome's close ally and a participant in the war against Praeneste. The Republican and Imperial periods saw widespread depopulation of the city, however, as the *lapis Gabinus* quarry expanded rapidly (Farr, 2014) and the *Aqua Alexandrina* aqueduct, which siphoned water from one of Gabii's lakes, was constructed in the second quarter of the 3rd century AD (Mogetta and Becker, 2014). Since historical records are spotty, most of the information known about Gabii comes from archaeological excavation.

Archaeological evidence of settlement at Gabii dates back to the late 8th/early 7th century BC, and the city was most densely populated during the Archaic and Early/Middle Republican periods (c. 6th–2nd centuries BC). By the Late Republican period, the city was contracting, with abandonment by the Late Roman/Early Medieval period (Becker et al., 2009). During the Imperial period, there is evidence for continued use of the temple to Juno, at least one public bath, and a monumental storefront, but not for large-scale settlement. Although numerous other cemeteries existed in the area (Bietti Sestieri, 1992a,b), and although the Romans had laws prohibiting burial within the populated city (Toynbee, 1971), the burials at Gabii are found within the previously inhabited area during the Imperial period (Fig. 2). Most of these burials are simple in nature, with graves cut directly into the tufo or made in the *cappuccina* style in the collapsed remains of buildings, but there are three burials involving lead, including one individual in a large, sarcophagus-like lead container (Becker, 2010). Gabii's city center was apparently slowly transformed into an ad hoc cemetery (Mogetta and Becker, 2014), with some burials being made within and on top of abandoned buildings on the periphery of the public/mercantile area that was still in use during the Imperial period. The abandonment layer into which burials were made dates to the middle of the 1st century AD (Opitz et al., 2016). Skeleton 8 in the lead sarcophagus was likely the first buried in this period, and there is a carbon-14 date for tomb 16 of *cal* 240–440 CE (2σ) (Calcagnile, 2010). Gabii was essentially completely abandoned by the Late Imperial/Early Medieval period (c. 4th–5th centuries AD), although there is evidence after that period of land use related to agricultural production (Zapelloni Pavia et al., 2017).

Rib samples were taken from both adult and subadult individuals from the Imperial phase burials. The demographics of the 21 individuals are provided in the first two columns of Table 1 – there were 9 females, 9 males, and 3 subadults (one infant and two young children). Age-at-death of adults was based primarily on the pubic symphysis (Brooks and Suchey, 1990; Todd, 1921a,b), the auricular surface (Lovejoy et al., 1985; Buckberry and Chamberlain, 2002), and cranial suture closure (Meindl and Lovejoy, 1985), and is reported using categories in Buikstra and Ubelaker (1994): Young Adult (20–35), Middle Adult (35–50), Older Adult (50 +). Subadults were aged based on dental development (Moorrees et al., 1963a,b; White and Folkens, 2005; Gustafson and Koch, 1974; Anderson et al., 1976) and epiphyseal closure (Baker et al., 2005), and age categories were assigned based on Baker et al. (2005): Infant (0–12 months), Young Child (1–6), Older Child (7–12), Adolescent (12 – 20). Sex of adults was based on pelvic morphology (Phenice, 1969; Buikstra and Ubelaker, 1994) and cranial features (Acsádi and Nemeskéri, 1970).

Collagen was extracted from bone following procedures based on Ambrose (1990) and modified by Tykot (2004, 2014), which were used

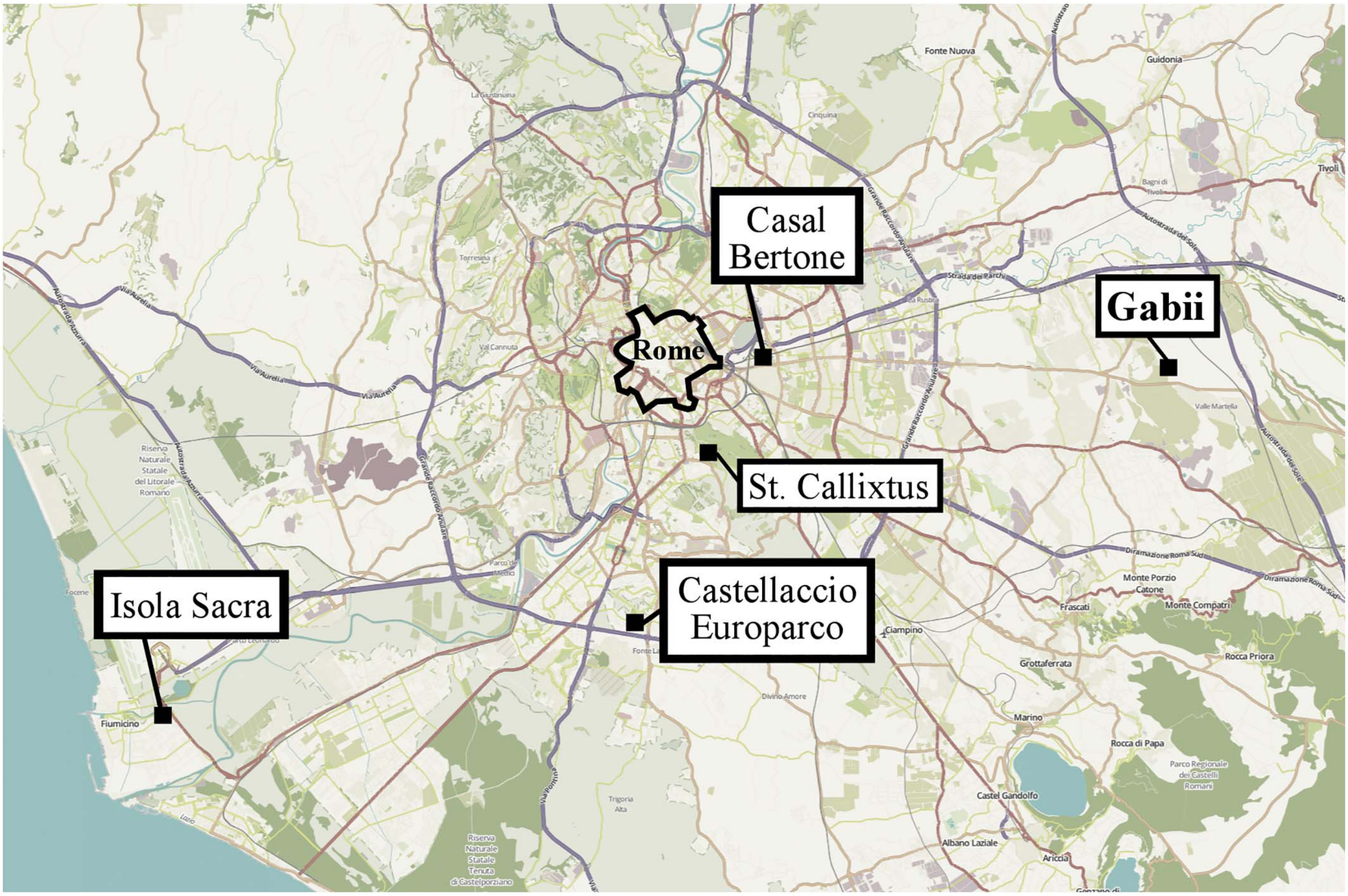

Fig. 1. Map of Gabii and comparative Rome-area sites (base map tiles © OpenStreetMap.org contributors, available for use under the open database license [CC BY-SA 2.0]).

in our previous analysis as well (Killgrove and Tykot, 2013). First, solid rib samples were placed in 0.1 M NaOH to remove contaminants. Samples were then demineralized with 2% HCl, followed by a second treatment of 0.1 M NaOH. Finally, the samples were treated with a 2:1:0.8 defatting mixture of CH_3OH, $CHCl_3$, and water. Dried, weighed samples were analyzed for $\delta^{13}C_{co}$ and $\delta^{15}N$ with a CHN analyzer connected to a Finnigan MAT Delta Plus stable isotope mass spectrometer. Reliability was confirmed through measurement of collagen yields and C:N ratios. Extracting carbon from bone apatite was done according to a modified method (Tykot, 2004, 2014) based on Koch et al. (1997). After cleaning, about 10 mg of powder was drilled from each rib sample. The bone was dissolved in 2% NaOCl, and 1.0 M buffered acetic acid was used to remove non-biogenic carbonates from the sample. The samples were processed on a ThermoFisher MAT253 stable isotope ratio mass spectrometer with a GasBench-II + continuous-flow interface. The preparation method removes nonbiogenic carbonates without fractionating the original bone apatite and produces consistent results. Apatite samples were weighed after each chemical step to address potential contamination or alteration issues. As all weights were consistent, there were no significant ground carbonates present in the samples. Analytical precision is ± 0.2‰ for $\delta^{15}N$, reported with respect to AIR, and ± 0.1‰ for $\delta^{13}C_{co}$, $\delta^{13}C_{ap}$, and $\delta^{18}O_{ap}$, reported with respect to the VPDB standard.

3. Results

3.1. Isotope ratios of human bone collagen and apatite

Table 1 presents the results of the analysis of bone for carbon and nitrogen isotopes, as well as results of the oxygen isotope analysis of bone carbonate. The C:N ratio and percent collagen yield are listed as an indication of the reliability of the $\delta^{13}C$ and $\delta^{15}N$ sample measurements.

Given the entire sample population (N = 21), $\delta^{13}C_{co}$ ranges from − 19.3‰ to − 15.8‰, with a mean of − 18.9‰ and a standard deviation (stdev) of 0.7. In terms of $\delta^{15}N$, the sample population ranges from 8.5‰ to 11.5‰, with a mean of − 10.7‰ and a 0.9 stdev. The $\delta^{13}C_{ap}$ values range from − 14.6‰ to − 9.3‰, with a mean of − 12.9‰ and a stdev of 1.3. Finally, the $\delta^{18}O_{ap}$ values range from − 4.1‰ to − 0.1‰, with an average of − 2.4‰ and stdev of 0.9.

Three individuals within the population stand out as anomalous. Skeleton 31, a young child, has a $\delta^{13}C_{ap}$ value one stdev higher than the average. Skeleton 14, a middle adult female, has a $\delta^{15}N$ value 2 stdev lower than the mean. Skeleton 47, a middle adult male, has anomalous values in all measured isotopes. His $\delta^{13}C_{co}$ is > 2 stdev higher than the average; his $\delta^{15}N$ value is > 2 stdev lower than the mean; and his $\delta^{13}C_{ap}$ value is 2 stdev higher than average. Interestingly, this man's $\delta^{18}O_{ap}$ value from rib bone is − 4.1‰, which is almost 2 stdev lower than the sample population mean of − 2.4‰.

3.2. Comparisons with previous faunal results

Animal bone from Gabii is plentiful, with large accumulations over the course of the centuries the city was occupied. As excavation is ongoing and the faunal assemblage is large, the focus of analysis thus far has been on the latest known habitation context, in the mid-Republican period (Alhaique, 2016; Alhaique et al., 2016). Common domestic animals are well represented – ovicaprines, pigs, cattle, and dogs – and their prevalence varies with respect to location and time period. The presence of fish hooks in the city suggests use of marine and fresh water resources, but few bone remains have been found. This is especially interesting considering Gabii's location near a volcanic lake (modern-

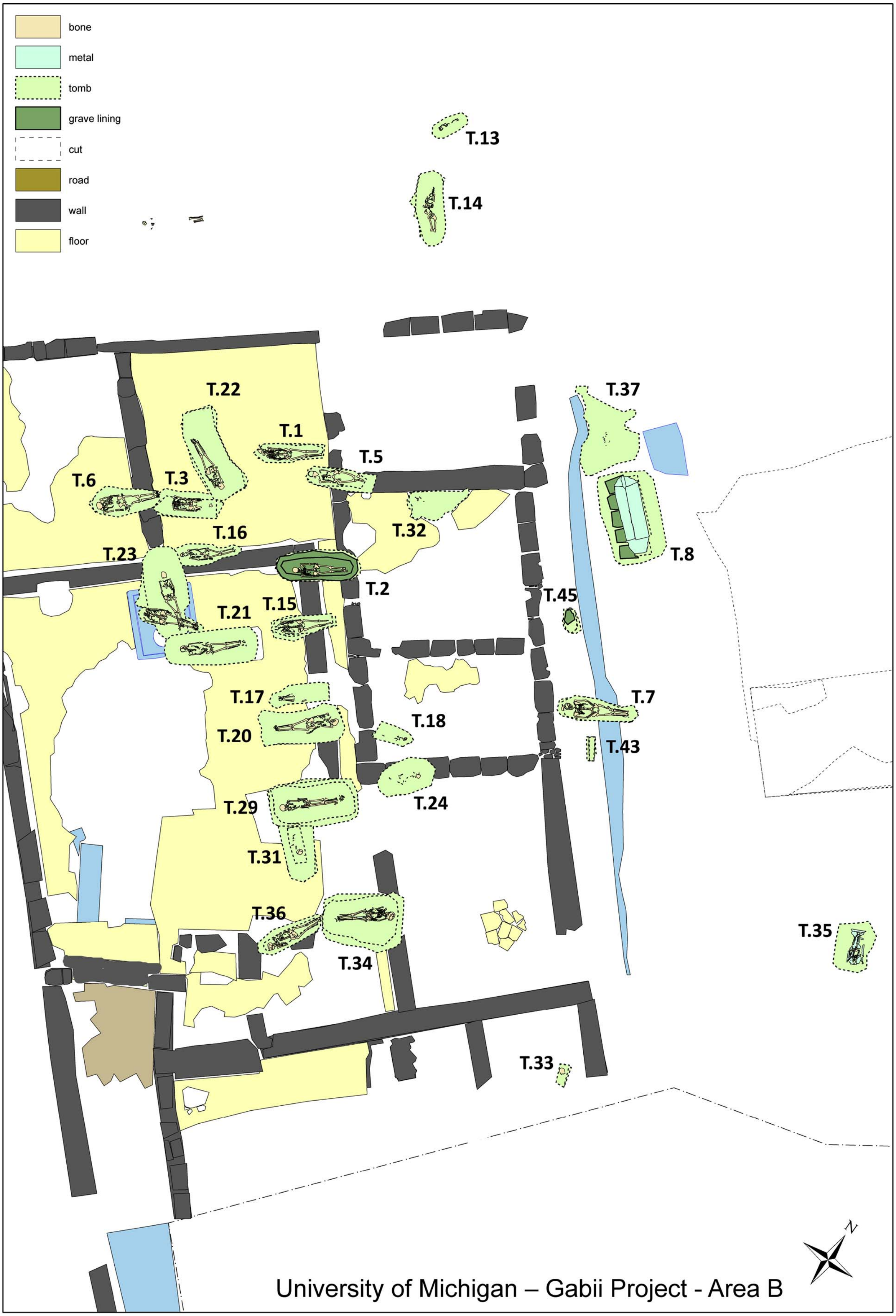

Fig. 2. Map of Imperial-era burials at Gabii, Area B (courtesy the Gabii Project, University of Michigan).

Table 1
Imperial Gabii $\delta^{13}C_{co}$, $\delta^{15}N$, $\delta^{13}C_{ap}$, and $\delta^{18}O_{ap}$ measurements.

Skeleton	SU	Sex	Age	$\delta^{13}C_{co}$ (‰ VPDB)	$\delta^{15}N$ (‰ AIR)	C:N	$\delta^{13}C_{ap}$ (‰ VPDB)	$\delta^{18}O_{ap}$ (‰ VPDB)
1	1004	F	YA	− 18.9	10.8	3.3	− 13.3	− 3.1
2	1019	M	MA	− 18.8	11.5	3.3	− 14.0	− 1.6
5	1013	F	MA	− 18.8	11.1	3.3	− 13.4	− 1.7
6	1017	M	MA	− 19.2	11.3	3.3	− 13.6	− 0.1
7	1026	M	MA	− 19.3	11.3	3.3	− 13.6	− 2.8
8	GPR	M	MA	− 19.3	11.0	3.3	− 14.6	− 3.1
9	22	M	MA	− 19.0	11.2	3.3	− 12.0	− 2.6
14	1068	F	MA	− 19.0	8.5	3.3	− 11.1	− 2.1
15	1072	F	YA	− 18.8	11.2	3.4	− 14.0	− 3.1
16	1076	F	MA	− 18.9	11.5	3.3	− 13.5	− 2.2
20	1120	M	MA	− 18.8	11.2	3.3	− 14.1	− 3.1
21	1124–5	F	MA	− 19.3	9.9	3.3	− 13.6	− 3.0
22	1130	F	MA	− 19.3	10.4	3.4	− 12.1	− 1.8
23	1150	M	MA	− 19.3	10.7	3.3	− 13.6	− 2.0
29	1195	F	MA	− 19.3	9.7	3.3	− 12.7	− 2.1
31	1334	I	YC (c. 2)	− 18.8	10.9	3.3	− 10.7	− 1.6
34	1345	F	OA	− 18.5	11.4	3.4	–	–
35	1358	I	YC (c. 1–3)	− 19.0	11.4	3.4	− 13.3	− 2.9
36	1365	M	MA	− 18.8	11.3	3.3	− 13.2	− 3.4
43	1460	I	Infant (0–2 months)	− 19.3	10.2	3.5	− 12.6	− 1.7
47	5055	M	MA	− 15.8	8.6	3.4	− 9.3	− 4.1
			Mean	− 18.9	10.7		− 12.9	− 2.4
			StDev	0.7	0.9		1.3	0.9

All delta values are reported in permil.

day Lago di Castiglione), but not surprising considering previous isotopic studies that have revealed a diversity of diets in Imperial-era Italy (Killgrove and Tykot, 2013; Craig et al., 2009; Prowse et al., 2004) and a lack of evidence of seafood consumption in Republican Rome (Killgrove, 2010, 2013). During the Imperial period, Gabii was not occupied as a habitation area, and many of the assemblages result from animals used in craft activities and for draught purposes. In general, there is more cattle and pig evidence, and less ovicaprid, in the Imperial phases (F. Alhaique, pers. comm.).

Although animal bone from Gabii has not yet been subjected to isotope analysis, there are comparable data from Portus Romae (Prowse, 2001; Prowse et al., 2004), including terrestrial animals and *garum*, and from Velia (Craig et al., 2009), including aquatic resources. These data sets have informed previous isotope studies in Imperial Rome (Rutgers et al., 2009; Killgrove and Tykot, 2013). The faunal data from these previous analyses are plotted in Fig. 3 with the human bone results from Gabii. This is the best approximation of the domesticated and wild animals that were available for consumption by the people buried at Gabii.

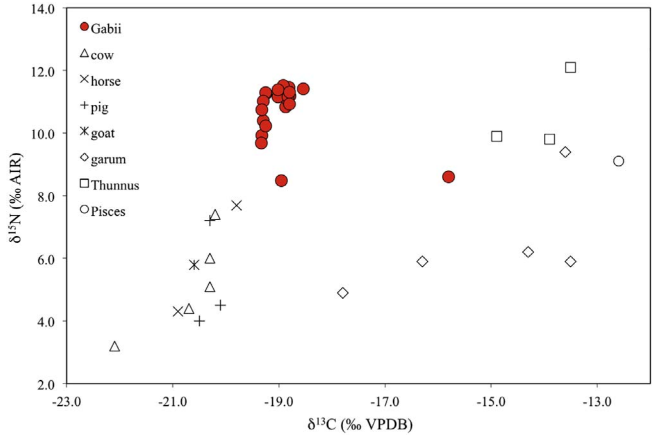

Fig. 3. $\delta^{13}C$ and $\delta^{15}N$ values for humans from Gabii with fauna from Portus Romae and Velia. Terrestrial faunal data and *garum* samples are from Prowse (2001); aquatic faunal data are from Craig et al. (2009).

While the average $\delta^{13}C$ and $\delta^{15}N$ of the human skeletons from Gabii is − 18.9‰ and 10.7‰, respectively, the values for herbivores are − 20.6‰ and 5.3‰, respectively. The people buried at Gabii were, on average, 1.7‰ higher in $\delta^{13}C$ and 5.4‰ higher in $\delta^{15}N$ than the terrestrial animals from Portus Romae. This means that the individuals buried at Gabii consumed a largely C_3 plant and herbivore based diet, with some consumption of aquatic protein (marine or freshwater fish), and minimal C_4 plant resources.

3.3. Dietary variation in Imperial Italy and the greater Rome area

Comparisons can be made between the adult data from Gabii and the data from other Imperial-era sites within Italy, as illustrated in Fig. 4. These sites include: Casal Bertone (located 2 km east of the city walls of Rome) and Castellaccio Europarco (located 12 km south of Rome in its suburbium) (Killgrove and Tykot, 2013); the Christian necropolis of St. Callixtus (about 4 km south of Rome as well) (Rutgers et al., 2009); the Isola Sacra cemetery of Portus Romae (about 25 km south of Rome on the coast) (Prowse, 2001; Prowse et al., 2004); and Velia (located 400 km south along the Italian peninsula) (Craig et al.,

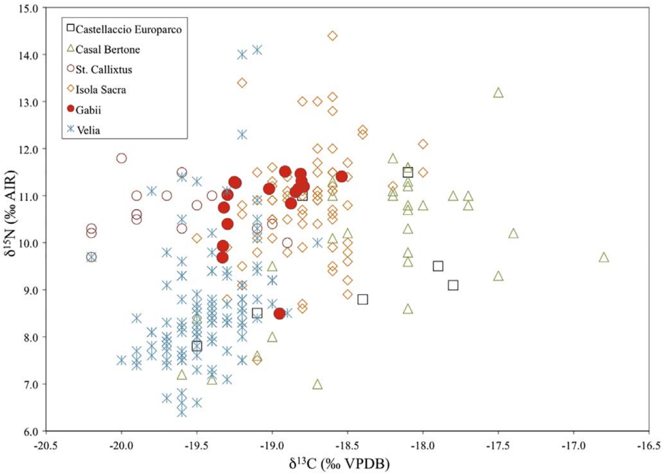

Fig. 4. Adult $\delta^{13}C$ and $\delta^{15}N$ data from comparative Imperial Italian sites.

Table 2
Mean $\delta^{13}C$ and $\delta^{15}N$ results from adults – Imperial cemeteries arranged based on distance from Rome.

	$\delta^{13}C$ ‰ VPDB	$\delta^{15}N$ ‰ AIR	$\delta^{13}C_{ap}$ ‰ VPDB
Casal Bertone	− 18.2 ± 0.6	10.0 ± 1.5	− 12.4 ± 0.8
St. Callixtus	− 19.7 ± 0.4	10.6 ± 0.5	–
Gabii	− 18.8 ± 0.8	10.7 ± 0.9	− 13.0 ± 1.3
Castellaccio Europarco	− 18.5 ± 0.6	9.5 ± 1.3	− 10.3 ± 0.6
Isola Sacra	− 18.8 ± 0.3	10.8 ± 1.2	–
Velia	− 19.4 ± 0.3	8.7 ± 1.3	–

2009).

The mean and 1σ standard deviation for $\delta^{13}C$ and $\delta^{15}N$ for the adults in these populations are presented in Table 2. While all of these means reflect a similar average diet for most sites – that of C_3 plant resources and terrestrial meat protein – there is variation within the six data sets.

Our previous analysis (Killgrove and Tykot, 2013) revealed that the site of Velia was statistically different in $\delta^{13}C$ and $\delta^{15}N$ compared to the two Rome-area cemeteries of Casal Bertone and Castellaccio Europarco, suggesting differing resource use between Rome and Velia, which were separated by 400 km (Craig et al., 2009). There was also a difference in $\delta^{13}C$ values between those two Rome-area cemeteries and the Christian necropolis St. Callixtus, where people may have been consuming freshwater fish because of dietary asceticism (Rutgers et al., 2009). Isola Sacra revealed a statistically higher $\delta^{15}N$ value than did Castellaccio Europarco or Casal Bertone, which likely reflects Portus's geographical position near a port city (Prowse et al., 2004), and those two Rome-area sites also had statistically higher $\delta^{13}C$ values than Isola Sacra, reflecting their more inland location and greater use of the C_4 resource millet. Within Rome, there were no significant differences between age or sex groups, but burial location and burial style were associated with different proportions of C_3 and C_4 plant resources, causing us to hypothesize that individuals from the lower classes likely consumed more millet, often considered a substandard grain by ancient authors (Evans, 1980; Spurr, 1983, 1986; Nenci, 1999).

We concluded our previous analysis by pointing to the heterogeneity of Imperial Roman diets (Killgrove and Tykot, 2013), as the data from the Roman sites of Casal Bertone and Castellaccio Europarco, without excluding outliers, showed roughly a 7‰ spread in $\delta^{13}C$ (but just 2.7‰ when an anomalously high individual is excluded) and a 4.8‰ spread in $\delta^{15}N$. Other Imperial-era sites have similarly large adult nitrogen ranges: namely, 6.9‰ at Isola Sacra and 7.7‰ at Velia (Prowse, 2001; Craig et al., 2009). Carbon isotope ranges, however, are smaller and more similar, especially when the extremely anomalous individual from Castellaccio Europarco is excluded. This fits with ranges from other sites, such as 1.3‰ at St. Callixtus, 1.5‰ at Isola Sacra, and 1.5‰ at Velia (Rutgers et al., 2009; Prowse, 2001; Craig et al., 2009). These ranges, however, are within expectations for populations with heterogeneous diets. For example, a study done on modern hair samples from Western countries found a spread of 4.4‰ in $\delta^{13}C$ and 2.5‰ in $\delta^{15}N$ in Europeans, and a 4.3‰ spread in $\delta^{13}C$ and a 2.2‰ spread in $\delta^{15}N$ in Americans (Valenzuela et al., 2012). Imperial-era Italian palaeodietary data is therefore less heterogeneous in carbohydrates but much more so in protein sources compared to contemporary Western populations.

Within the context of that previous work, we expected to see similar heterogeneity in the data from Gabii. These isotope data, however, are more tightly clustered, particularly with respect to $\delta^{15}N$, than hypothesized. The ranges at Gabii include a 3.5‰ spread in $\delta^{13}C$ (which drops to 0.8‰ when individual 47 is excluded) and a 3‰ spread in $\delta^{15}N$. A series of Mann-Whitney *U* statistical tests, however, still reveals numerous differences between the adult Gabii sample and previously reported adult $\delta^{13}C$ and $\delta^{15}N$ values in Imperial Italy.

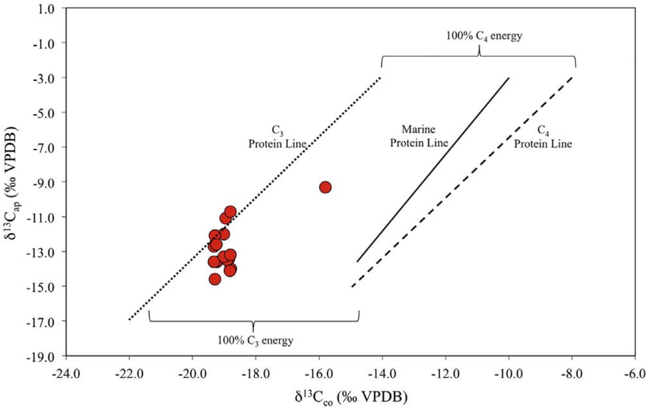

Fig. 5. $\delta^{13}C_{co}$ vs. $\delta^{13}C_{ap}$ from Imperial Gabii.

The 18 adults buried at Gabii had a statistically different $\delta^{13}C$ value distribution compared to four of the five comparative sites: Casal Bertone (Mann-Whitney $U = 115.5$, $p \leq 0.01$); St. Callixtus (Mann-Whitney $U = 25$, $p \leq 0.01$); Isola Sacra (Mann-Whitney $U = 418$, $p = 0.007$); and Velia (Mann-Whitney $U = 255$, $p < 0.001$). No significance was found in comparing the $\delta^{13}C$ data from Gabii to Castellaccio Europarco (Mann-Whitney $U = 67.5$, $p = 0.15$). In the cases of significance, Gabii had a higher average carbon isotope value than St. Callixtus, Isola Sacra, and Velia, and a lower value than Casal Bertone. This suggests that the people buried at Gabii may have been consuming more C_4 resources than were people buried outside of Rome, but less than those buried near Rome at Casal Bertone and Castellaccio Europarco.

As the $\delta^{13}C_{ap}$ values from Casal Bertone and Castellaccio Europarco previously obtained (Killgrove and Tykot, 2013) revealed a significant difference between those two sample distributions, with the more rural site of Castellaccio having a diet that included more energy from C_4 foods like millet, comparisons were made between those values and the Gabii $\delta^{13}C_{ap}$ data (see Fig. 5). Gabii significantly differed from both of these Imperial Roman cemeteries, with a significantly lower $\delta^{13}C_{ap}$ value than either Casal Bertone (Mann-Whitney $U = 85$, $p = 0.009$) or Castellaccio Europarco (Mann-Whitney $U = 8.5$, $p < 0.001$), suggesting greater use of C_3 over C_4 plant resources. Gabii was similar to most of the other Rome-area sites in terms of $\delta^{15}N$ values, but differed significantly from Castellaccio Europarco (Mann-Whitney $U = 38$, $p = 0.006$) and Velia (Mann-Whitney $U = 220.5$, $p < 0.001$). The individuals buried at Gabii had significantly higher average $\delta^{15}N$ values than these two sites, suggesting a greater use of aquatic resources compared to the more terrestrial and/or vegetarian diets at Castellaccio and Velia.

3.4. Dietary variation within the Gabines

Age- and sex-related differences in diet at Gabii were also investigated, as previous work in the Isola Sacra cemetery found variation between the sexes and through the life course (Prowse et al., 2004, 2005; Prowse, 2011); our previous work in Rome, however, revealed no statistical differences (Killgrove and Tykot, 2013).

First, in order to look at breastfeeding and weaning, we compared the three subadults from Gabii to the average $\delta^{13}C$ (− 19.0‰) and $\delta^{15}N$ (10.5‰) of females in the sample. Children who are still nursing or have been recently weaned at time of death are generally expected to have $\delta^{13}C$ values about 1‰ higher and $\delta^{15}N$ values of 2–3‰ higher than the female average. All three subadults were within the average female range for $\delta^{13}C$; two were within the average female range for $\delta^{15}N$. Young child 35 (between 1 and 3 years old at death) had a $\delta^{15}N$ value of 11.4‰, which is higher than the female average but not high enough to suggest the child was exclusively breastfeeding at time of death. As two of the subadults (31 and 35) were young children in the

1- to 3-year-old age range, and Roman doctors (Soranus, *Gynaecology* XXI, 46) recommended weaning by age 2, it is possible these children were already weaned. The third subadult (43) was a neonate who may have died before his or her isotope ratio could reflect a diet of breastmilk. Another possibility is that the neonate's mother or wetnurse may have had a lower than average δ^{15}N diet herself. For example, middle adult female 14 from Gabii has the lowest nitrogen isotope value in this sample, 8.5‰. If she were to nurse an infant, it is possible the trophic shift of drinking her breastmilk would be invisible in a neonate. There is therefore no clear evidence from the dietary isotopes of the Gabii subadults for exclusive breastfeeding.

Second, in comparing the average female and male dietary isotope values within the sample from Gabii, there were no statistically significant results in two-tailed *t*-tests of the sex-segregated means of δ^{13}C ($t = 0.7282$, $p = 0.48$), $\delta^{13}C_{ap}$ ($t = 0.2287$, $p = 0.82$), δ^{15}N ($t = 0.9033$, $p = 0.38$), or $\delta^{18}O_{ap}$ ($t = 0.3174$, $p = 0.76$). Further, Mann-Whitney *U* tests for differences between the sexes were also not significant for δ^{13}C ($U = 40$, $p = 0.96$), $\delta^{13}C_{ap}$ ($U = 25$, $p = 0.29$), δ^{15}N ($U = 28.5$, $p = 0.29$), or $\delta^{18}O_{ap}$ ($U = 30$, $p = 0.56$). Within this small population, males and females have similar isotope values and therefore similar diets.

Three individuals within the population, however, stand out as anomalous. Skeleton 31 has a $\delta^{13}C_{ap}$ value one standard deviation higher than the average; this is not particularly surprising considering this is a young child and may therefore reflect the end of the weaning period. Skeleton 14, a middle adult female, has a δ^{15}N value 2 stdev lower than the mean. Skeleton 47, a middle adult male, has anomalous values in all measured isotopes. His $\delta^{13}C_{co}$ is > 2 stdev higher than the average; his δ^{15}N value is > 2 stdev lower than the mean; and his $\delta^{13}C_{ap}$ value is 2 stdev higher than average. Interestingly, this man's $\delta^{18}O_{ap}$ value from rib bone is −4.1‰, which is about 2 stdev lower than the sample population mean of −2.4‰.

4. Discussion

For decades, the best evidence of the Roman diet came from plant and animal remains, mosaic and fresco depictions, satirical fiction (e.g., Petronius's *Satyricon*), and historical records (e.g., Cato's *de Agricultura*, Varro's *de re Rustica*, Columella's *de re Rustica*, and the cookbook *de re Coquinaria* attributed to Apicius). These lines of evidence, however, were largely produced by elite individuals and do not fairly reflect the diet of the average Roman. The growing data set of palaeodietary isotope data from Imperial-era Rome and its suburbs, though, is now revealing a much more nuanced picture of food consumption by individuals, populations, and cultural groups.

Although all comparative samples reflect a diet based primarily on terrestrial meat and plants such as wheat and barley, dietary heterogeneity can be seen when comparing the adult Gabine isotope values with those from other nearby Imperial-era sites. Carbon isotope results suggest that the individuals buried at Gabii were significantly different than all other populations except Castellaccio Europarco, a suburban agricultural site with evidence of millet eating, consuming on average more millet – or animals foddered on millet – than most others were. Nitrogen isotope values also range widely, with the Gabii samples showing higher consumption of aquatic resources compared to both the inland site of Castellaccio and the coastal site of Velia, but similar levels of aquatic resource use compared to the other sites. Palaeodietary isotope values from all sites fit within the broadly-defined ‘Mediterranean triad,’ which was made up of cereals, wine, and olives (Garnsey, 1999), but also reveal deviations from the basic wheat-and-meat diet we have come to know from historical records.

How the differences play out within and between skeletal samples, however, is less clear. Geographic location appears to matter to diet, although not always in predictable ways. Coastal Velia has a low consumption of aquatic resources, for example, and periurban Casal Bertone has more millet use than expected. Although Gabii was located near a volcanic lake, and although fishing equipment has been found on the site, the low nitrogen values suggest very little use of aquatic food resources.

Time period may also factor into dietary variation. That is, although all of these sample populations date to the same general Imperial time period, historically we have more precise information about famines, wars, and socioeconomic and political crises. For example, the Crisis of the 3rd century AD caused major problems with the economic and transportational infrastructure of Italy, leading to a compromised food distribution and market system. If one or more of these sample populations came from that crisis or its aftermath, the dietary isotope values may reflect an anomalous or abnormal diet.

Inter- and intra-group variation is also present in Imperial Roman diets. For example, the people buried in the Christian necropolis of St. Callixtus were consuming a different diet than others, possibly due to religious asceticism, and the people buried in suburban Castellaccio were consuming more millet than anyone else, perhaps due to socioeconomic differences. And while samples such as Isola Sacra show differences between males and females and in different age classes, other sample populations do not.

The Gabii subadults are particularly interesting in this context, as none of them shows clear evidence of breastfeeding at time of death or any major deviations from the average adult diet. The 2nd century AD physician Soranus recommended in his *Gynaecology* that children be breastfed for at least six months, and fully weaned by 2 years of age, so the two young children among the Gabine skeletons may have already been weaned onto porridge or other foods. The neonate, on the other hand, was likely consuming breastmilk from its mother or from a wetnurse (Fildes, 1986; Lefkowitz and Fant, 2005); however, its short life (under 2 months) was insufficient in duration to show the increases in carbon and nitrogen isotopes that come with breastmilk. Alternatively, a failure to thrive on breastmilk or too-early weaning may have been a component in this infant's death (Reitsema, 2013).

A final major factor in dietary differences, however, is almost certainly migration. Previous research at both Rome (Killgrove and Montgomery, 2016) and Portus Romae (Prowse et al., 2007) found large numbers of immigrants through isotope analysis of dental enamel. Further, comparison of carbon isotope values from dental enamel and bone apatite from the Rome migrants also showed that many of them changed their diets, presumably after migration (Killgrove and Montgomery, 2016; Killgrove and Tykot, 2013). Although strontium and oxygen isotope analyses have not yet been done on the Gabii enamel samples to investigate homeland, the anomalous oxygen isotope value for skeleton 47 suggests he may have been an immigrant. At nearly two standard deviations lower than the mean, this middle adult male's bone apatite oxygen value suggests a potential migration to Gabii from a cooler, wetter area of the Empire some time within the previous decade before his death. This hypothesis about migration is backed up by anomalous palaeodietary isotope values, as he was consuming significantly more C_4 resources than the rest of the population, with significantly less aquatic resources. His diet fits in well with what Pliny described for rural Italians – one of millet and beans (Spurr, 1983). Finally, the presence of shovel-shaped maxillary second incisors in this individual is an uncommon trait in skeletal samples from Rome and further north, but is quite common elsewhere in Italy (Coppa et al., 1998). This individual from Gabii therefore provides more evidence that migration and diet were inextricably linked in Imperial Italy, and that further biochemical research into both diet and movement within the Roman Empire will result in useful information about the heterogeneous population.

The rise and fall of Gabii as a city is still somewhat mysterious, although continuing archaeological investigation is revealing clear phases of occupation. As such, even though these Imperial era burials mark a transition from large-scale habitation, they do not appear to indicate absolute collapse and abandonment of the Gabii urban area. Dietary information obtained from these 21 skeletons dating to the

Imperial period is most similar to data from Castellaccio Europarco, a burial area in the southern Roman suburbs associated with a villa and an agricultural area. This suggests that the individuals buried at Gabii were consuming a more rural diet rather than an urban one, and perhaps therefore lived near the disintegrating urban center rather than in or near Rome itself. The continued use of the land around Gabii for pasturage well into the early Medieval period may bolster the idea that local food production was occurring in the Imperial period. At least one individual buried at Gabii was non-local, however, suggesting migration in the Empire was common even in suburban and rural areas.

5. Conclusions

Imperial Rome defies easy classification, as its massive population was diverse in demographics, homeland, socioeconomic status, occupation, and more. We are continually refining our understanding of Roman skeletons by combining multiple lines of evidence (Killgrove, 2017a,b), but are still at the beginning of teasing out similarities and differences in how the Romans interacted with their natural and cultural environments. Additional research is needed along these lines, both to increase the available isotope data on palaeodiet in Imperial Italy and to correlate skeletal and dental pathologies, evidence of migration, stature and life course, and archaeological context with these biochemical studies.

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