Title: 'From the mouths of babes': a subadult dietary stable isotope perspective on Roman London *(Londinium*)

Authors: Rebecca Redfern[a*], Rebecca Gowland[b], Andrew Millard[b], Lindsay Powell[b], Darren Gröcke[c]

Affiliations: a Centre for Human Bioarchaeology, Museum of London, 150 London Wall, London, EC2Y 5HN, rredfern@museumoflondon.org.uk; b Department of Archaeology, Durham University, South Road, Durham, DH1 3LE, r.l.gowland@durham.ac.uk, a.r.millard@durham.ac.uk, linzy_184@hotmail.co.uk; c Department of Earth Sciences, Durham University, South Road, Durham, DH1 3LE, d.r.grocke@durham.ac.uk

* denotes corresponding author

Highlights

- First temporal analysis of childhood diet in a northern Roman city
- Periods of economic instability reflected in dietary choices
- Evidence for the childhood consumption of freshwater fish

Abstract

Londinium (AD 48-410) was the focus for Roman administration and trade in Britain; it was established and inhabited by people from across the Empire who continued to practice their diverse food-ways. Roman London was a unique settlement, whose fluctuating economic and political fortunes throughout Roman occupation are clearly evidenced in the archaeological and historical records. This study conducts stable isotope analysis of the diet of a large sample of subadults (0-20 years old) dating from the 1st to 4th centuries AD in London. It includes an assessment of breastfeeding and weaning practices, but aims to focus more on the diets of older children and the transition to 'adult' dietary behaviours. The rib bones of 100 subadults and 20 adults were sampled for carbon and nitrogen isotopes. Using these data, we identified an infant feeding pattern that differed from contemporaneous sites in Italy and which remained unchanged over time, a special diet for nursing females, and temporal changes in diet, whereby subadults consumed greater quantities of freshwater resources compared to adults during periods of economic instability.

Key words: childhood, Roman, diet, stable isotopes, life course

1.0 Introduction

1.1 Roman London (*Londinium*)

The settlement of *Londinium* is unique in Roman Britain, as it appears to have been established in c. A.D. 48 by merchants from the Continent with the support of the military, particularly with respect to the provision of infra-structure (Wallace, 2014). The settlement spanned the River Thames and was home to migrants from across the Empire, the military and merchants, but also acted as the Imperial administrative centre for the province and its economic hub, being the location where the coinage was minted (Perring, 1991, Marsden, 1986, Perring, 2015). *Londinium*'s fortunes fluctuated throughout the 400 years of Roman occupation (Table 1). The earliest phase (AD 48-60) has evidence for links to the Continent, through primary sources such as letters and the presence of imported food-stuffs (e.g., olives) and material culture (e.g., Samian ware). It was razed to the ground during the Boudican revolt of AD 60, but afterwards was extensively rebuilt and by AD 100 was the administrative centre of the province (*Britannia*); however, large parts of it were again destroyed during the 2nd century AD by the 'Hadrianic fire'. By the third and fourth centuries AD, the political instability on the Continent affected *Londinium*'s fortunes once more and it experienced episodes of decline and regeneration, until Imperial rule was withdrawn in the early 5th century AD (Perring, 1991, Marsden, 1986).

Following the Roman urban tradition, cemeteries were located on the periphery of the settlement (Figure 1), alongside the main roads leading from *Londinium* to other centres across Britain (Perring, 1991). These extra-mural burial locations were first recorded by antiquarians, but have been intensively investigated more recently through contractor archaeology in response to development and infra-structure projects, during which many hundreds of burials have been recovered (Hall, 1996, Barber and Bowsher, 2000). Overviews of the burial evidence show that both cremation and inhumation were practiced from the outset in *Londinium*, with inhumations typically placed within wooden coffins, although more expensive containers (stone sarcophagi or lead coffins) and high status or 'exotic' funerary contexts have been encountered (Barber and Bowsher, 2000, Ridgeway, et al., 2013). One such is the 18-25 year old adult female from Spitalfields who had travelled from Rome to *Londinium*. Her body had been embalmed, dressed in a silk and gold fabric with her head lying on a bed of bay leaves in a lead coffin, and within her stone sarcophagus were several glass vessels and a jet rod (Swain and Roberts, 1999, Brettell, et al., 2015, Montgomery, et al., 2010).

1.2 Environmental archaeological evidence for diet in *Londinium*

The environmental record from the settlement provides rich and varied evidence for the range of food-stuffs imported and consumed in *Londinium*, but as summarised in Table 1, the changing fortunes of the settlement affected availability (Cowan, et al., 2009). The city is marked-out from other areas of Britain because of its diverse record and the presence of exotic plant species (e.g., black cumin and cucumber). As with other areas of the Empire, the majority of the diet is thought to have been cereals and pulses (Garnsey, 1999). The most frequently recovered cereal species are spelt wheat and barley, although the latter was considered to be more suitable for animals (Cowan and Wardle, 2009, Davis, 2011a, 2011b, Cool, 2006). The only evidence for millet consumption is a single grain from a 2nd century AD deposit (Willcox, 1977); but it has also been identified isotopically in one adult from Spitalfields (Shaw, et al., 2016). Oats and rye have been recovered but in very low quantities, suggesting that spelt wheat was the main cereal resource. The Boudican and later Hadrianic fire destruction deposits have preserved large quantities of lentils, which would have been imported from the Mediterranean (Davis, 2011a, 2011b, Tyers, 1988, Callender, 1965). Post-conquest, the evidence for horticulture increases in Roman Britain (van der Veen, 2014) and this is attested in *Londinium,* with evidence for peas and beans as well as fruit and vegetables, including native species of nuts and wild cherry, blackberry/raspberry, along with imports including, dates, damsons, walnuts and almonds (Cowan and Wardle, 2009, Davis, 2011a, 2011b, Willcox, 1977, van der Veen, et al., 2008, Wardle and Rayner, 2011). Pollen evidence has identified carrots, beets and the brassica/sinapis family (e.g., cabbage) as well as non-native and native herbs and spices (e.g., anise and poppy seeds) (Davis, 2011a, 2011b, van der Veen, et al., 2008).

The abundant evidence for butchery in *Londinium* suggests that, for many, their diet included a proportion of meat. The most frequently consumed animals were cattle and pig, which King (1999a, 1999b, 2001) has found to be common on urban and military sites in Britain. Some deposits in the settlement contained the remains of neonate and young calves, suggesting that milk was produced, supported by the discovery of a cheese-press and other strainers in *Londinium* (Cool, 2006, Bluer, et al., 2006). Other domesticates included sheep/goats, poultry and domestic fowl, with chickens being the most commonly identified species, and fragments of their eggshells have also been recovered (Cowan and Wardle, 2009, Drummond-Murray and Thompson, 2002, Sidell, 2011, Hill and Rowsome, 2011). Again, as with the presence of exotic imports, the consumption of poultry is proposed to have been confined to high status individuals (Cool, 2006), therefore the relative abundance of these in *Londinium* reflects its status as place of administrative and financial power. In contrast to other settlements in Britain, particularly military ones (King, 1999b), there is a limited range of wild game, such as deer, hares and woodcocks (Cowan and Wardle, 2009, Bluer, et al., 2006, Hill and Rowsome, 2011). Once again, this is interpreted as being reflective of high status consumption (Cool, 2006).

The evidence for fish consumption in *Londinium* reflects its river location and through this, access to the coast, but also the presence of people with Mediterranean-style food-ways. Analysis has found that the most commonly encountered species were freshwater and estuarine types, mainly eel and flounder/flatfish (Locker, 2007), but species such as cod, mackerel, herring, pike, chub and trout have also been recovered (Locker, 2007). Expensive and rare fish, such as sturgeon and turbot have been identified, suggesting that elite dining took place within the settlement (Locker, 2007). Overall, it seems that local resources were more likely to be exploited rather than relying on imported fish, although fish sauce (garum) was an important commodity, transported from Spain and north Africa in amphora (Cool, 2006). Many complete and fragmentary amphora have been discovered – one imported from Antibes (southern France) and still containing mackerel heads was stamped: “Lucius Tettius Africanus’ excellent fish sauce from Antipolis” (Tomlin, et al., 2009, RIB ii.6, 2 2492.24).

1.3 The children of *Londinium*

The archaeology of *Londinium* has revealed primary source evidence for children, such as the famous writing tablet detailing the sale of Fortunata, a Gaulish slave girl (Tomlin, 1993), as well as a limited number of funerary inscriptions, such as that of 15 year old Marcus Aurelius Eucarpus (Tomlin, et al., 2009, RIB 10), and a fragment of a sculpture depicting a small child holding a ball. Numerous children’s leather shoes have also been recovered, which is unsurprising as leatherworking was an important industry in the settlement, and two small leather bikini briefs, possibly worn by children (Wilmott, 1982, Keily, 2011). The most fruitful source of evidence for examining the experiences and perceptions of children in *Londinium*, however, are the funerary remains.

Unfortunately, no comprehensive study of the funerary evidence has been undertaken to explore the relationship between social and biological age, such as Gowland's (2001) research on Lankhills cemetery (Hampshire), which linked burial practice and grave inclusions to life course stages. Such a study from *Londinium* would be immensely difficult, because of the paucity of grave-goods for all age-groups throughout the four centuries of use (Hall, 1996, Barber and Bowsher, 2000). Study of the cemetery reports reveals that the inhumed subadults were buried with animal inclusions (e.g., chicken), a coin, pottery and/or glass ware, accompanied by piped clay figurines, and often in coffins (wood and lead) (Barber and Bowsher, 2000, MacKinder, 2000, Watson, 2003). The skeletal remains are therefore the key source of evidence for understanding childhood in *Londinium*.

1.3 Childhood diet in Roman Britain

There is no primary source evidence for childhood food-ways and parenting behaviours, pertaining specifically to Roman Britain, but there is from the Mediterranean regions of the Empire (Fulminante, 2015). Migrants from these regions did live in *Londinium*, and one might expect that they continued to practice their cultural dietary and child-rearing norms in this new province (Gowland and Redfern, 2010, Redfern, 2008, Redfern, et al., 2012). The transformation wrought by conquest (see Mattingly, 2006) and the introduction of new cultural practices, however, can be observed in childhood diets, where the period of exclusive breastfeeding and supplementary feeding appears to have lasted longer than in the preceding Iron Age, or in the following Anglo-Saxon period (Haydock, et al., 2013).

The Roman medical writers Galen and Soranus wrote extensively about children's health and their works contain crucial insights into Roman perspectives on breastfeeding and weaning practices (Fildes, 1985). Stable isotope studies on populations across the Empire have also provided independent evidence for these practices, which show temporal and spatial variation (e.g. Dupras and Tocheri, 2007, Keenleyside, et al., 2009). Analysis of childhood diets from Roman Britain has found that supplementary foods (e.g., cereal-based) were often introduced from the age of six months old, with a prolonged period of transitional feeding, with weaning usually completed by the age of four years (e.g., Redfern, et al., 2012, Nehlich, et al., 2011, Powell et al., 2014).

Stable isotope studies from Romano-British contexts have revealed evidence for intense regional heterogeneity in terms of population diversity (Eckardt, et al., 2010). This diversity is also reflected in infant care practices, affecting the type of weaning foods used and the age at which these were introduced. For example, weanlings in Dorset consumed a regionally specific diet from the age of 6 months which was low in marine resources (Redfern, et al., 2012), whereas in Oxfordshire, weaning was later and their diet was higher in marine protein contributions (Nehlich, et al., 2011). Nevertheless, we should remember that these data are from non-survivors, whose mortality risks also appear to have been significantly impacted by their living environment (Redfern, in press, Redfern, et al., 2015). This is an important consideration, because studies of other archaeological periods have shown that non-survivors sometimes had a different childhood diet compared to those who reached adulthood (Beaumont, et al., 2015). While we must therefore be cautious in our interpretations of isotopic evidence from those who have died, it still remains a primary source of information concerning infant care. While infant feeding has been extensively examined for Roman Britain, the diet of older children and adolescents has been overlooked. In order to understand constructions of childhood and the transition to adulthood in the Roman provinces it is important to extend dietary studies to these older childhood age groups. For the first time, this study will examine dietary transitions throughout childhood and into adulthood and will consider these in relation to Roman constructions of the developmental stages of the life course.

2.0 Materials and methods

2.1 Human remains

A total of 146 subadult and adult individuals were recorded using standardised techniques, which conform to widely accepted professional standards (Brickley and McKinley 2004, Buikstra and Ubelaker 1994, Butler and Ridgeway, 2009, Langthorne, 2011, Powers, 2007, 2012) (Table 2). We did not attempt to determine the sex of subadult individuals (contra. Arthur, et al., 2016), but for those over the age of 20 years old, sex was determined by scoring morphological traits of the skull and pelvis (Powers, 2012, Brickley and McKinley 2004, Buikstra and Ubelaker 1994). For subadults, age-at-death was estimated using a combination of dental eruption and development, diaphyseal lengths and epiphyseal fusion data (Powers, 2012, Brickley and McKinley, 2004). As this study focuses on the Roman period of London’s history, we chose to employ different age-categories to the ones stated in the Wellcome Osteological Research Database (WORD) standards in order to reflect the Roman construction of the life course (see, Revell, 2005): infant (0-3.5 years), childhood (3.5-7.5 years old); juvenile (8-16.5 years old); adolescent (17-20 years old). In adult individuals, age-at-death was estimated by assessing degenerative changes of the pubic symphysis, auricular surface, sternal rib end morphology and dental wear (Powers, 2012, Brickley and McKinley, 2004). Adults were assigned to the following age-categories: young adult (20-25 years old); early middle adult (26-35 years old); later middle adult (36-45 years old); mature adult (>46 years old) and unassigned adult (> 20 years old). In this study, however, adults are treated as a single age category to be compared with subadult age groups. In order to determine whether dietary patterns could have been altered by *Londinium*'s changing fortunes, the sample was divided into two broad periods, early (AD 43 to 250) and late (AD 250-450). Reported dates for many individuals spanned the AD 250 divide, in which case they were assigned to the period into which the majority of their date range fell.

2.2 Stable isotope analysis of collagen

A total of 139 individuals had rib samples analysed for carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes, of whom 109 were subadults and 30 were adults. Twenty-five samples were taken from animal bones excavated from domestic contexts at 1 Poultry (ONE94) and Monument Street (MFI87) from chickens (N=5), pig (N=5), sheep (N=5) and marine fish (N=5) (Table 4).

Collagen extraction was undertaken in the Department of Archaeology at Durham University following a modified Longin (1971) method, with an additional ultrafiltration step (Brown, et al., 1988). A sample of 2-3g of bone was taken, and cleaned by hand or by shot-blasting to remove markings or soil. Approximately 200mg of bone was weighed into a test tube, 0.5M hydrochloric acid was added and the acid replaced on alternate days for about two weeks. Demineralised bone was rinsed to neutrality with purified water, hydrochloric acid added to make a pH 3 solution (pH3) and the sample heated at 75°C for 24-48 hours to gelatinise the collagen. The supernatant liquid was filtered using an Ezee filter (Evergreen Scientific, 5-8 microns), ultrafiltered at 30kDa and lyophilised. If sufficient yield of freeze-dried gelatin was obtained, approximately 0.3mg was weighed in duplicate into tin capsules.

Total organic carbon, total nitrogen content and stable isotope analyses of the samples were performed using a Costech Elemental Analyser (ECS 4010) connected to a Thermo Scientific Delta V Advantage isotope-ratio mass-spectrometer. Carbon isotope ratios were corrected for ^{17}O contribution and reported in standard delta (δ) notation in per mil (‰) relative to Vienna Pee Dee Belemnite (VPDB). Isotopic accuracy was monitored through routine analyses of in-house standards, which were stringently calibrated against international standards (e.g., USGS 40, USGS 24, IAEA 600, IAEA N1, IAEA N2): this provided a linear range in $\delta^{13}C$ between –46 ‰ and +3 ‰ and in $\delta^{15}N$ between –4.5 ‰ and +20.4 ‰. Analytical uncertainty in carbon and nitrogen isotope analysis was typically ±0.1 ‰ for replicate analyses of the international standards and typically <0.2 ‰ on replicate sample analysis. Total organic carbon and nitrogen data was obtained as part of the isotopic analysis using an internal standard (Glutamic Acid, 40.82 % C, 9.52 % N).

Comparisons of isotopic values between groups were undertaken using non-parametric tests, as there is no reason to expect normal distributions in data arising from mixing of multiple components in differing proportions. Mann-Whitney tests were used for two groups of data, while Kruskal-Wallis tests were used for multiple comparisons, with post-hoc pairwise Mann Whitney tests. All statistical analyses conducted for this study were performed using PAST Palaeontological Statistics software version 3.15 (Hammer, et al., 2001).

3.0 Results

A total of 32 subadult human and four faunal samples failed to yield sufficient collagen, or had abnormal C:N ratios and were therefore excluded; but the remainder of the samples had collagen yields between 2.4% and 28.2% (Tables 3 and 4). The range of stable isotopic values for humans (4‰ in $\delta^{13}C$, 6.8‰ in $\delta^{15}N$) indicates a high degree of dietary variation in the settlement. The values for the faunal samples (Table 4 , Figure 2) show values for the herbivores (cow, sheep and pig) and omnivores (chicken) typical in C_3 ecosystems, and the marine samples show the expected high $\delta^{15}N$ value but variable $\delta^{13}C$.

3.1 Infant feeding practices

Our earlier study focusing on breastfeeding patterns in *Londinium*, using part of the current dataset, revealed some variability in the cessation of breastfeeding, with some two and three year olds having values close to the adult female mean (Powell, et al., 2014). By the age of four years, all of the subadult sample were fully weaned, with only one individual (a ten year old, WES89 sk781) having $\delta^{15}N$ more than one standard deviation from the adult female mean (Powell, et al., 2014).

The current study increases the previous infant dataset by 25%, but shows no new trends. Notably, this reinforces the finding that the $\delta^{13}C$ values for under 5 years old mostly fall below the adult female mean and are more variable. This group are statistically significantly different from the adult females (Mann Whitney U=183, p=0.049). This result probably reflects a specific weaning diet, which includes a higher proportion of terrestrial resources, and is paralleled in modern infants weaned with cereal diets (Fuller et al., 2006). After the age of five years old, no statistically significant difference is observed between the subadults and the adult females (U=271, p=0.261).

3.2 Post-weaning diet

Figure 3 shows that the variations in $\delta^{15}N$ and $\delta^{13}C$ values between age-groups were small, but those aged 4-16.5 years old had a greater spread of values than 17-19 year olds, whose diets were similar to adults. There is no significant difference between adult male and adult female diets expressed in either $\delta^{13}C$ (Mann-Whitney U=165, p=0.666) or $\delta^{15}N$ (Mann-Whitney U=154, p=0.443), so these groups are combined in the analyses by age and time period.

There is increasing enrichment in $\delta^{13}C$ with increasing age in the subadult age-groups (Table 5), with significant differences across the groups (Kruskal-Wallis K=8.47, p=0.015), which post-hoc testing indicates is due to the difference between the first and last age groups. The similarity in $\delta^{15}N$ values between these age groups (Kruskal-Wallis K=1.15 p=0.563) suggests that the changes in $\delta^{13}C$ are not caused by changing animal protein consumption but perhaps there was a small proportion of aquatic resources in the diet that shifted from freshwater to marine.

3.3 Diet and time period

Individuals less than four years old are excluded from the following discussion, because of the $\delta^{15}N$ enrichment with breastfeeding (Jay, 2009); one subadult who could not be assigned to a time period was also excluded (for more details on these individuals see Powell et al. 2014).

Figure 4 shows comparable $\delta^{15}N$ and $\delta^{13}C$ values of the total population for the early (AD 43-250) and late (AD 250-450) periods of *Londinium*, and these were not statistically significantly different ($\delta^{15}N$, U=728, p=0.905; $\delta^{13}C$, U=555, p=0.068). Nevertheless, some individuals in the early period, particularly adults, have enriched isotopic values, suggesting that marine resources were regularly consumed. Only one statistically significant difference was observed between the diets of subadults and adults within periods, with the adults in the late period slightly less negative in $\delta^{13}C$ (with Bonferroni corrected α=0.0250; early: $\delta^{15}N$, U=78.5, p=0.848, $\delta^{13}C$, U=61.5, p=0.283; late: $\delta^{15}N$, U=331.5, p=0.627, $\delta^{13}C$, U=229, p=0.0247). The late period adults are also distinguished by a correlation between $\delta^{13}C$ and $\delta^{15}N$ (r^2=0.51, p<0.001), which is not observed in the early period adults or the subadults of early or late periods (r^2=0.09, p=0.362; r^2=0.09, p=0.268; r^2<0.01, p=0.892 respectively). The set of regression lines differ (ANCOVA F=7.7, p<0.001) with post-hoc test indicating that the late period adults differ from the early period adults and the late period subadults. The correlation suggests that late period adults consumed a mixture of terrestrial and marine resources, while the other groups consumed freshwater resources in addition to terrestrial and marine foods.

Comparing values between periods for subadult and adult $\delta^{15}N$ and $\delta^{13}C$ gives similar results to the total sample (Figure 4, Table 5), with no significant differences (subadult: $\delta^{15}N$, U=261, p=0.652; $\delta^{13}C$, U=188.5, p=0.053, adult: $\delta^{15}N$, U=92, p=0.603; $\delta^{13}C$, U=92, p=0.607). The late group have a wider distribution with more individuals showing evidence for consumption of freshwater resources, but this may be an artefact of the smaller sample size for the early group.

4.0 Discussion

In Figure 2 our results from humans are compared with our own faunal results and the mean and standard deviation of results from a compilation of British fish and animal samples (Mays & Beavan 2012: Supplementary Table 2). The small sample of animals and marine species from Roman London are very comparable to the values expected from earlier studies. Our results demonstrate that the overall dietary protein intake of the inhabitants of *Londinium* was dominated by C_3 terrestrial foods, including a mixture of terrestrial plants, herbivorous animal protein, with possibly a small amount of chicken and/or egg, however, some foods with higher δ15N such as marine and freshwater resources were also included in the diet. Of the terrestrial plants, grain is usually considered to be a major component of Roman diet, though its contribution to the protein component of diet which is primarily reflected in collagen will be less than its calorific contribution (Fernandes et al. 201x). If grain is grown in manured fields, then its δ15N values may be raised to the equivalent of herbivores (Fraser et al. 2011), and thus grain and herbivore meat become indistinguishable. The δ15N values of many of the humans from Londinium are sufficiently high that no combination of herbivore protein and manured grain protein can explain them, and aquatic resources must be a component of the diet.

This contrasts with literary descriptions emphasising the primarily vegetarian diet of the urban poor and peasantry (Garnsey and Scheidel, 2004). Other isotopic studies of Roman urban settlements at Gloucester, Dorchester, Winchester and York (Redfern, et al., 2012, Cummings, 2009, Müldner, 2005, Chenery, et al., 2010, Cheung, et al., 2012, Richards, et al. 1998, Redfern, et al., 2010, Bonsall and Pickard, 2015) have also inferred a C_3 terrestrial diet that included significant amounts of animal protein, with a small proportion of marine and/or freshwater resources. Importantly, there is also heterogeneity in food consumption, which given the number of migrants identified isotopically in some of these urban centres, including *Londinium*, is to be expected (Shaw, et al., 2016, Chenery, et al., 2010, Leach, et al., 2009). In principle C_4 plants could also have provided food sources with high δ^{13}C values similar to those of marine foods, of which millet is the most likely. However, the evidence for millet in Roman Britain is negligible (Willcox, 1977), and to have high δ^{15}N values associated with C_4 δ^{13}C values would require that C_4 plants were being imported to be used as animal fodder, which seems unlikely.

The non-terrestrial dietary component of the majority of subadults until adolescence was either fresh-water fish, or a mixture of marine and freshwater resources. The typical diet shifted with subadult age, with increasing δ^{13}C suggesting this element of diet switched from freshwater to marine. This probably reflects the influence of several intertwined socio-cultural and economic choices. Firstly, it reflects their lower social status as children, as childhood was considered to be a distinct social category in Roman society (Katz, 2007, French, 1988), and Galen (2000) recommended that juvenile diet should primarily be cereals during weaning before moving on to include meat and fish. The distribution of isotope data shows that only subadults and two female adults fall in the region above 10 ‰ in δ^{15}N and below -20 ‰ in δ^{13}C where the freshwater fish component of the diet would be greatest. The influence of age as a contributory factor is further emphasized by the increasing δ^{13}C with subadult age, suggesting the aquatic element of diet switched from freshwater to marine, and the similarity of adolescents' diet to adults'. Women in the Roman Empire were always considered to be 'less than' males, afforded a lower social, economic and legal status (Dixon, 2001, Evans Grubb, 2002, Saller, 1998). They too were treated differently by dining practices (Roller, 2006), and stable isotope evidence from Isola Sacra (Italy) shows that females and children had different consumption patterns to males, eating predominantly cereal based diet and having little meat (Prowse, et al., 2005, Prowse, 2011, 2004). This is also supported by Killgrove and Tykot's (2013) analysis of Imperial-period Romans from lower socio-economic areas around Rome, whereby the diet of the poor could be quite heterogeneous, though their study, like ours, failed to identify differences between males and females. The funerary record of *Londinium* suggests that much of the population were not high status, and the consumption of cheaper freshwater fish by children and a small proportion of women could reflect this wider socio-economic driver.

Overall, we propose that this result is most likely to reflect locally-situated and culturally determined food-ways, shaped by the food resources available to the settlement, with people choosing resources immediately available, fresh and within their means, as Roman sources tell us that marine fish were more expensive than freshwater ones (Locker, 2007, Guptill, et al., 2013). Water was key to *Londinium*'s development and planning (Rogers, 2013), and although these waterways did experience some pollution (Maloney and de Moulins, 1990, Smith, 2012), the River Thames particularly would have been an important source of fish. Locker's (2007) review of the evidence for fish consumption in Roman Britain observed that *Londinium* dominates the datasets in terms of sample size and number of sites (e.g., an inn), with evidence for the processing and consumption of freshwater and marine fish, as well as imported fish in amphorae. The majority of evidence points to the consumption of local riverine/estuary and marine fish from the inshore waters near to the Thames estuary; cod seem to have been particularly popular in *Londinium* (Locker, 2007).

A surprising result was the temporal change in dietary patterns, which we believe to be related to the changing fortunes of the settlement. In both periods, the breastfeeding and weaning timetable remains constant (Powell, et al., 2014), and no change in average diet is detectable between the early (AD 43-250) and late (AD 250-450) periods for subadults or adults. There is, however, a difference between the late period subadults and adults, and the distribution of isotope data changes, with correlation of $\delta^{13}C$ and $\delta^{15}N$ in the late period adults showing evidence for diets mixing marine and terrestrial foods, in a way that is not evident in the other groups. The instability of the late period, marked by political uncertainty and the abandoning of portions of the settlement, may have impacted on the socio-economic choices made about diets, including those of children. Thus the early period shows concordance in adult and subadult dietary patterns, but in the late period adult diets do not appear to include freshwater fish in detectable quantities; in contrast, many subadult diets are characterised by this foodstuff. During the 3rd and 4th centuries AD, the change in diet is set within a wider decline in the diversity and variety of plant and archaeozoological remains, evidence for the increasing exploitation of wild resources, as well as a downturn in long distance trade (Cowan, et al., 2009, Davis, 2011a, Milne, 1985). This waning in fortunes was a consequence of turbulence in the Empire caused by political and structural instability (Table 1), and although its geographical location offered some protection, the impact of these wider events on trade-connections would have been felt in *Londinium*'s market place (Marsden, 1986, Fulford, 2004, Gerrard, 2015).

Inscription and stable isotope evidence for Italian migrants in Londinium, raised the expectation that there may be similarities in our results between these two locations, but this was not the case. Prowse et al.'s (2008), study of the population from the port settlement of Isola Sacra (Fig. 8.8) observed that subadults had a very restricted diet compared to adults, further emphasizing the heterogeneous nature of foodways in societies, because of the pivotal role played by status, culture, regionality and, in times of want, necessity.

5.0 Conclusions

Our study of diet from childhood to adulthood in Roman London has found that diet shifted through the life course, from weaning before 4 years of age, through childhood and juvenile stages, with adult dietary patterns achieved by the age of 17 years old. Adults consumed terrestrial animal protein and isotopically enriched foods, such as marine fish. Adult dietary practices appeared to have changed in response to the changing economic fortunes and trade-connections of *Londinium*. By contrast, those responsible for feeding subadults chose to include greater proportions freshwater fish, a cheaper and locally available source of protein, resulting in a wider range of isotopic signatures for children and adolescents.

The results of this study underline the intense regional and temporal heterogeneity with respect to diet in the Roman world. It underscores the importance of recognising that diet is more than just the eating of food, it is an activity imbued with tremendous social, cultural and economic importance. The dietary choices made for children and breastfeeding practices are particularly diverse across the Empire and perhaps there was greater cultural leeway in childhood diets. Though speculative, this could be because childhood eating was less socially visible and therefore subject to fewer cultural proscriptions. (Dettwyler, 1996, Liamputtong, 2007, Stuart-Macadam and Dettwyler, 1995).

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Table 1. Summary of the archaeological phases of Roman London (Londinium) (Wallace, 2015; Hill and Rowsome, 2011; Marsden, 1980; Perring, 2011).

Phase and date (AD)	Summary of major changes and finds
1: 1st century	Wooden settlement founded in c. A.D. 48, whose material culture shows strong connections to Gaul and the Mediterranean. Destroyed during the Boudican rebellion (AD 60).
2: 1st and 2nd centuries	Height of the settlement's success. By A.D. 100 it replaced Colchester as the main centre for the province but was devasted by the ‘Hadrianic fire’ in A.D. 122. Rebuilt with substantial public architecture (e.g. forum and port) and made capital of Britannia Superior in A.D. 193.
3: 2nd and 3rd centuries	Continuation of public building works but the settlement went into decline and some areas were abandoned. This is likely to be a result of the social and political upheaval caused by the province separating to form part of the Gallic Empire and then rejoining the Roman Empire.
4: 4th century	Many of the public buildings are demolished as punishment for joining the Gallic Empire. Londinium remained financial and administrative centre of Britannia, and the material culture record shows its continuing wealth.
5: 4th to early 5th centuries	The southeast area of the walled-settlement on the north bank contained houses with evidence for luxury imports but the northern part had been cleared and was wasteland or fields. Roman rule ended in A.D. 410 with the withdrawal of army.

Table 2. List of sites and numbers of individuals included in the study

Site Code	Site Name	Publication	Infant	Subadult	Adult	Total
ATC97	Atlantic House	Watson 2003	1	2	0	3
BAR79	St.Bartholomew's Hospital	Bentley and Pritchard 1982	0	5	0	5
BDC03	Basinghall Street	Powers 2008	0	1	1	2
COSE84	Courage Brewery	Cowan 2003	0	1	0	1
DGT06	Courage Brewery	Cowan 2003	1	0	0	1
GDV96	Great Dover Street	Mackinder 2000	1	2	2	5
HAY86	Haydon Street	Barber and Bowsher 2000	0	1	0	1
HOO88	Haydon Street	Barber and Bowsher 2000	4	1	1	6
LTU03	Lant Street	Sayer 2006; Ridgway et al 2013	6	2	4	12
MSL87	Northgate House	Powers 2006b	3	16	11	30
MST87	Mansell Street	Barber and Bowsher 2000	0	1	1	2
PNS01	Paternoster Row	Watson and Heard 2006	1	0	0	1
REW92	Red Cross Way	Drummond-Murray and Thompson 2002	0	2	0	2
SRP98	Spitalfields Market	Powers 2011b	5	8	6	19
STO86	250 Bishopsgate	Powers 2011b	1	0	0	1
TIY07	Trinity Street	Langthorne 2011	0	3	1	4
WES89	1-4 Giltspur Street	Department of Urban Archaeology 1990	0	9	3	12
Total			23	54	30	107

Table 3: Roman London human bone collagen results given by site code (see Table 2) and context number, age and period (early/late)

References for previously published data: 1 Powell et al (2014); 2: Millard et al. (2013)

Site Code and Context Number	Specific Age	Sex	Yield (%)	%C	$\delta^{13}C$	%N	$\delta^{15}N$	C:N	Period	Reference
DGT06 4579	36 weeks gestation		3.8	44.6	-19.9	14.3	12.7	3.6		1
GDV96 347	28 weeks gestation		5.8	41.8	-19.5	15.0	12.6	3.3	Early?	
LTU03 170	40 weeks gestation		3.1	44.6	-19.7	14.8	12.8	3.5	Late	1
LTU03 86	46 weeks gestation		2.3	40.9	-19.2	14.0	13.4	3.4		1
SRP98 15400	0 years		10.2	44.8	-19.4	15.6	13.5	3.4	Early	1
HOO88 832	0.5 years		7.4	44.5	-21.5	15.7	12.3	3.3		1
HOO88 869	0.5 years		3.4	43.7	-18.6	15.0	13.1	3.4		1
SRP98 15386	0.5 years		5.4	42.3	-22.4	15.1	12.3	3.3	Early	1
HOO88 1350	1 year		4.9	44.0	-20.3	15.5	13.8	3.3		1
MSL87 1116	1 year		5.0	42.3	-20.8	14.5	12.5	3.4	No date	1
PNS01 162	1 year		8.9	43.7	-20.5	15.9	13.0	3.2		1
STO86 73	1 year		5.7	41.5	-19.5	15.2	13.9	3.2		
HOO88 854	1.5 years		14.1	42.4	-20.1	15.2	11.9	3.3		1
LTU03 91	2 years		8.6	42.4	-18.9	15.4	12.5	3.2	Late	
LTU03 375	2 years		2.6	42.4	-20.1	14.9	10.5	3.3	Early	1
MSL87 227	2 years		5.3	44.4	-18.9	15.7	12.8	3.3	Late	1
ATC97 375	3 years		3.8	43.8	-20.9	15.0	12.4	3.4	Early	1
LTU03 93	3 years		5.8	41.7	-20.6	15.2	11.5	3.2	Late	
LTU03 397	3 years		4.0	42.0	-20.5	14.8	12.9	3.3	Early	
MSL87 194	3 years		2.2	43.7	-21.5	15.0	12.3	3.4	Early	1
SRP98 3341	3 years		5.7	41.2	-18.7	15.3	13.0	3.1	Late	
SRP98 15644	3 years		4.6	47.1	-20.2	16.6	10.6	3.3	Late	1
SRP98 15871	3 years		7.9	41.8	-20.6	14.7	12.1	3.3	Early	1
GDV96 107	4 years		3.1	40.7	-19.8	13.9	10.2	3.4	Early	1

MSL87 516	4 years	5.3	43.2	-20.3	14.4	10.8	3.5	Late	1
MSL87 675	4 years	6.9	44.4	-20.2	16.0	11.4	3.2	Late	1
MSL87 1700	4 years	1.1	43.8	-20.6	14.7	10.8	3.5	Late	1
MSL87 1714	4 years	8.9	44.9	-20.1	16.5	10.8	3.2	Late	1
WES89 429	4 years	1.4	43.4	-20.5	15.2	9.4	3.3	Late	1
HOO88 1345	4.5 years	7.6	40.5	-19.8	14.5	10.4	3.3	Early	1
MSL87 204	4.5 years	3.1	44.3	-20.8	15.5	10.4	3.3	Late	1
ATC97 409	5 years	11.0	42.3	-19.1	15.2	11.2	3.3	Early	1
BAR79 344	5 years	3.3	44.2	-20.2	16.0	11.8	3.2	Late	1
MSL87 1707	5 years	4.1	43.8	-21.1	14.3	11.1	3.6	Early	1
SRP98 23873	5 years	7.2	44.8	-20.2	15.2	10.0	3.4	Late	1
BDC03 415	6 years	15.9	42.6	-19.5	15.5	11.2	3.2	Early	1
WES89 1004	6 years	7.0	44.0	-20.6	14.6	10.9	3.5	Late	1
SRP98 8990	6.5 years	6.8	42.6	-21.0	15.1	10.6	3.3	Late	1
BAR79 180	7 years	3.3	45.5	-20.5	16.3	10.9	3.3	Late	
MSL87 377	7 years	10.5	41.5	-20.0	14.7	9.2	3.3	Early	1
WES89 756	7 years	7.3	42.8	-19.6	15.0	10.2	3.3	Late	1
REW92 227	7.5 years	5.3	43.9	-20.7	15.1	11.4	3.4	Late	1
WES89 527	8 years	3.9	42.1	-20.7	14.8	12.0	3.3	Late	1
TIY07 427	8.5 years	8.5	43.0	-19.6	14.9	11.4	3.4	Late	1
TIY07 476	8.5 years	11.6	42.7	-19.0	15.4	11.0	3.2	Late	1
HAY86 413	9 years	2.5	42.4	-19.2	14.9	10.8	3.3	Late	1
MSL87 491	9 years	8.5	42.3	-19.7	15.0	11.1	3.3	Late	1
MSL87 578	9 years	3.1	43.2	-21.2	14.6	11.3	3.4	Late	1
SRP98 15345	9.5 years	9.9	42.5	-19.5	15.7	10.4	3.2	Late	1
WES89 781	10 years	2.7	44.1	-20.7	15.0	8.8	3.4	Late	1
MSL87 464	11 years	5.4	44.5	-20.3	15.6	10.5	3.3	Early	1
MSL87 805	11 years	12.1	42.1	-19.8	15.4	10.0	3.2	Early	1
WES89 460	11 years	8.1	42.2	-19.7	15.6	9.6	3.2	Late	
MSL87 505	12 years	6.3	42.4	-20.1	15.2	11.5	3.3	Late	1

MSL87 922	12 years		5.6	43.1	-20.8	15.0	12.1	3.4	Late	1
SRP98 5765	12 years		2.8	41.0	-19.5	14.4	11.2	3.3	Early	1
WES89 228	13 years		6.5	43.5	-20.5	15.1	11.3	3.4	Late	1
WES89 427	13 years		9.6	42.4	-20.2	14.9	10.8	3.3	Late	1
BAR79 341	14 years		2.7	41.6	-21.2	13.9	10.3	3.5	Late	1
LTU03 385	14 years	F	1.7	43.9	-20.2	13.4	10.9	3.3	Late	
BAR79 181	15 years		4.5	43.1	-20.2	15.1	10.8	3.3	Late	1
GDV96 56	15 years		1.9	40.0	-19.2	14.3	12.2	3.3	Early	1
SRP98 15438	15 years		11.0	42.4	-19.9	15.1	10.6	3.3	Early	1
COSE84 1951	16 years		4.0	42.4	-19.4	14.7	10.5	3.4	Late	1
MSL87 6	16 years		7.8	42.0	-19.3	14.7	11.2	3.3	Late	1
ATC97 292	16.5 years		11.4	42.4	-19.1	15.4	9.8	3.2	Late	1
MST87 114	17 years		3.6	41.7	-19.5	15.3	10.4	3.2	Early	
WES89 848	17 years		2.9	42.4	-19.8	15.0	10.7	3.3	Late	1
TIY07 267	17.5 years		3.4	41.8	-20.1	14.2	9.9	3.4	Late	1
BAR79 182	18 years	F	1.5	43.7	-20.7	14.7	9.5	3.5	Late	
LTU03 259	18 years	M	3.1	41.9	-19.4	14.6	12.4	3.4	Early	
MSL87 547	18 years	M	2.8	42.3	-19.3	14.5	10.5	3.4	No date	
SRP98 3662	18 years	F	10.2	42.0	-19.3	15.6	11.5	3.2	Late	
MSL87 753	18.5 years	M	5.9	42.2	-19.4	15.2	10.1	3.2	Early	
REW92 204	18.5 years	F	4.5	42.2	-18.2	14.9	11.0	3.3	Late	
SRP98 3251	19 years	M	2.4	42.1	-19.2	15.2	10.9	3.2	Late	
SRP98 5668	19 years	M	1.6	41.7	-19.8	14.6	10.4	3.3	Early	
BDC03 400	Adult	F	8.1	43.0	-18.7	15.1	11.8	3.3	Early	
GDV96 325	Adult	F	9.9	42.3	-19.8	15.6	11.5	3.2	Early	
LTU03 13	Adult	F	1.1	45.0	-19.5	15.5	10.5	2.9	Late	2
LTU03 157	Adult	F	5.9	44.4	-20.0	15.2	7.7	2.9	Late	2
MSL87 254	Adult	F	10.9	42.5	-18.5	15.6	12.1	3.2	Late	
MST87 390	Adult	F	7.9	42.5	-20.1	15.1	8.8	3.3	Late	
MSL87 39	Adult	F	9.9	42.1	-18.7	15.6	11.1	3.2	Early	

SRP98 34126	Adult	F	4.4	43.2	-19.4	15.2	10.4	3.3	Late
TIY07 203	Adult	F	2.6	42.5	-19.3	14.9	12.7	3.3	Late
WES89 504	Adult	F	2.5	43.4	-20.7	14.4	11.8	3.5	Late
MSL87 336	Adult	F	4.9	42.9	-20.7	14.7	9.3	3.4	Late
MSL87 390	Adult	F	10.9	42.5	-20.1	15.1	8.8	3.3	Late
WES89 599	Adult	F	4.6	42.6	-19.2	15.3	11.2	3.3	Late
SRP98 12147	Adult	F	14.1	42.7	-18.9	15.1	13.6	3.3	Late
MSL87 606	Adult	?F	8.3	42.8	-19.8	15.2	9.7	3.3	Early
SRP98 5919	Adult	?F	2.3	43.2	-20.9	14.1	12.7	3.6	Early
LTU03 10	Adult	?M	2.7	42.0	-22.2	14.1	6.8	3.5	Late
WES89 718	Adult	?M	4.3	41.0	-20.3	14.4	9.6	3.3	Late
SRP98 23879	Adult	?M	7.2	42.6	-19.6	15.5	10.0	3.2	Early
GDV96 70	Adult	?M	1.8	42.0	-19.3	15.1	11.0	3.2	Early
MSL87 450	Adult	?M	9.4	42.3	-18.7	15.8	10.6	3.1	Early
MSL87 566	Adult	M	5.9	42.1	-19.8	14.8	10.7	3.3	Late
MSL87 569	Adult	M	2.1	38.9	-19.3	13.7	12.4	3.3	Late
MSL87 720	Adult	M	6.6	42.8	-19.0	15.2	11.7	3.3	Late
MSL87 2034	Adult	M	5.2	42.4	-19.3	15.4	10.0	3.2	Early
SRP98 35553	Adult	M	6.8	42.0	-19.6	15.0	10.0	3.3	Early
SRP98 34273	Adult	M	1.7	41.2	-19.9	14.6	11.4	3.3	Early
LTU03 321	Adult	M	2.5	44.4	-19.4	15.0	9.9	3.0	Late
HOO88 981	Adult	M	8.0	42.1	-19.1	15.7	11.2	3.1	Late
MSL87 538	Adult	M	11.0	42.4	-19.0	15.5	10.3	3.2	Late

Table 4: Roman London Animal Bone Collagen Results (FER97: Plantation House; MFI87: Docklands Light Railway; ONE94: 1 Poultry)

Number	Site Code and Context Number	Species	Yield (%)	%C	δ^{13}C	%N	δ^{15}N	C:N
C1	ONE94 3218	Cow	6.3	42.7	-22.3	15.0	7.3	3.3
C2	ONE94 11236	Cow	6.4	42.6	-21.4	15.4	6.2	3.2
C3	ONE94 11236	Cow	5.8	42.1	-21.8	15.1	6.5	3.3
C4	ONE94 3782	Cow	9.6	42.3	-22.5	15.4	4.1	3.2
C5	ONE94 3782	Cow	12.9	48.1	-21.9	16.5	8.2	3.4
S1	ONE94 11243	Sheep	2.4	41.4	-22.4	13.9	5.6	3.5
S2	ONE94 11243	Sheep	6.8	42.1	-20.8	15.3	6.0	3.2
S3	ONE94 3218	Sheep	9.3	42.4	-21.8	15.3	6.5	3.2
S4	ONE94 3782	Sheep	9.2	42.1	-21.4	15.2	7.7	3.2
P2	ONE94 6046	Pig	4.3	42.2	-21.1	15.0	7.3	3.3
P3	ONE94 3218	Pig	10.1	42.7	-21.0	15.4	7.9	3.2
P4	ONE94 7475	Pig	6.9	42.2	-21.3	15.0	4.9	3.3
P5	ONE94 7475	Pig	4.4	42.4	-21.5	15.0	7.3	3.3
CH1	ONE94 11243	Chicken	3.7	42.0	-21.6	14.2	9.3	3.5
CH2	MFI87 156	Chicken	13.1	42.5	-20.4	15.3	11.9	3.2
CH3	MFI87 156	Chicken	14.8	41.8	-19.9	15.4	10.7	3.2
CH4	MFI87 156	Chicken	10.7	42.8	-20.5	15.6	10.6	3.2
CH5	MFI87 156	Chicken	28.2	42.7	-20.2	15.6	8.9	3.2
F3	FER97 156	Conger Eel	2.9	42.5	-12.8	14.7	14.7	3.4
F5	MFI87 156	Cod	2.7	42.8	-15.4	14.6	14.3	3.4
F6	GYE92 15174	Fish - Marine	6.4	40.7	-13.4	14.5	14.1	3.3
	Herbivore mean and sd				-21.8	0.6	6.5	1.2

Table 5: Summary statistics of isotopic data for groups (mean±sd)

Group	N	$\delta^{13}C$		$\delta^{15}N$	
4-7.5 years	19	-20.2	±0.53	10.7	±0.67
8-16.5 years	24	-20.0	±0.65	10.8	±0.80
17-19 years	11	-19.5	±0.62	10.7	±0.79
Adult	30	-19.6	±0.79	10.6	±1.49
Early Period	26	-19.6	±0.57	10.8	±0.86
Late Period	57	-20.0	±0.76	10.7	±1.16

Figure 1: Map of Roman London

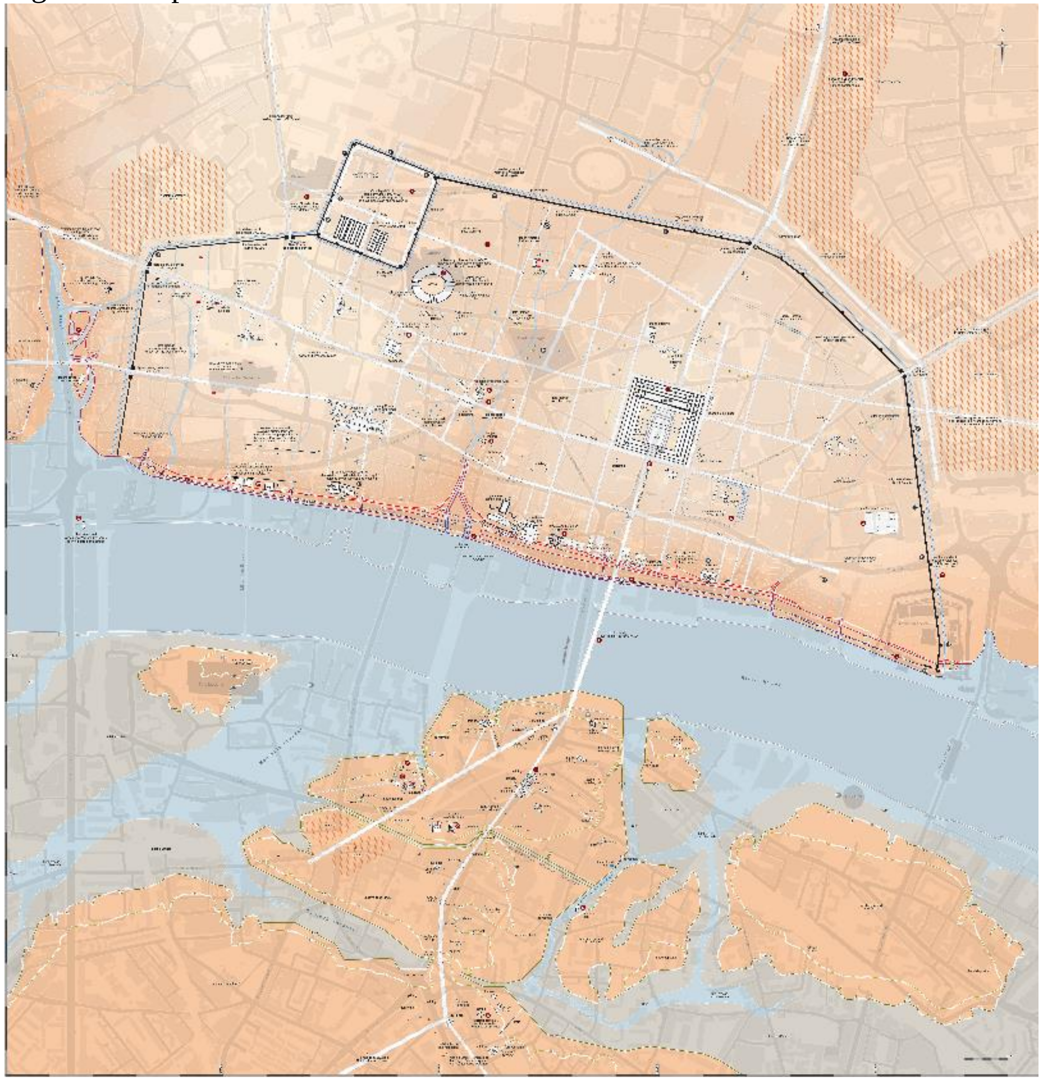

Figure 2: Scatterplot comparing the $\delta^{15}N$ and $\delta^{13}C$ values of the Roman London population to faunal values. Plotted points are data from this study. Large symbols with 1 standard deviation error bars are from the synthesis of British faunal isotope values in Mays and Beavan (2012: Supplementary Table 2) .

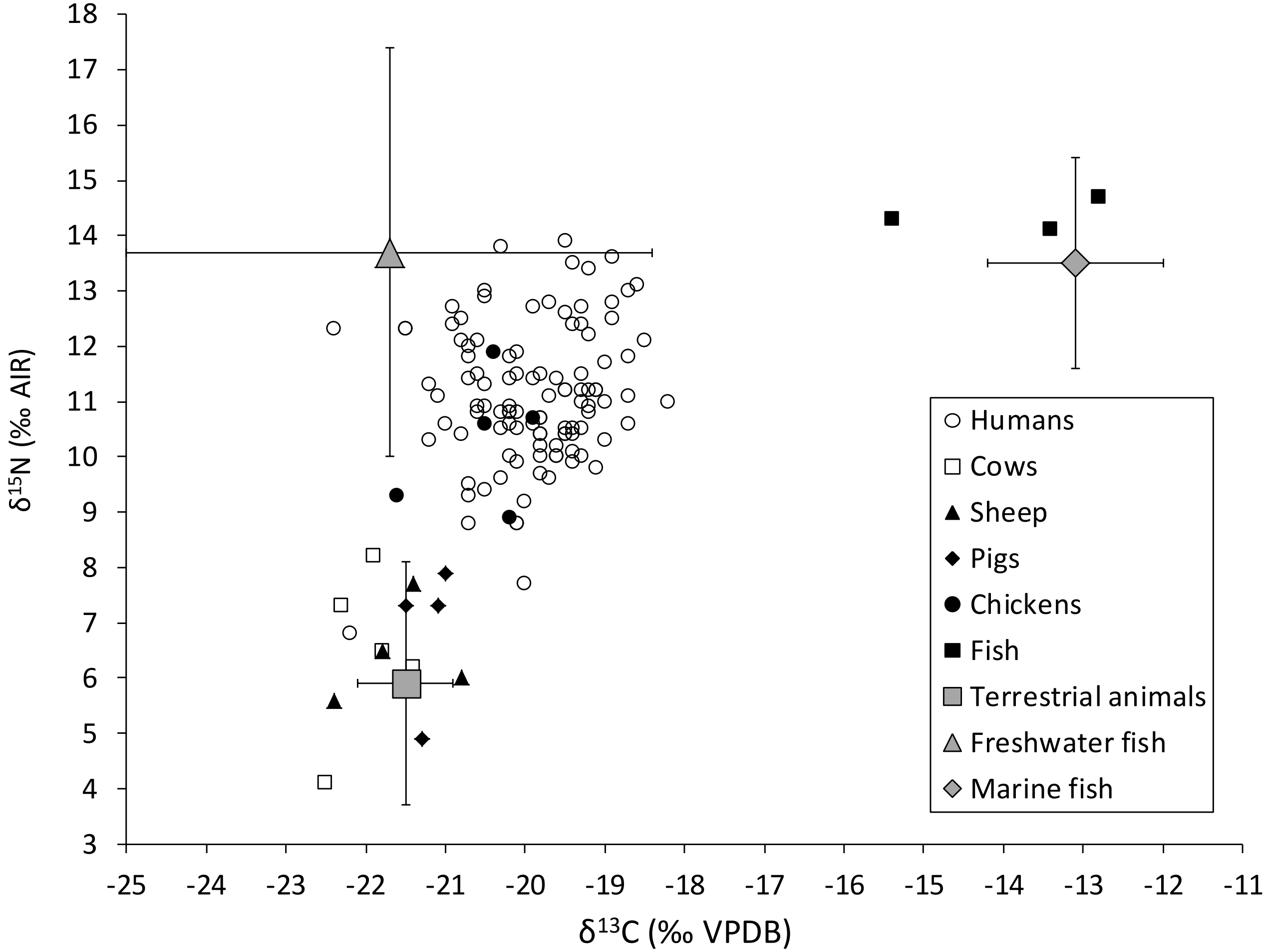

Figure 3: Scatter plot comparing the δ15N and δ13C values of the Roman London subadults by age categories

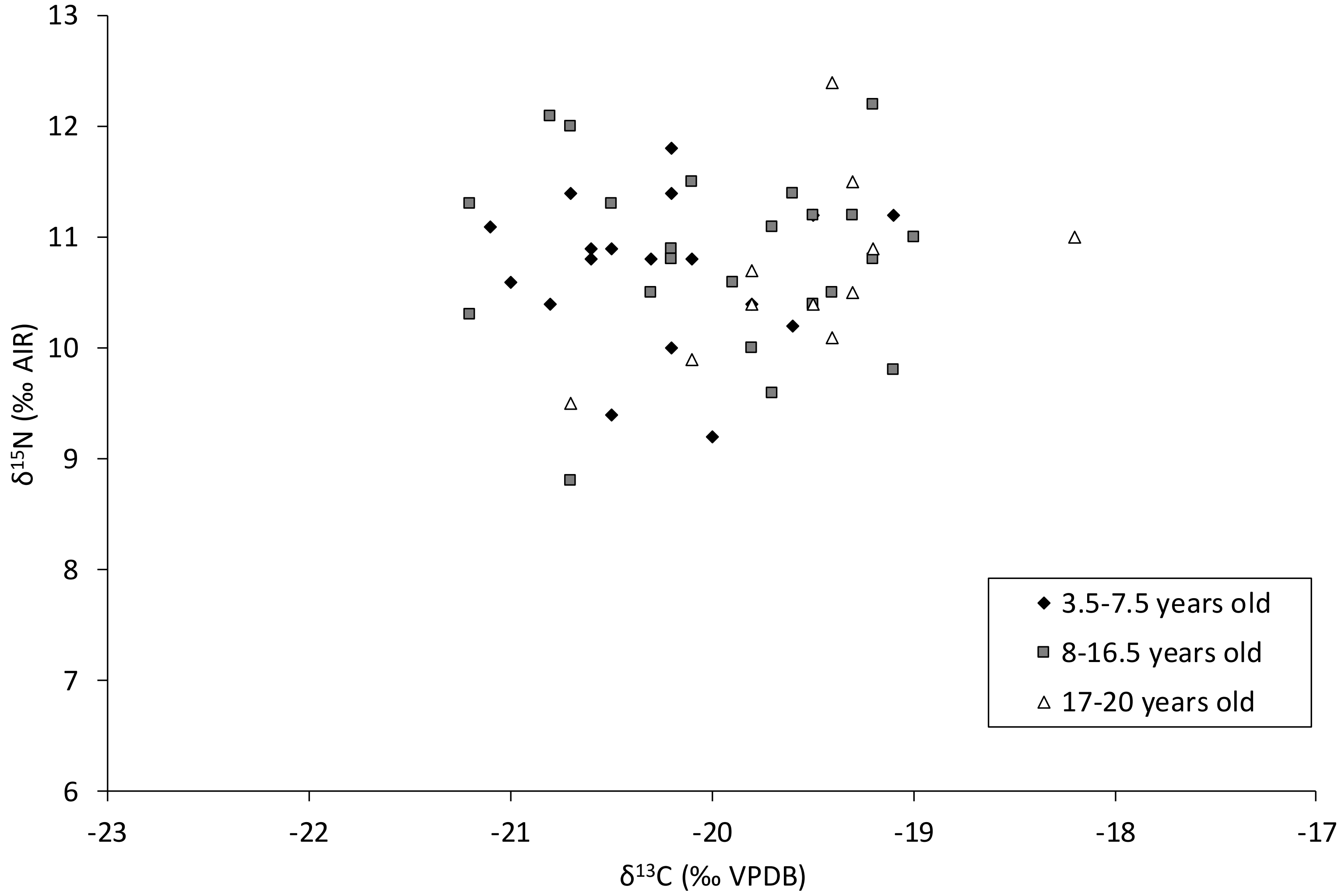

Figure 4: Scatter plot of δ^{15}N and δ^{13}C values of the Roman London sample by early and late periods, and by subadult and adult age groups