

# 11. Multi-isotope evidence of diet (carbon and nitrogen) and mobility (strontium) at Neolithic Çatalhöyük

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## Introduction

The past 20 or so years of stable isotope analysis at Neolithic Çatalhöyük have focused on reconstructing human diet through carbon and nitrogen isotope analysis of bone collagen almost exclusively (see also Styring et al. 2016). Here, this chapter provides the final carbon and nitrogen data for the remaining houses at the site not yet measured and supplements these (and previous data) with a large-scale study of strontium isotope analysis throughout the duration of the site's occupation. Despite previous extensive analyses resulting in the sampling of almost 1,300 bones and results of over 900 measured individuals (see also Pearson 2013), several questions related to diet remain, chiefly: how important were particular domestic and wild resources, how do houses compare through the site's occupation and can differences be identified between houses with different features and elaboration? For the strontium isotope analysis there are two new considerations: did the population of Çatalhöyük originate from the local area, and if not, can we find evidence for patrilocal or matrilineal kinship practices?

## Previous work

Earlier work (Pearson et al. 2007; Pearson 2013) has shown that animal carbon and nitrogen isotope values are surprisingly diverse, reflecting natural and anthropogenic

feeding regimes that result in large ranges (up to 9.5‰ variation) in isotope values even amongst animals with narrow, herbivorous diets. A summary of the faunal data from Pearson (2013) can be found in table 11.1.

All species show small to moderate consumption of C<sub>4</sub> plants in some animals, but overall the mean carbon isotope values for fauna suggest the impact of these plants was relatively small, with many more animals observing a C<sub>3</sub> plant-dominated/exclusive diet. These interpretations are based on C<sub>3</sub> plant carbon isotope measurements averaging around -23‰ for wild and domestic plants (Pearson 2013); and slightly higher (ca -22.5‰) for crops alone (Pearson 2004; Wallace et al. 2015). Therefore an exclusive C<sub>3</sub> plant-consuming animal that eats a mixture of wild plants from grazing and some fodder from crop waste will measure around -17.8‰. Individual animals with more C<sub>4</sub> plants in their diets tended to be species of sheep, goats and the later specimens of *Bos* spp. suggesting that the role of these plants in animals' diets was a feature of their management by humans and the mosaic landscape visited by them, together with changes in these habitats over time, with the drier episodes offering optimal growth to C<sub>4</sub> plants. That some equids had a C<sub>4</sub> component to their diet suggests these plants (likely grasses) were available in hunting and perhaps also in

Genus	N	$\delta^{13}C\text{‰}$ (VPDB)					$\delta^{15}N\text{‰}$ (AIR)				
		Min	Max	Range	Mean	s.d.	Min	Max	Range	Mean	s.d.
<i>Ovis</i> sp.	154	-20.2	-13.6	6.6	-17.5	1.2	4.9	14.4	9.5	10.1	1.6
<i>Capra</i> sp.	22	-19.8	-12.5	7.3	-17.7	1.6	5.2	12.2	7.1	9.0	2.0
<i>Bos</i> spp.	79	-19.8	-14.6	5.1	-18.1	1.1	6.0	13.8	7.7	9.8	1.7
<i>Equus</i> spp.	45	-19.9	-14.8	5.1	-19.0	1.0	5.1	11.3	6.2	8.3	1.4
<i>Sus</i> sp.	28	-21.3	-15.3	6.0	-19.5	1.2	5.9	11.9	6.4	8.0	1.6
<i>Vulpes</i> sp.	8	-19.0	-16.9	2.2	-18.2	0.7	8.2	15.0	6.8	10.8	2.7
<i>Canis</i> spp.	19	-21.3	-16.3	5.1	-18.5	1.6	7.7	13.2	5.5	11.2	1.5
<i>Canis lupus</i>	1	-	-	-	-14.3	-	-	-	-	16.8	-
<i>Cervus</i> sp.	8	-20.1	-14.1	6.0	-18.7	2.2	6.7	13.8	7.2	8.7	2.3
<i>Lepus</i> sp.	3	-20.4	-18.7	1.7	-19.3	1.0	3.5	6.6	3.1	4.9	1.6

Table 11.1. Summary carbon and nitrogen isotope data from fauna bone collagen (data taken from Pearson 2013).

grazing zones. Equids have a relatively smaller range in values, which as wild species (*Equus ferus* and *Equus hemionus*) may indicate the average isotope values of grasses in the local area that were available to free-to-roam wild animals. Data from suids alongside human isotope values have been used elsewhere to determine successfully whether these animals were consuming the human meal leftovers and thus indicating proxy evidence of early domestication (for a review see Rowley-Conwy et al. 2012). Table 11.1 shows mean values for boar at Catalhöyük were  $\delta^{13}\text{C}$   $-19.5\%$  and  $\delta^{15}\text{N}$   $8.0\%$ , which considered alongside the mean values for the inhabitants of Catalhöyük ( $\delta^{13}\text{C}$   $-18.7\%$  and  $\delta^{15}\text{N}$   $12.7\%$ ) strongly suggests that the majority of animals did not eat discarded food waste and instead points to these animals being wild boar living in their natural habitat. In contrast, the canids ( $\delta^{13}\text{C}$   $-18.5\%$  and  $\delta^{15}\text{N}$   $11.2\%$ ) are more similar to humans, suggesting these animals had access to leftovers. Only a single wolf at the site has been measured successfully, which provided a nitrogen isotope value of  $16.8\%$  and provides one example of what might be expected in consumers with meat-dominated diets.

Previous work on the human remains from the site has shown while  $C_4$  plants play an important role as food for some animals, there is no evidence for the passing on or direct consumption of these resources in humans ( $\delta^{13}\text{C}$   $-18.7\%$ ). In terms of the importance of houses as locations for food-sharing, Pearson et al. (2015a) show how the isotope data generated from the middens of specific houses do not seem to be part of the same foodweb as the adults buried beneath the house floors. The reasons for this could be because people spent some time away from the site, foods were not strictly shared, food was consumed in different locations or houses, people came from outside of the area originally, or people were not permitted to consume some of the foods available. It was also possible that whole food groups, which had not been measured, might account for some of the discrepancy. In particular, birds/eggs, reptiles and fish are found at the site, but their role in human diet so far is unknown isotopically. Whatever the reason for this variation, it suggests that food production, consumption and disposal were the result of carefully structured agentive processes. Comparing values across the inhabitants revealed some surprising data: male and female diet was probably the same, as indicated by virtually identical isotope values (female:  $\delta^{13}\text{C}$   $-18.8\%$ ,  $\delta^{15}\text{N}$   $12.6\%$ ; males:  $\delta^{13}\text{C}$   $-18.6\%$ ,  $\delta^{15}\text{N}$   $12.7\%$ ). Instead the population differentiated between social groups through age (Pearson, Meskell 2013; Pearson et al. 2015b), a finding echoed in the figurine corpus and grave goods (Nakamura, Meskell 2009; 2013a; 2013b).

## **The principles of stable isotope analysis**

### *Carbon isotope analysis and dietary reconstruction*

Carbon in animal tissues originates from atmospheric carbon dioxide where it is fixed by plants during photosynthesis. There are three methods of photosynthesis used by terrestrial plants:  $C_3$ ,  $C_4$  and crassulacean acid metabolism (CAM). Each pathway discriminates against the heavier carbon isotope  $^{13}\text{C}$  in different ways resulting in characteristic values for each form of photosynthesis (See O'Leary 1981):  $C_3$  plant  $\delta^{13}\text{C}$  values range between  $-34\%$  and  $-22\%$ ;  $C_4$  plants from  $-20\%$  to  $-7\%$  and CAM plants from  $-23\%$  to  $-11\%$ .  $C_3$  plants account for most plants globally, including cereals such as wheat and barley, most trees, fruit, nuts, pulses, all leguminous plants and tubers. Typical  $C_4$  plants include maize, millet and sugarcane and arid-adapted grasses and chenopods but only account for  $\sim 8,000$  ( $<5\%$ ) of terrestrial plants. CAM plants (such as cacti) form a smaller percentage but have little nutritional importance in Southwest Asia during the Neolithic, in contrast to  $C_4$  plants, which have been identified among charred plant taxa recovered from the site (Fairbairn et al. 2005a; Bogaard et al. 2013), including in sheep dung (Bogaard et al. 2013). Isotope values in plants can also be affected by global climatic, micro climatic and environmental conditions and anthropogenic activities (e.g., van der Merwe, Medina 1989; Tieszen 1991; Glagoleva, Chulanovskaya 1992; Tieszen, Fagre 1993; Heaton 1999). Plant water-use efficiency also influences plant carbon isotope ratios, causing lower carbon isotope values in well-watered plants. Nutrient impoverishment (lack of nitrogen or phosphorus) and cooler temperatures also lower carbon isotope values in  $C_3$  plants (Tieszen 1991). Phenomena that increase carbon isotope values include aridity, salinity and high altitudes (Tieszen 1991; Stewart 1995; Araus et al. 1997; Long 1999; 2001).

$C_4$  plant consumption by animals raises an interesting question, because the photosynthetic structures of  $C_4$  plants, comprised of more silica and fibre than their  $C_3$  counterparts, makes their palatability to animals inferior (Heckathorn et al. 1999). Thus, the relative consumption of  $C_3$  and  $C_4$  plants in animal tissues is unlikely to be representative of the standing plant biomass available to free-to-roam animals because, given a choice,  $C_4$  plants will be avoided unless they are the only available food seasonally (that is, in late summer) or because they are used as fodder. Ruminant animals have a greater tolerance for such plants on account of their digestive physiology, so normally  $C_4$  plants would be avoided by non-ruminants such as equids and suids, especially if those species are considered to be wild. Previous work by Pearson et al. (2007) has demonstrated the consumption of both types of plants at Catalhöyük and elsewhere, and how this may be indicative of herding practices.

Carbon is passed from plants through the food chain at two trophic levels: a ~5‰ shift between plants and herbivores, and a ~1‰ shift between herbivore and carnivore (DeNiro, Epstein 1978) along with any environmental or physiological influences. Other resources that have an impact on reconstructing human diets in particular include the consumption of aquatic foods such as fish, aquatic mammals and molluscs. These resources tend to cause much higher carbon isotope values for marine foods and slightly lower values for freshwater resources in consumers. While marine resources are unlikely to have made a major contribution to human diet at Çatalhöyük, even if some inhabitants travelled to the Mediterranean coast (ca 200km away), freshwater resources are a distinct possibility. Fish bones have been found on site originating from small cyprinids and loaches (under 15cm in length) (Van Neer et al. 2013; Hamilton-Dyer this volume, Chapter 12) and the identified bird bones reflect a range of local aquatic species, some of which are shown to have been eaten (Russell, McGowan 2005; Russell 2019a; Best et al. this volume, Chapter 13).

#### *Nitrogen isotope analysis and dietary reconstruction*

Nitrogen also enters the food chain, either as adsorbed nitrogenous compounds in soil or, in the case of leguminous plants, having been fixed directly from the atmosphere. The enrichment factor between diet and a body (the so-called trophic level effect) is ~4‰ (DeNiro, Epstein 1981; Ambrose, Norr 1993; Hedges, Reynard 2007). Nitrogen isotope values are also influenced by a large number of specific environmental factors, most of which cause values to rise. In plants these include aridity (e.g., Heaton 1987; Ambrose 1991; Cormie, Schwarcz 1994; Gröcke et al. 1997; Schwarcz et al. 1999), salinity (e.g., Handley, Scrimgeour 1997; Robinson et al. 2000; van Groenigen, van Kessel 2002), high temperatures (Ambrose 2000), ruminating (Macko et al. 1982; Sealy et al. 1987; Wattiaux, Reed 1995; Cormie, Schwarcz 1996) and starvation (Barboza et al. 1997; cf. Ambrose 2000; Faber 2003; Fuller et al. 2004; Stewart, Smith 2005). More recently, Bogaard et al. (2007) and Fraser et al. (2011) have shown that anthropogenic inputs from crop manuring have the same effect and may influence how accurately the trophic level of an individual can be determined.

#### *Strontium isotope analysis and mobility*

Strontium (Sr) is a naturally occurring trace element present in geological substrates, organic organisms and water sources. It is present as four stable isotopes:  $^{84}\text{Sr}$ ,  $^{86}\text{Sr}$ ,  $^{87}\text{Sr}$  and  $^{88}\text{Sr}$ . The isotope  $^{87}\text{Sr}$  is formed by the radioactive decay of rubidium (Rb), specifically  $^{87}\text{Rb}$ . This isotope is also present in geological substrates, and hence

substrates of different ages will have different Rb/Sr ratios and  $^{87}\text{Sr}/^{86}\text{Sr}$  profiles (Faure, Mensing 2005; Bentley 2006). Strontium in the local water, plants and fauna is deposited into the skeleton and tooth enamel by substituting for calcium in apatite crystals formed in consumer tissues. Adult tooth enamel in humans forms during childhood and does not remodel, thus the food and water ingested at the time of tooth enamel mineralisation reflects the  $^{87}\text{Sr}/^{86}\text{Sr}$  profile of where people were living at the time (e.g., Bentley et al. 2004). In order to identify an individual as local or non-local, a baseline for the local geological substrates must be produced. This can be generated using the bone apatite values of the same individual (which equilibrate with local soil during burial) or local plants and soils from the site where the individual was found. If the  $^{87}\text{Sr}/^{86}\text{Sr}$  values of an individual's tooth enamel do not match values of local plants or the bone apatite of the individual themselves, then they are likely to have spent their childhood (the age range depends on the tooth analysed) in a different location.

#### **Materials and methods**

The following section details the methodology by which samples were identified to species, chosen for sampling, prepared and assessed for sample integrity, homogeneity and analytical error. All samples discussed here were taken from seasons 1996–2017.

#### *Carbon and nitrogen stable isotope analysis*

As discussed elsewhere (Mellaart 1967; Andrews et al. 2005; Molleson et al. 2005; Boz and Hager 2013; Haddow et al. this volume, Chapter 15), burial practices at Çatalhöyük included single inhumations as well as multiple and secondary burials, many of which were frequently disturbed. The choice of individuals sampled follows Pearson (2013), but briefly: all individuals were sampled except those that were burnt or represented by only a few elements or fragments; secondary burials, specifically crania, were sampled from the least diagnostic fragments that were clearly associated; pathological conditions were avoided; for multiple burials, care was taken only to sample from elements clearly associated to a particular individual. Age and sex estimation for all human remains follows previous work (Andrews et al. 2005; Molleson et al. 2005; Hillson et al. 2013; Larsen et al. 2013). In contrast to the human remains, animals were sampled at a maximum of c. ten samples per taxa per point of interest (that is, midden or level or building) following Pearson and Grove (2013). Details regarding the species recovery and identification can be found in Russell and Martin (2005), Russell et al. (2013) and most recently, this volume, Chapter 8. All reagents used were Analytical (AR/Analar) Grade or

above and all water used was of ultrapure (18.2 M $\Omega$ ) quality. All bone samples were taken as ~500mg chunks using a diamond powder-coated cutting wheel from the broken diaphysis, avoiding glue, id number, pathological conditions, articulations and cut marks. To prevent lipid contamination, fish samples were subjected to a chemical liquid lipid extraction using 2:1 chloroform:methanol, following the method described in Guiry et al. (2016), prior to collagen extraction. Collagen extraction for all samples follows the modified Longin (1971) method (Brown et al. 1988): samples were immersed whole in a test tube of 0.5M HCl<sub>(aq)</sub> and refrigerated at 4°C. Once the bone was fully demineralised (2–10 days), it was rinsed with ultrapure H<sub>2</sub>O to neutral pH (three rinses). Samples were gelatinised by adding pH3 H<sub>2</sub>O (HCl) and heated at ~70°C for 48 hours in a heater block. The gelatinous solution was then filtered through an 8 $\mu$ m EZee filter, transferred to a plastic test tube and sealed with Parafilm, and frozen before freeze-drying until dry (~48 hours). Once dried the new samples reported here were loaded into tin capsules and combusted online to CO<sub>2</sub> and N<sub>2</sub> in an elemental analyser (Flash/EA) coupled to a ThermoFinnigan Delta Plus XL isotope ratio mass spectrometer via a ConFlo III interface (running in continuous flow mode) which measures the  $\delta^{13}\text{C}$  ratio of CO<sub>2</sub> and the  $\delta^{15}\text{N}$  of N<sub>2</sub>. M1360p (powdered gelatine, British Drug Houses) with expected  $\delta^{13}\text{C}$  values of -20.32‰ (calibrated against CH7, IAEA) and  $\delta^{15}\text{N}$  values of +8.12‰ (calibrated against N-1 and N-2, IAEA) was used as the internal reference standard material. The long-term 1 $\sigma$  reproducibility for internal reference standards is normally better than  $\pm 0.1\%$  for  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ , which represents the measurement precision for this study. We used the following measures to indicate collagen integrity: Atomic C:N ratios between 2.9 and 3.6 (DeNiro 1985; Ambrose 1993); at least 1% collagen yield and elemental yields of 15.3%–47% for carbon and 5.5%–17.3% for nitrogen (Ambrose 1990). Particularly poor preservation was noted amongst the secondary burials, amongst crania especially, and hints at different post-mortem treatment and taphonomic processes, as seen previously (Pearson 2013).

#### *Strontium stable isotope analysis*

All humans were potentially available for sampling; however, there were several caveats that reduced the sample size: samples were to be taken from individuals with a fully mineralised, erupted and little-worn second (M2) or third molar (M3) tooth where the antimer was also present. These criteria confined the sampling to adolescent and adult individuals. Teeth with pathological conditions or developmental disruptions (caries, obvious signs of linear enamel hyperplasia) were also

avoided. This approach allowed for a total of 80 individuals to be selected for strontium isotope measurement. The majority of teeth sampled were the second molar (n=78) and rarely a third molar (n=2). This sample set represents one of the largest studies currently undertaken of adult mobility from a single site and is the largest from Southwest Asia in any time period. Teeth were not exported whole, instead, using a diamond-coated cutting wheel, the roots were completely removed and the crown cut in half. Each tooth was photographed on the occlusal and buccal/lingual surface before sampling. Samples exported, prepared and measured therefore comprised a half crown of an M2 or M3 tooth. Samples were restricted to the Neolithic occupation of the site and were sampled in both the North Area (n=38) and South Area (n=41); a single sample came from the KOPAL environmental trenches excavated between 1996 and 2001 (Boyer et al. 2006). Within this sample, 23 were males/possible males, 33 were females/possible females and 24 have no recorded sex estimation, either because they are too young, or because they were too poorly preserved to enable an accurate assessment.

The enamel deposited on permanent adult human M2 and M3 teeth covers a period of 2.5–8.5 years for M2 and 8.5–14.5 years for M3 (AlQahtani et al. 2010). The first molar (M1) was not selected because of the overlap with breastfeeding, which for the purposes of strontium isotope analysis changes the source water consumed by the individual being analysed, being instead formed from the water ingested by the individual providing breast milk to the nursing infant, which may not be the biological mother. Since breastmilk is formed over a relatively short period of time, breastfeeding might also pass on evidence of group logistical mobility as the mother engages with community activities (see Humphrey 2014 for a review).

Sample preparation follows the method described in Evans et al. (2006). Briefly, tooth enamel was cleaned using high-purity water in an ultrasonic bath and rinsed twice to remove loosely adhered material. The enamel surface of the tooth crown half was abraded to a depth of >100 $\mu$ m and all dentine and cementum removed using a tungsten carbide dental burr. Thin enamel slices were then cut from the tooth using a flexible diamond-edged rotary dental saw. These samples were then transferred to a clean (class 100, laminar flow) working area and cleaned ultrasonically in high-purity water to remove dust, rinsed twice before being dried down in high-purity acetone and weighed into pre-cleaned Teflon beakers. A known amount of <sup>84</sup>Sr tracer solution was added to each sample and dissolved in Teflon-distilled 8M HNO<sub>3</sub>. Samples were then converted to chloride using quartz

distilled in 6M HCl before being taken up in 2.5M HCl. Strontium was separated using conventional, Eichrom®AG50 X8 resin ion exchange methods and loaded onto a single Re Filament with TaF<sub>3</sub>, following the method of Birck (1986). The isotope composition and concentrations were determined by thermal ionisation mass spectroscopy (TIMS), using a Thermo Triton multi-collector mass spectrometer.

**Results and discussion**

A total of 1,507 Neolithic samples are reported here (excluding those presented previously in Richards et al. 2003; Richards, Pearson 2005). All samples were positively identified prior to sampling where practicable. Ovicaprids (sheep and goat bones indistinguishable from one another) were not sampled; however, the equids reported here are comprised of two species (see below) and were included because the post-cranial remains cannot currently be differentiated (Russell, Martin 2005; Russell et al. 2013; Twiss et al. this volume, Chapter 8). A total of 520 samples failed to yield sufficiently well-preserved collagen, leaving an overall dataset of 987. The samples were taken from the full range of occupation levels across the North, South, TP/TPC and KOPAL Areas with the following failure rates broken down by area (table 11.2).

Area	Samples (n)	Failures (n)	Failure rate (%)
North	436	169	39
South	756	180	24
TP/TPC	298	169	57
KOPAL	17	2	12
Total	1,507	520	35

Table 11.2. Collagen extraction failure rate by excavation area.

Genus/Species	Samples (n)	Failures (n)	Failure rate (%)
<i>Bos</i>	313	162	52
<i>Canis</i>	30	6	20
<i>Capra</i>	50	13	26
Deer	19	6	32
Equid	101	56	55
<i>Lepus</i>	3	0	0
<i>Ovis</i>	352	117	33
<i>Sus</i>	47	15	32
<i>Vulpes</i>	25	3	12
Birds	72	0	0
Fish	5	3	60

Table 11.3. Failure rate by genus/species.

*Carbon and nitrogen stable isotope analysis: animal*

A total of 493 faunal samples (including 118 failures) were reported in Pearson (2013). These data are supplemented here with an additional 494, giving an overall total of 987 faunal samples for the duration of the

project (Pearson 2004; 2013). Failure rate (averaged at 35%) is greatest in the upper levels of occupation (table 11.2) and amongst the larger mammals especially the *Bos* spp. and Equids (table 11.3).

Genus	N	$\delta^{13}C\text{‰}$ (VPDB)					$\delta^{15}N\text{‰}$ (AIR)				
		Min	Max	Range	Mean	s.d.	Min	Max	Range	Mean	s.d.
<i>Ovis</i> sp.	235	-21.0	-13.6	7.4	-17.6	1.3	4.9	14.4	9.5	10.2	1.7
<i>Capra</i> sp.	37	-19.8	-12.6	7.2	-17.8	1.5	5.2	15.2	10.0	9.5	2.4
<i>Bos</i> spp.	151	-20.6	-14.6	6.0	-18.2	1.0	6.0	14.8	8.8	10.1	1.6
<i>Equus</i> spp.	56	-19.9	-14.5	5.4	-19.0	0.9	4.8	11.3	6.5	8.4	1.5
<i>Sus</i> sp.	32	-21.3	-15.3	6.0	-19.5	1.2	5.1	11.9	6.8	8.0	1.9
<i>Vulpes</i> sp.	21	-20.7	-15.3	5.4	-17.8	1.3	4.6	15.0	10.4	11.3	2.9
<i>Canis</i> spp.	23	-21.3	-16.3	5.0	-18.4	1.5	7.7	15.0	7.3	11.5	1.6
<i>Canis lupus</i>	1	-	-	-	-14.3	-	-	-	-	16.8	-
<i>Cervus</i> sp.	12	-21.2	-14.1	7.1	-19.0	1.9	4.0	13.8	9.8	7.9	2.4
<i>Lepus</i> sp.	3	-20.4	-18.7	1.7	-19.3	1.0	3.5	6.6	3.1	4.9	1.6
Birds	71	-25.0	-14.5	10.5	-20.2	2.3	3.6	13.4	9.8	9.1	2.0
Fish	2	-23.4	-22.5	0.9	-23.0	-	7.7	8.6	0.9	8.2	-

Table 11.4. Final summary carbon and nitrogen isotope data from fauna bone collagen (data taken from Pearson 2013 and incorporating new data discussed here), with additional categories: birds and fish. Not listed: one *Dama*:  $\delta^{13}C$ : -18.9 ‰;  $\delta^{15}N$ : 6.2 ‰; and one *Ursus*  $\delta^{13}C$ : -19.6 ‰;  $\delta^{15}N$ : 6.7 ‰.

*Bos spp.* The results of 151 *Bos spp.* samples are given in figures 11.1 and 11.2 and these data are summarised in table 11.4. The  $\delta^{13}\text{C}$  values range from  $-20.6$  to  $-14.6\text{‰}$  (6.0‰ range), and in  $\delta^{15}\text{N}$  from 6.0 to 14.8‰ (8.8‰ range), with mean values of  $-18.2\text{‰}$  and 10.1‰ in carbon and nitrogen, respectively. These additional data provide a new lower end in carbon isotope values of  $-20.6\text{‰}$ . However, these extra 72 samples have only altered the mean by 0.1‰. For nitrogen the lowest value remains unchanged, but the highest value has now increased by 1‰, and this has affected the mean by 0.3‰.

The range in carbon and nitrogen values remains relatively small when compared with the caprines. In terms of diet, these data suggest a small contribution of  $\text{C}_4$  plants in some animals' food. The poor preservation of *Bos* remains, especially in the North Area, has prevented a systematic examination of variation between the two areas of the mound, and while the North Area specimens do cluster together, this may be an artefact of sample size (data not shown).

Figure 11.2 shows the *Bos* species over time.  $\text{C}_4$  plant consumption seems to be a feature of diets in the earlier and later levels of the site (compare also fig. 11.1), with the Middle period showing few animals with a  $\text{C}_4$  plant input in their food.

*Ovis spp.* The sheep (the most abundant number of identified macrofauna) measured still represent the largest dataset for a single species from an archaeological site. Previously, the dataset totalled  $n=154$  and was used to model the impact of sample sizes in general (Pearson, Grove 2013). This chapter adds a further 85 specimens (fig. 11.3). In terms of the range of stable isotope values at the site, these extra samples have had very little impact on the mean values (compare data in table 11.2 with table 11.4). The mean carbon isotope values shift by 0.1‰ but with a new lower end value of  $-21.0\text{‰}$  and the upper end remaining unchanged at  $-13.6\text{‰}$ . This gives an increased overall range of 7.4‰. These additional data now illustrate that sheep have the largest carbon isotope range for an individual species. The nitrogen isotope value mean of 10.2‰ represents an increase of 0.1‰ but with a range of values that remains unchanged (9.5‰). These variations are within machine error and thus suggest that overall this species' mean data remain essentially unchanged by these additional samples. Sheep no longer have the largest nitrogen isotope range, being overtaken by new samples for both fox and *Bos* (discussed below). Much of the carbon isotope value range is due to the consumption of  $\text{C}_4$  plants, which in some animals is

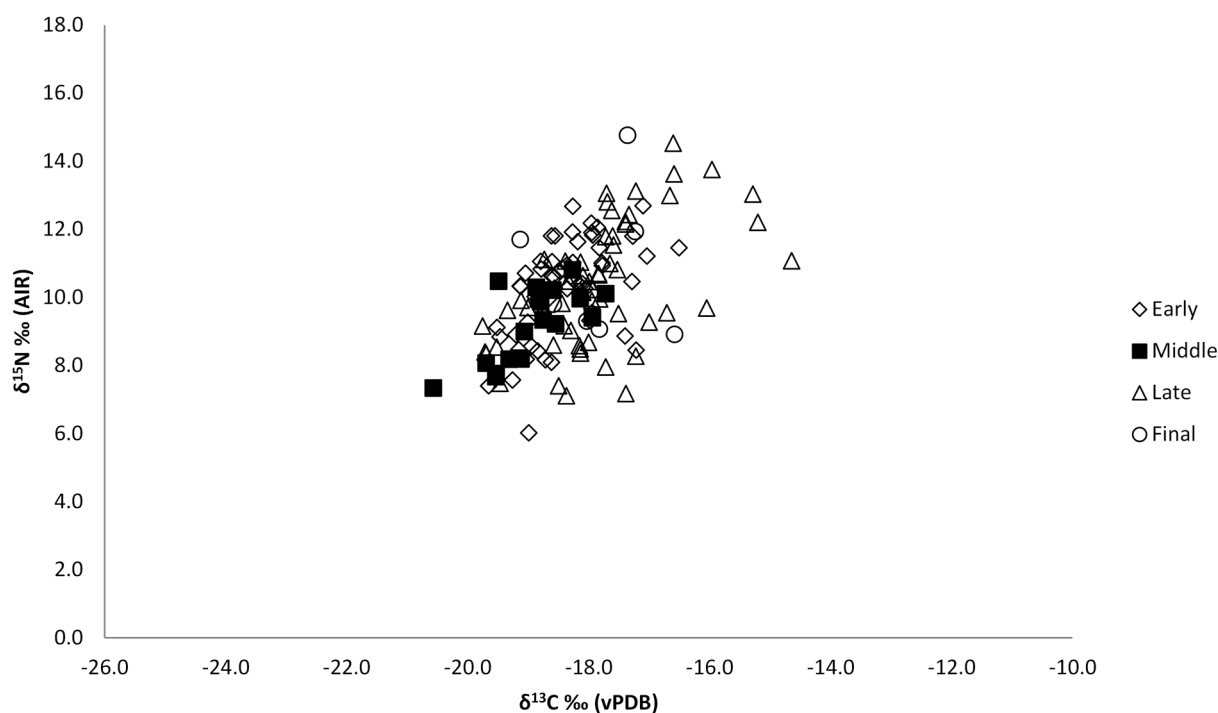


Figure 11.1. *Bos sp.* carbon and nitrogen isotope data plotted by excavation area.

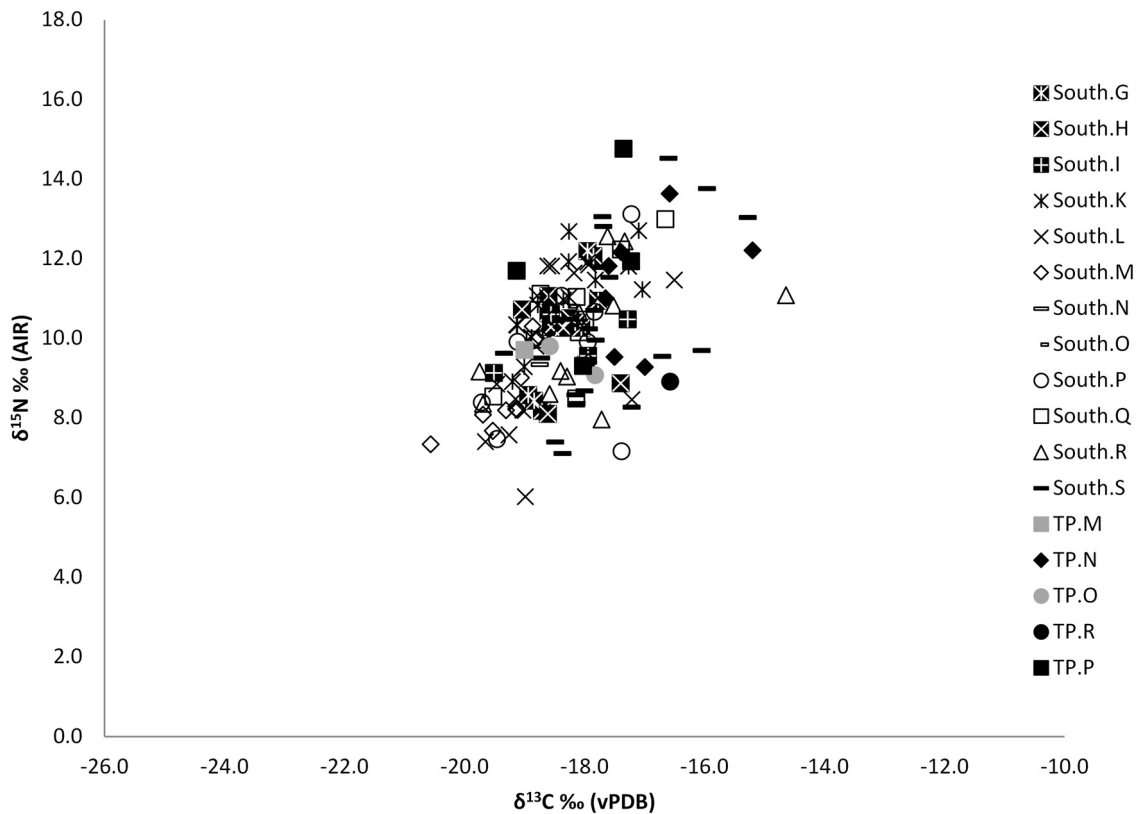


Figure 11.2. *Bos sp.* plotted according to individual occupation level in the South and TP Areas ( $n=131$ ).

substantial. The mechanism behind this differential consumption by the domestic sheep has been discussed elsewhere as being an anthropogenic effect of sheep management (Pearson et al. 2007; Pearson 2013) and other evidence from the site corroborates these data as indicative of  $C_4$  plant consumption by direct evidence for consumption in the form of  $C_4$  plant seeds in burnt animal dung (Bogaard et al. 2013). The presence of  $C_4$  plant-containing dung on site also suggests this food resource must have been relatively close to the site, potentially in reasonable quantity at certain times of the year (that is, late summer).

In previous work, much of the isotope variation was confined to the South Area. This was largely due to the small sample size available for the North Area ( $n=16$ ) (Pearson 2013: fig 13.5). These data are now supplemented by a further 19 individuals. The North Area fauna are poorly preserved compared with the South Area, and this partly accounts for a relatively smaller sample size. The TP excavations (adjacent to the South Area) suffer from a similar problem. The TP and North Areas are much shallower than the South Area, thus it seems likely that recovery of bone from the deeper excavations affords better organic preservation. The additional samples in both the TP and North Areas expand the sample set at the lower end for both

isotopes, and at the top end for nitrogen isotopes, adding new individuals with lower carbon isotope values than have been seen previously, although this has no major impact on the overall site mean (see above).

A finding in previous work (Pearson 2013) identified that part of the isotope variation was caused by higher isotope values over time, except for the sheep, which seem to show a 'reflux' in diet where both isotope values are higher in the earliest (Level South G) and latest (Level South T) levels. The additional 85 specimens corroborate this finding, suggesting that in the Middle period sheep management was different to the preceding and successive practices. The isotope data in the Middle period may indicate wetter and cooler conditions in the landscape in general, or the use of a specific zone with much reduced access to  $C_4$  plants.

This change may indicate a response to climatic or environmental change, forcing herders to graze their animals in a different part of the landscape or the rescheduling of activities to new zones (fig. 11.4).

Figure 11.5 shows the sheep plotted by individual levels and illustrates that  $C_4$  consumption (animals with carbon isotope values higher than  $-17.8 \text{ ‰}$ ) is apparent particularly in the earlier and later levels of the site, a feature also of *Bos* diet (figs 11.1 and 11.2).

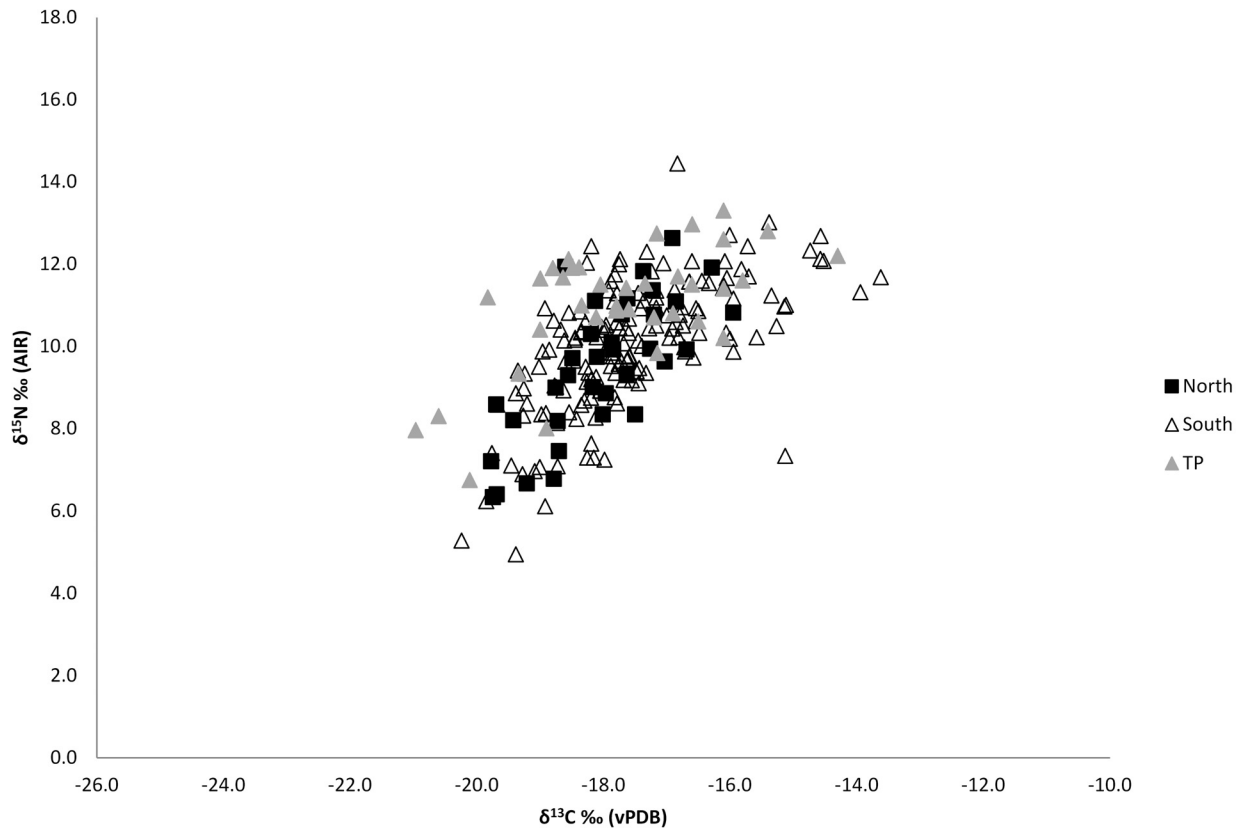


Figure 11.3. *Ovis spp.* carbon and nitrogen isotope data plotted by excavation area.

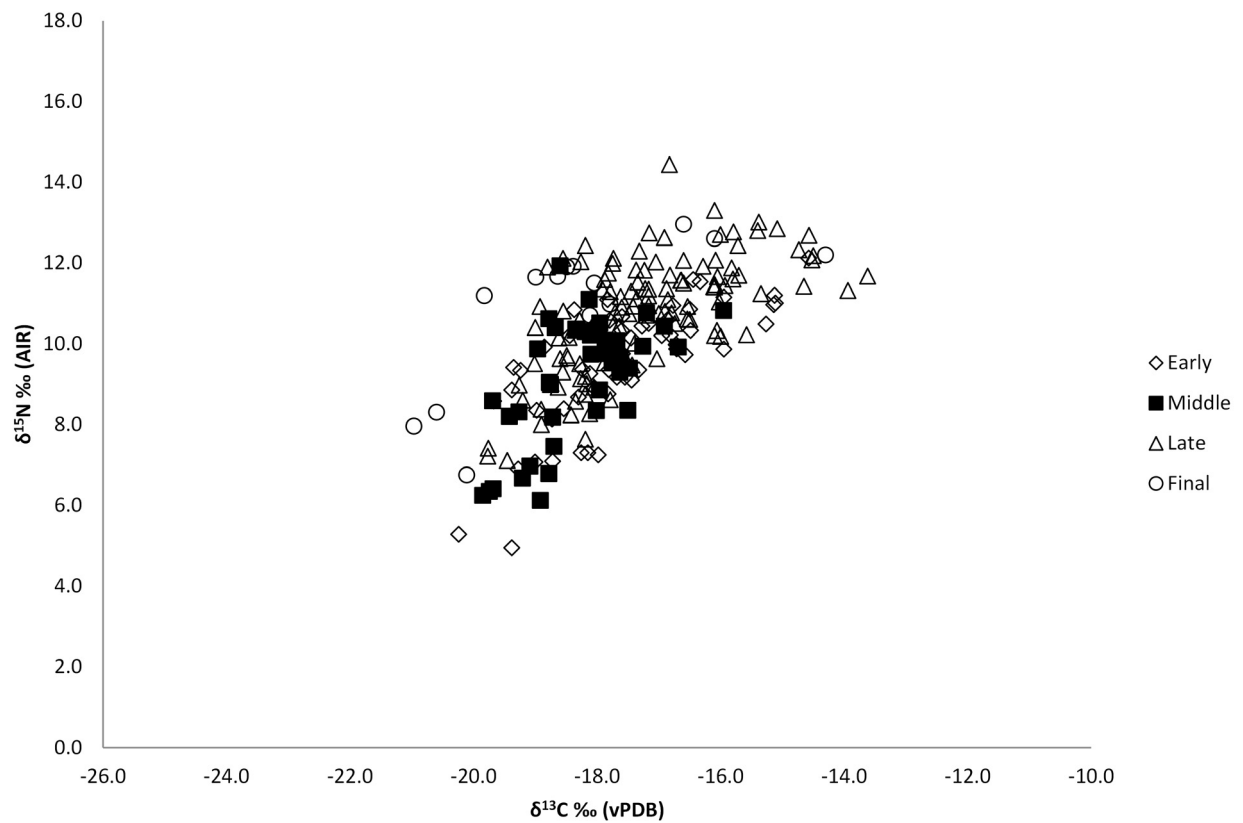


Figure 11.4. *Ovis spp.* plotted according to broad occupation period ( $n=184$ ).



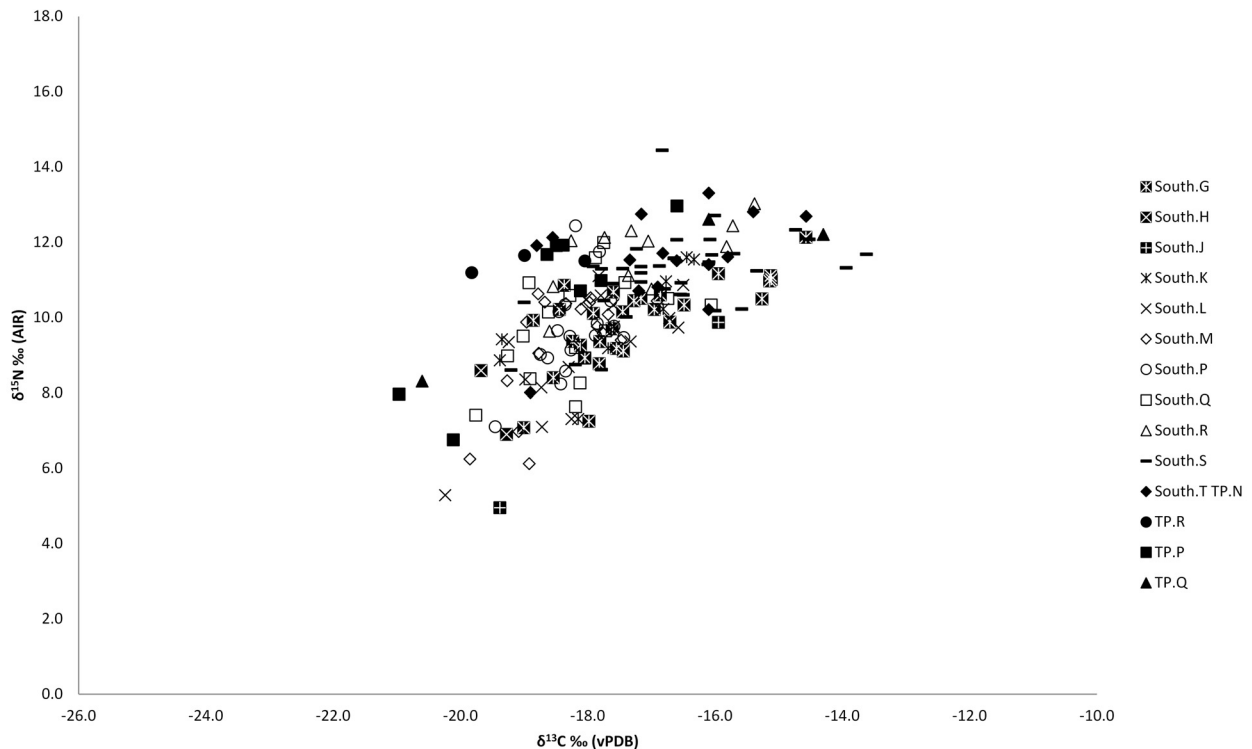


Figure 11.5. *Ovis spp.* plotted according to level in the South and TP Areas ( $n=184$ ).

*Capra spp.* In addition to the 22 individuals previously measured, a further 15 specimens of goat have been added (fig. 11.6). Goats remain a rarely exploited species at the site, being vastly outnumbered by sheep in terms of identified specimens, and cattle/aurochs too when meat volume is considered (Twiss et al. this volume, Chapter 8). These additional samples shift the mean, maximum, range and standard deviation values by just 0.1‰, although the range is no longer the largest at the site (table 11.4). The number of  $C_3/C_4$  plant consumers has increased, with a large quantity of  $C_4$  plants identified in a small number of additional animals. The nitrogen isotope values have been affected by the additional samples, with the range now covering between 5.2‰ and 15.2‰, a range of 10‰. These data also increase the mean to 9.5‰, which brings this species closer to *Bos* and *Ovis* species averages and subsequently has not alleviated the difficulty in establishing the relative importance of all three species to human diet. The temporal variation is based on only a small number of samples in the Middle period, but again these data seem to show lower values for both isotopes, with none of the individuals from this period seeming to consume  $C_4$  plants (fig. 11.6).

This suggests a similar scenario to the sheep, depending upon whether individual animals are domestic or wild and whether the Middle period represents responses to climatic, environmental or socio-political change, altering how herders managed and/or

hunted the animals they consumed. The individuals from the Middle period that are affected by a transition in behaviours are one individual from Level South M and three from Level North G.

*Equids.* A further 11 equids can be added to the original 45 specimens (fig. 11.7). It should be noted that this group is represented by two species (*Equus ferus* and *Equus hemionus*), which cannot be distinguished between based on postcranial bone sampled here. Again the extra samples make only a small difference to the previously reported values (Pearson 2013). The  $\delta^{13}C$  values are from -19.9‰ to -14.5‰ (5.4‰ range), and in  $\delta^{15}N$  from 4.8‰ to 11.3‰ (6.5‰ range), with mean values of -19.0‰ and 8.4‰ in carbon and nitrogen, respectively. The two taxa comprised of 56 specimens still have a smaller range in isotope values compared to key ruminants. The diets of these animals remain dominated by  $C_3$  grasses, in stark contrast to the sheep, goats and cattle. This might give a clue as to the ‘natural’ grazing available for animals free to roam and point to the small but consistent role of  $C_4$  plants in animal management and herding.

The three animals with a small  $C_4$  plant contribution and one other with a larger portion in their diet were reported previously (Pearson 2013). In terms of considering the management of the other species, there is no shift in diet in the Middle period for equids,

suggesting that the shifts seen in the sheep, goats and cattle may point to any change in this period of occupation being the result of anthropogenic factors. In contrast, the equids show a different dietary pattern in the Late period of occupation, which may reflect a shift

to different equid hunting grounds, where a greater quantity of C<sub>4</sub> grasses were consumed by animals living there. The C<sub>4</sub> consumers appear in Levels South S and R, with no C<sub>4</sub> plants in the diet in the early levels (unlike the sheep).

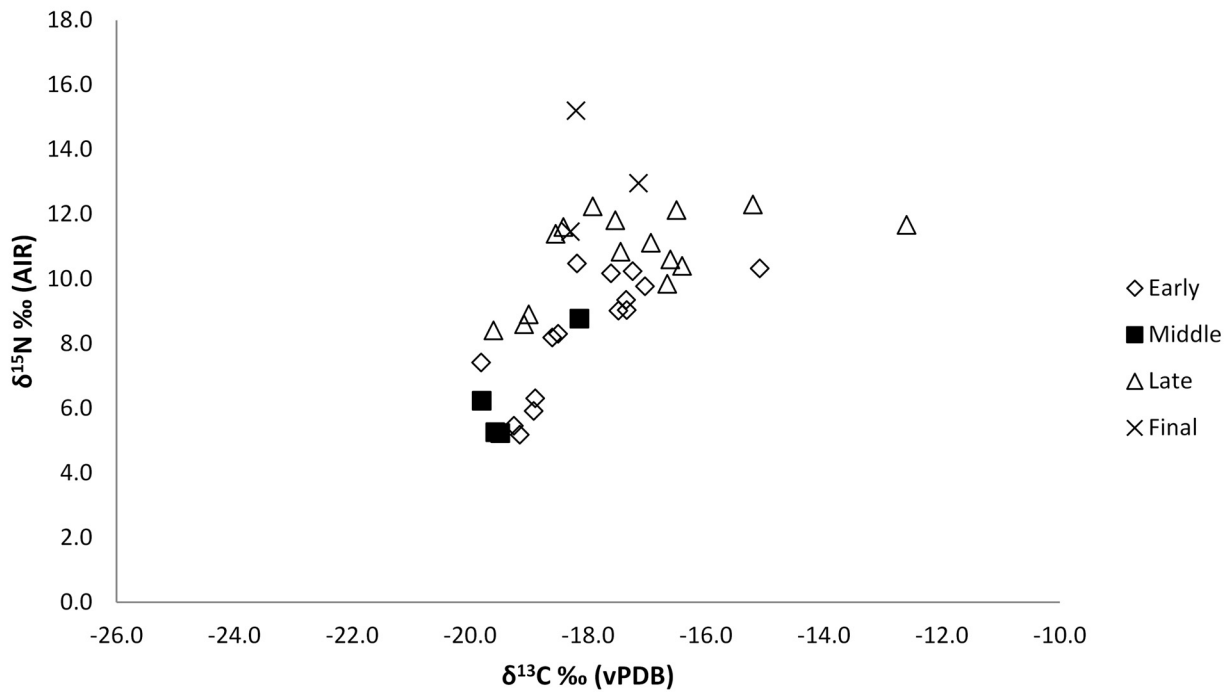


Figure 11.6. *Capra sp.* plotted according to broad occupation period in all areas (n=37).

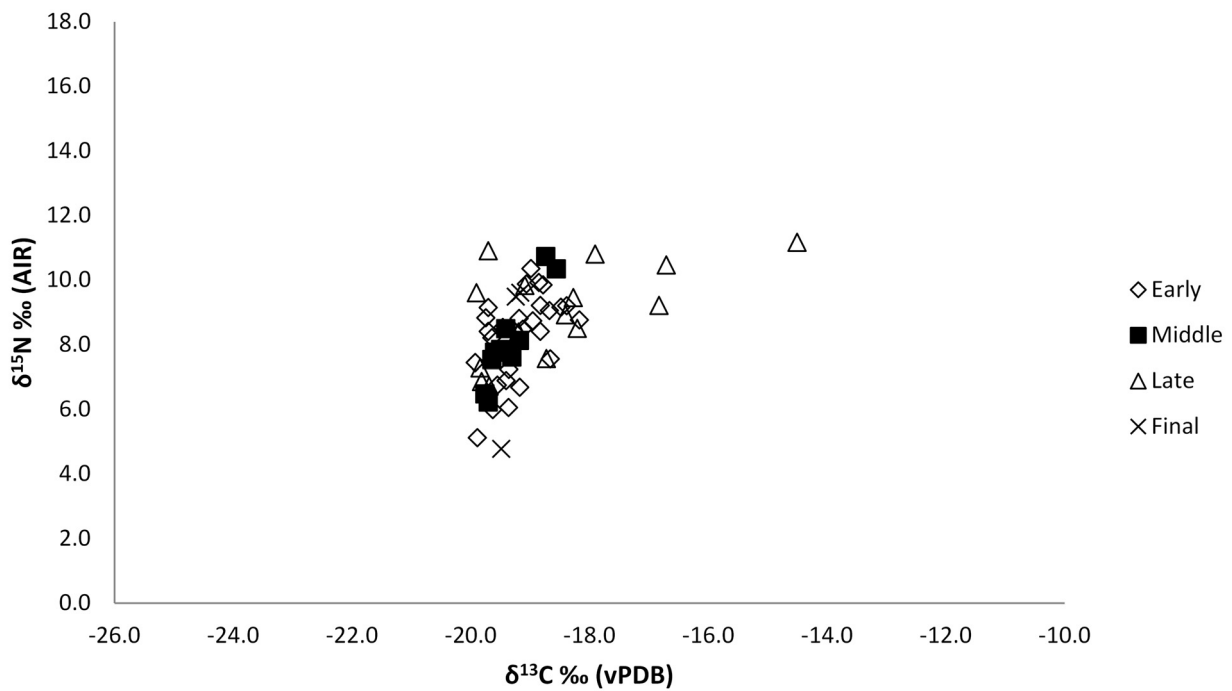


Figure 11.7. *Equids* plotted according to broad occupation period in all areas (n=56).

*Boar.* A further four samples can be added to the existing dataset, leaving an overall total of 32 measured specimens (fig. 11.8). Most of the samples came from the South Area. The carbon isotope values for the taxa remain unchanged:  $-21.3\text{‰}$  to  $-15.3\text{‰}$  ( $6.0\text{‰}$  range), but the nitrogen isotope values have a new lower end of  $5.1\text{‰}$ , leaving an overall range of  $5.1$  to  $11.9\text{‰}$  ( $6.8\text{‰}$  range), with no effect on the mean values, which remain  $-19.5\text{‰}$  and  $8.0\text{‰}$  in carbon and nitrogen respectively.

The presence of  $C_4$  plants in wild boar diet remains an unexpected finding.  $C_4$  plant taxa are almost exclusively restricted to the grass and sedge families and have a relatively higher silica and fibre content compared to  $C_3$  plants, as described earlier. The preferred habitat of wild boar in wetter and shaded areas of the landscape would seem to exclude zones where  $C_4$  plants might flourish – more open, drier areas – from being areas that wild boar might visit for food, and yet some of the specimens have a significant component of this resource in their diet. This apparent signature may have been acquired through the consumption of a lower/adjacent-trophic level  $C_4$  plant consumer, which may have included leftovers from human foods or an as yet unmeasured resource. The appearance of  $C_4$  plants only occurs during the Late period (Level South S), similar to equids described above. However, since there are no  $C_4$  plants eaten by

humans present at the site, the hypothesis that the  $C_4$  input in boar was through leftover human foods seems unlikely. Similarly, the mean  $\delta^{15}\text{N}$  value of  $8.0\text{‰}$  is  $4\text{‰}$  lower than humans and thus instead seems to point to a food not consumed at the site.

*Carnivores.* The results of 46 samples including 18 new samples from the Carnivora family (*Vulpes vulpes*  $n=21$ , *Canis* sp.  $n=23$ , and *Canis lupus*  $n=1$ , *Ursus* sp.  $n=1$ ) are given in figure 11.9.

These species show a broad range of both carbon and nitrogen isotope values, suggesting that diets varied between the different species. Overall the mean values for this order are  $-18.1\text{‰}$  and  $11.4\text{‰}$  with a range of  $-21.3$  to  $-14.3\text{‰}$  ( $7\text{‰}$  range) in carbon and  $4.6$  to  $16.5\text{‰}$  ( $11.9\text{‰}$  range) in nitrogen. These ranges serve as an illustration for the potential range of different meat-eating taxa and help to bookend the values that might be expected in humans. The mean nitrogen isotope value for the order overall is surprisingly low given the combined mean for sheep, goats and cattle ( $9.9\text{‰}$ ) and adult humans ( $12.3\text{‰}$ ). This suggests a range of trophic level foods in the diet of the site's carnivores, and while the lower nitrogen isotope value relative to humans might suggest *more* plants in their diet, the very high nitrogen isotope values in the site's cereals (Bogaard et al. this volume, Chapter 5) may be the cause of high nitrogen

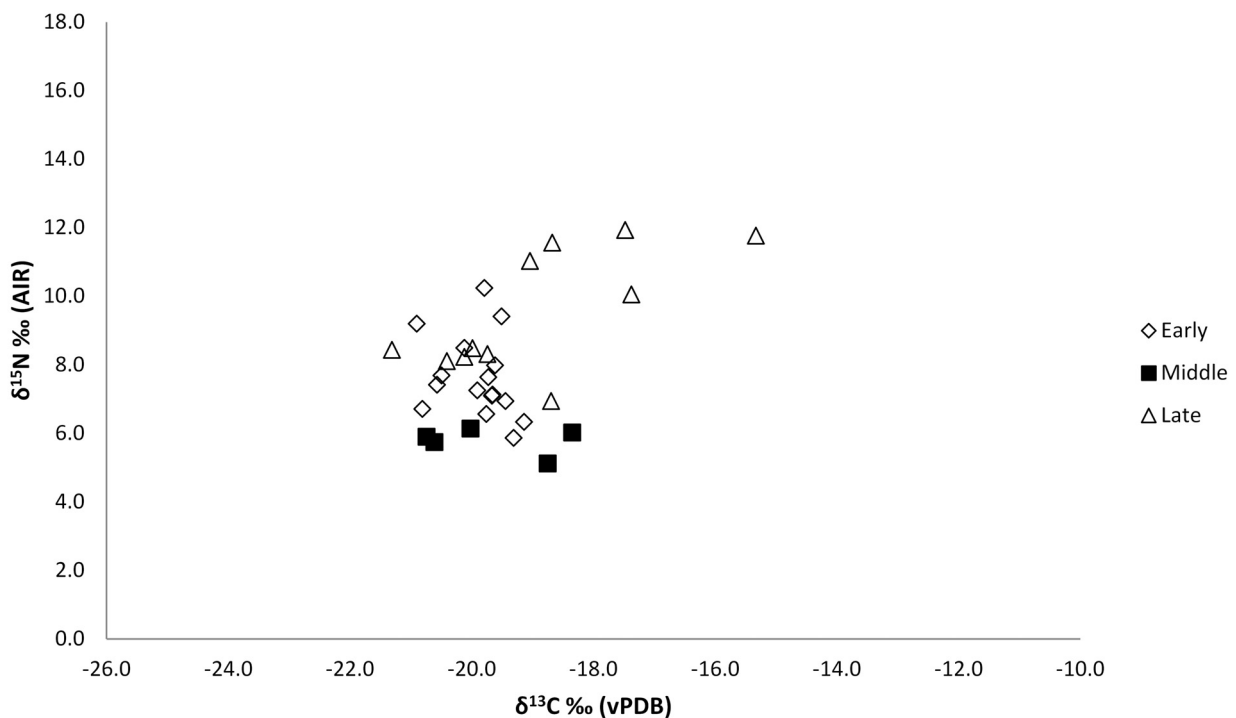


Figure 11.8. Boar plotted according to broad occupation period in all areas ( $n=32$ ).

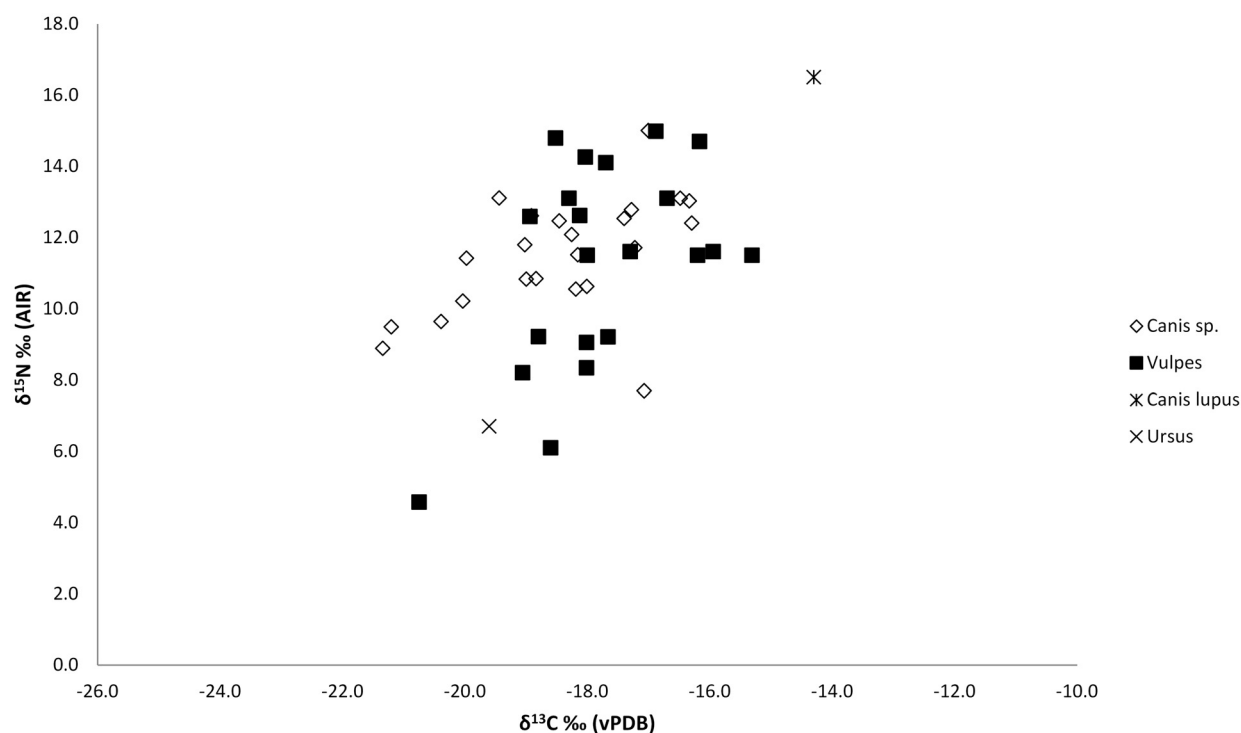


Figure 11.9. Carnivora plotted according to species in all areas (n=47).

isotope values in humans. The carnivore carbon isotope values are higher than for humans by 0.7‰, almost one trophic level, which suggests a different source of low trophic-level foods in their diet. This perhaps indicates consumption of the meat-based human foods, perhaps parts of animal carcasses considered less desirable, but not human plant-based foods such as breads or gruels. As discussed elsewhere, dogs, wolves, foxes and bears will consume smaller animals such as insects, smaller mammals, birds and eggs, which may also explain the difference between these animals and humans, despite their omnivorous physiology. For individual genera and species, the additional five *Canis* sp. specimens result in no changes to the  $\delta^{13}\text{C}$  value, which remains  $-21.3\text{‰}$  to  $-16.3\text{‰}$  (5‰ range) and mean of  $-18.4\text{‰}$ .

The  $\delta^{15}\text{N}$  values now range from 7.7‰ to 15.0‰, a new range of 7.3‰ and a new mean of 11.5‰. For *Vulpes vulpes* with 13 new values, the range has now increased in  $\delta^{13}\text{C}$  value from  $-20.7$  to  $-15.3\text{‰}$  with a new mean of  $-17.8\text{‰}$ , and in nitrogen the new lower end of the range is 4.6‰ with the same upper end 15.0‰, resulting in a slightly different new overall mean of 11.3‰. In terms of temporal change, figure 11.10 illustrates these taxa according to the broad occupational periods. Again, as illustrated with other fauna, the consumption of foods with the highest carbon and nitrogen values occurs in the later periods.

*Other mammals: Cervus and Lepus.* Five additional deer (four *Cervus* sp. and one *Dama* sp.) can now be added to the 11 samples previously discussed (Pearson 2013). Although based on a small number of individuals, these taxa offer an insight into the diets of true wild herbivores. There are now 12 *Cervus* sp. samples (fig. 11.11), which have a slightly larger range than the previous work (Pearson 2013).

The carbon isotope values now range from  $-21.2\text{‰}$  to  $-14.1\text{‰}$  (7.1‰ range) with a new mean of  $-19.0\text{‰}$ , and in nitrogen isotope values from 4.0‰ to 13.8‰ (9.8‰ range) with a new mean of 7.9‰. The *Dama* sp. specimen ( $\delta^{13}\text{C}$   $-18.9\text{‰}$ ;  $\delta^{15}\text{N}$  6.2‰) sits towards the lower end of the nitrogen isotope range for *Cervus* sp. The *Lepus* sp. samples reported previously (Pearson 2013) remain the species with lowest  $\delta^{15}\text{N}$  values.

All animals except two of the *Cervus* specimens have  $\text{C}_3$ -plant dominated diets. The presence of  $\text{C}_4$  plants is surprising given their ecological preference for a wooded environment, although perhaps this illustrates the presence of  $\text{C}_4$  plants in mixed zones of woodland and grassland vegetation, or relatively close to woodland. Figure 11.12 shows these taxa according to the broad chronological periods at the site. Again, animals with a significant  $\text{C}_4$  component to their diet came from the later periods of occupation at the site (Levels South Q and South S).

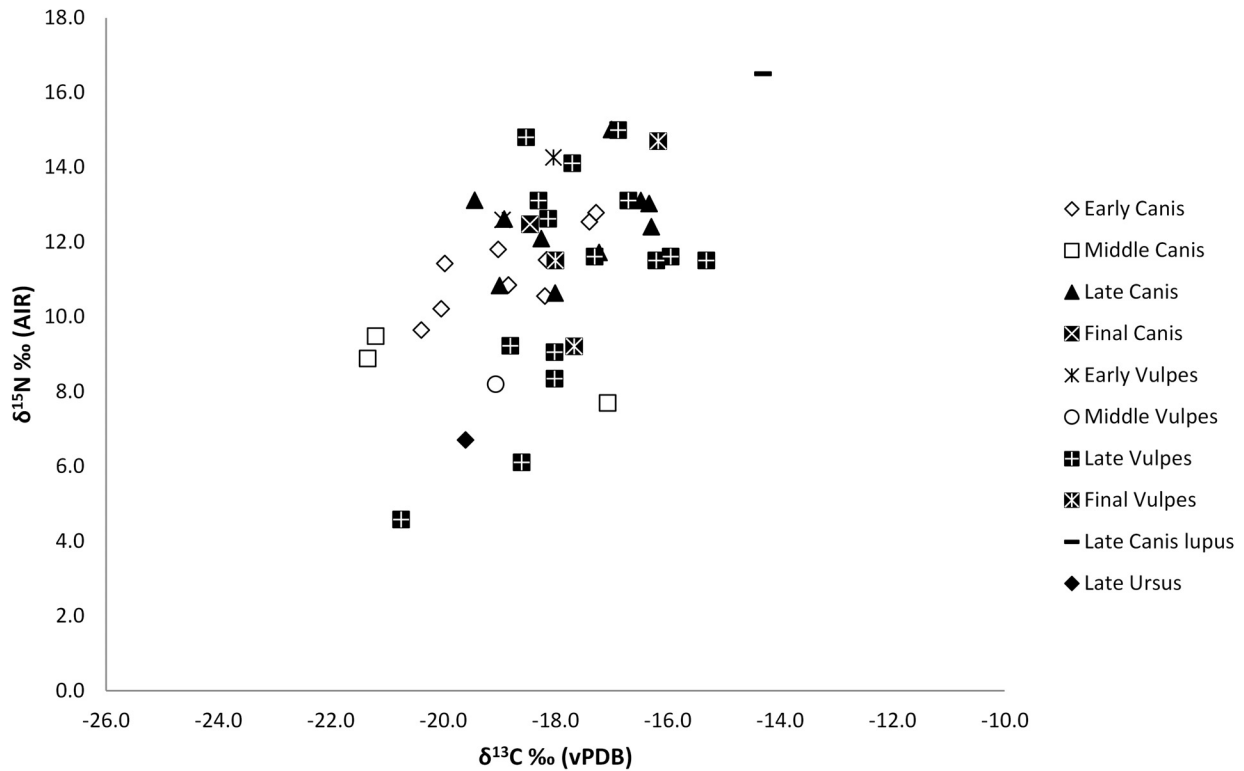


Figure 11.10. Carnivora plotted according to broad occupation period in all areas (n=46).

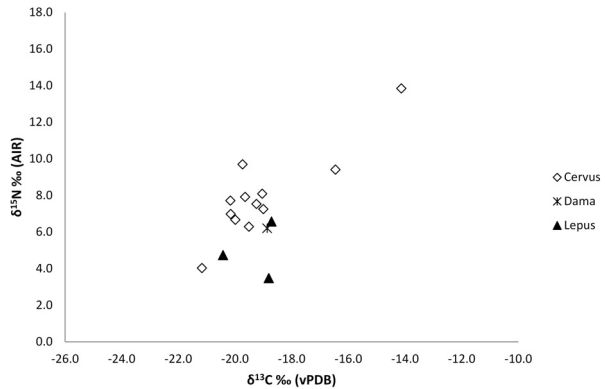


Figure 11.11. Wild herbivores plotted according to species in all areas (n=16).

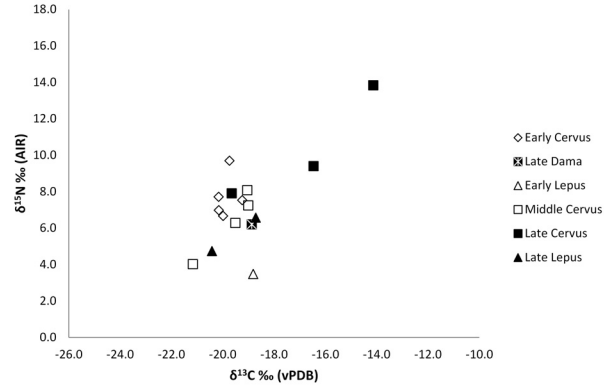


Figure 11.12. Wild herbivores plotted according to broad occupation period in all areas (n=16).

*Birds (with contributions by Nerissa Russell).* Figure 11.13 shows the first Neolithic data from Çatalhöyük birds. Previous work identifying and studying the skeletal remains (Russell, McGowan 2005; Russell 2019a; 2019b; see also Best et al. this volume, Chapter 13) indicates that the inhabitants acquired birds predominantly for their feathers rather than their meat. The majority of the birds recovered were wetland taxa, with Great bustard being the main species exploited from steppic zones. Geese and ducks are common,

particularly Greater and Lesser White-Fronted Goose, which may have been taken for feathers, but also the Greylag goose, which would have been a locally breeding species and was exploited for meat. The most common ducks were Mallard, Common Pochard and Tufted Duck, which would have been around the site for much of the year.

The Mallards and other *Anas* spp. specimens seem to have been more important for feathers, as were storks, but the Common Pochard and Tufted Duck and

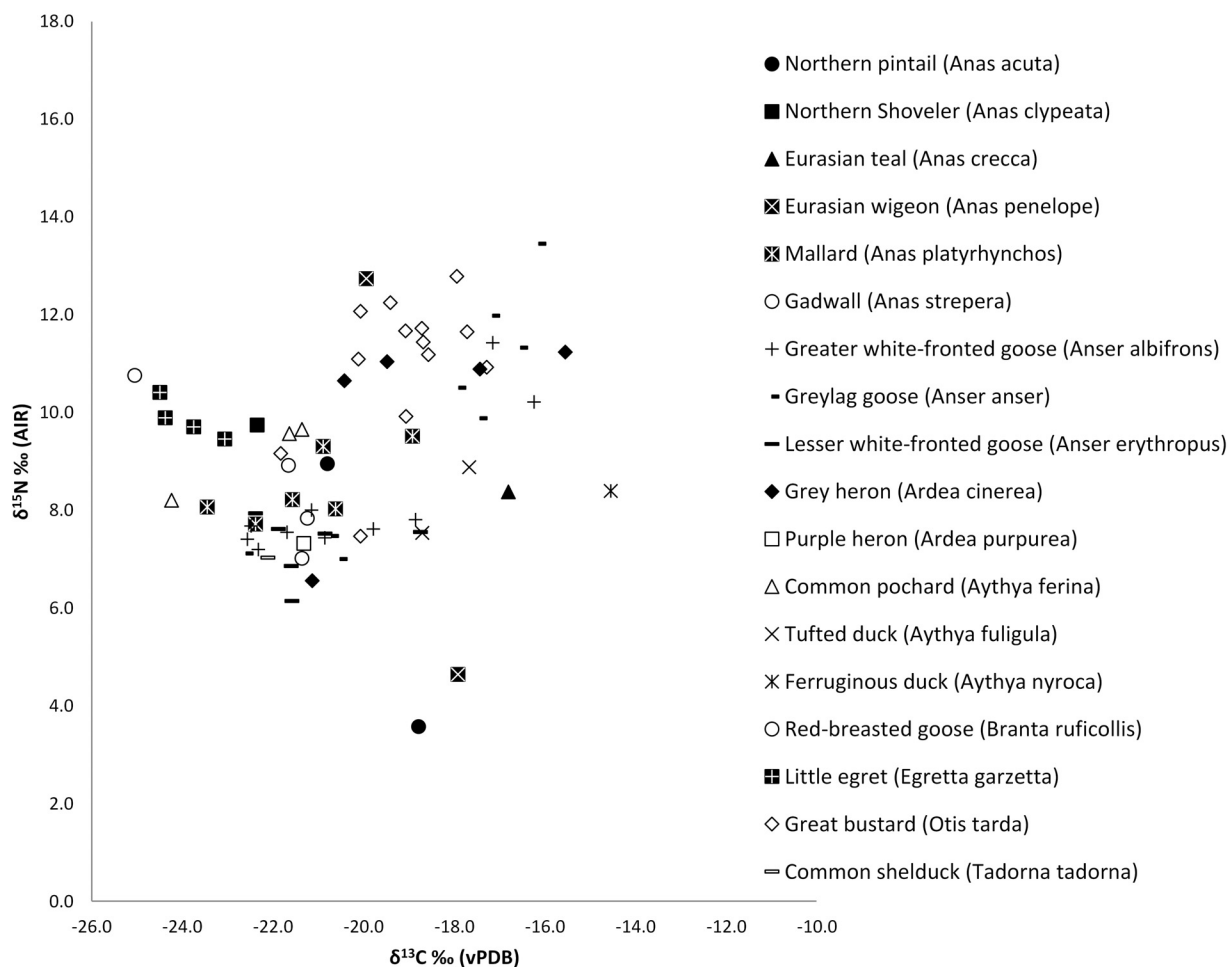


Figure 11.13. Wetland and terrestrial birds plotted according to species in all areas ( $n=71$ ).

other *Aythya* spp. were likely important sources of food, as were grebes. Of the wading birds, herons are numerous and would have been local residents all year round. The body-part representations indicate that while wings were the focus of some individuals, others, including the Little Egret, were eaten. Cranes seemed to be more important for their wings and feathers (Russell, McGowan 2003). Overall, the 71 birds reported here, which are comprised of 18 species, have  $\delta^{13}\text{C}$  values ranging from  $-25.0\text{‰}$  to  $-14.5\text{‰}$  (10.5‰ range), with an average of  $-20.2\text{‰}$ , and  $\delta^{15}\text{N}$  values ranging between  $3.6\text{‰}$  and  $13.4\text{‰}$  (9.8‰ range) and an average value of  $9.1\text{‰}$ .

Of the 18 species measured and discussed here, those of dietary importance to the inhabitants include: the Greylag goose, diving ducks (*Aythya* spp.), grebes and spoonbills, herons, Great bustard and coots, while seemingly obvious species including Mallard were not apparently consumed (Russell 2019a). Food versus feather birds (following Russell 2019a; 2019b), are plotted in figure 11.14.

Figure 11.15 does not appear to show any variation in bird diets across major occupation periods; that is, Early and Middle versus Late and Final. This may also be the result of small sample size of multiple species across multiple periods of occupation.

*Fish (with contributions by Wim Van Neer and Wim Wouters).* Fish at the site are dominated by cyprinids and loaches measuring up to 15cm in length (see also Hamilton-Dyer this volume, Chapter 12). Selecting the samples was difficult because of the large starting weight required, and this resulted in only a handful of contexts yielding sufficient volumes of fish bone identified to family or species to be identified for measurement. The two fish samples reported here include one from the genus *Pseudophoxinus* spp. ( $\delta^{13}\text{C} -23.4\text{‰}$ ;  $\delta^{15}\text{N} 7.7\text{‰}$ ) and another from the Cyprinids, which were also abundant but could only be identified to family level. The one sample of this family gave the following values: ( $\delta^{13}\text{C} -22.5\text{‰}$ ;  $\delta^{15}\text{N} 8.6\text{‰}$ ). Overall this gives a mean value for fish of  $-23.0\text{‰}$  and  $8.2\text{‰}$  in carbon and

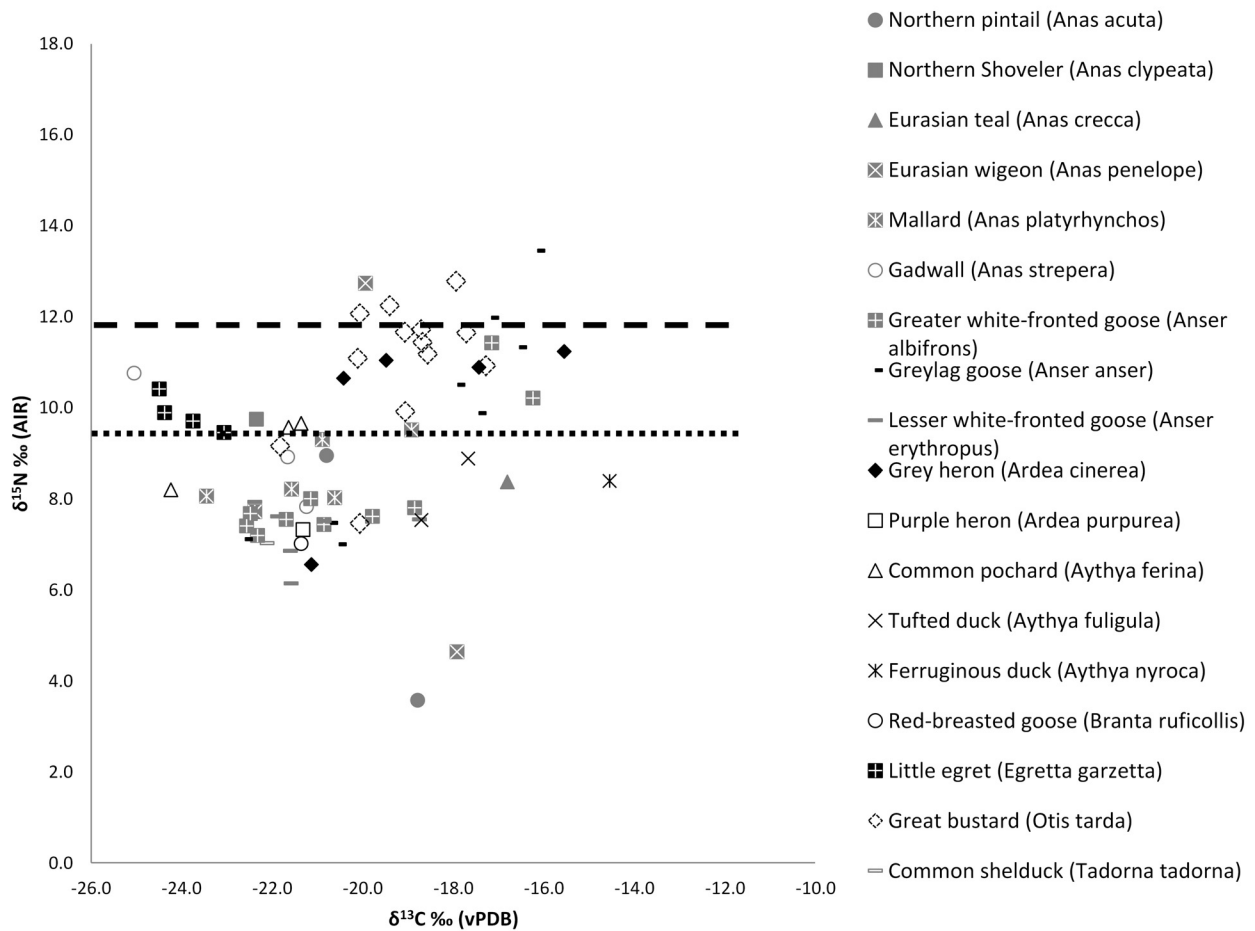


Figure 11.14. Bird species plotted according to their food (black) or feather (grey) importance (n=71) with the dashed line representing the mean  $\delta^{15}\text{N}$  value of terrestrial birds, and the dotted line representing the mean value of all  $\delta^{15}\text{N}$  aquatic birds.

nitrogen respectively. This mean is lower by ~1‰ in both isotopes compared to the mean for all the birds. The carbon values for birds and fish together suggest that any freshwater aquatic consumer would have relatively lower carbon isotopes values compared to a food derived from terrestrial mammals. In terms of understanding the role of aquatic species through trophic level shifts, the isotope values for freshwater resources generally lie between the ruminants and the equids and suids.

*Synthesis of faunal data by area and occupation period.*  
In conclusion, the final results from the faunal remains have shown that the potential for isotope variation amongst the range of domestic and wild animals is large, and within species of sheep, goat, cattle, foxes and red deer the nitrogen isotope range is between 8 and 10‰. While this might be expected for carnivorous or omnivorous species transcending trophic levels as they adapt their diet to food available, this range is more difficult to

explain amongst domestic and wild herbivores. The likely explanation is the variety of hunting and herding zones used and how these link with other socioeconomic systems that demand movement around the local and more distant landscape. The repeated wetting and drying of the basin soils also likely contributes to elevated nitrogen isotope values in this area, as well as a potential manuring signal being passed through the food chain. The range in carbon isotope values is largely due to the presence of both  $\text{C}_3$  and  $\text{C}_4$  plants in the immediate environment.  $\text{C}_4$  plant consumption is seen in a surprisingly large range of species including sheep, goat, cattle, equids, suids, foxes, dogs, wolf, red deer and some birds. But these plants only made a significant contribution to the diet of sheep, goats and cattle, and only a few specimens amongst the other species. The link between high nitrogen isotope values and  $\text{C}_4$  consumption still stands, and is yet to be resolved through direct measurement of nitrogen isotope values in  $\text{C}_4$  plants. As

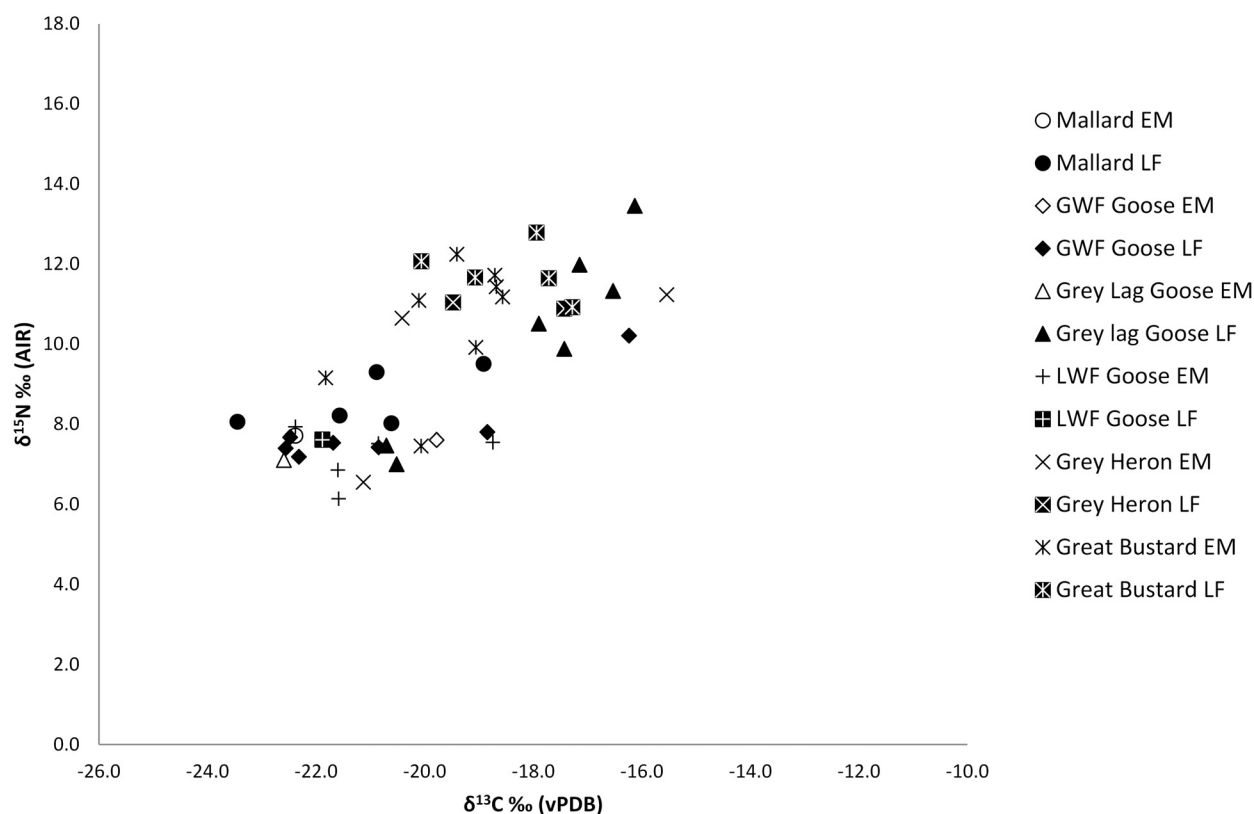


Figure 11.15. Bird species plotted according to the broad periods of occupation (Early-Middle versus Late-Final).

also discussed in Pearson (2013), there is a hiatus in the presence of  $C_4$  consumers, with evidence of such diets occurring generally in the early levels and late levels, and fewer consumers of this nature in the Middle period of the site. This is especially clear in *Bos* (fig. 11.1) sheep (fig. 11.4), goat (fig. 11.6) and equid (fig. 11.7) diets. New species of bird and fish are also reported here for the first time. Birds in particular are well preserved across the site and through the occupation levels, and show large variation across the group ( $\Delta^{13}C^{\text{min-max}}$ : 10.5‰ and  $\Delta^{15}N^{\text{min-max}}$ : 9.8‰), which is due to the feeding ecology across species that occupy a range of habitats in both the aquatic and terrestrial environments.

In addition to understanding the diets of animals at the site in relation to hunting, herding and management strategies, the long-term occupation at Çatalhöyük also raises questions about changing carbon and nitrogen isotope values over time that might reflect local environmental change, differences in hunting and herding locations, and whether there is evidence for specific group behaviours, all of which may influence the human carbon and nitrogen isotope values. In particular, the potential privileging of specific species for consumption, such as *Bos*, has long been a goal of the human dietary reconstruction. However, large sample

sizes have demonstrated that sheep and cattle, which would have formed the majority of diet of the Çatalhöyük inhabitants, are almost indistinguishable from one another. The nitrogen isotope means are virtually identical, and the carbon isotope values differ only by 0.6‰ and are often tied to shifts in specific occupation levels. However, previous work (Pearson 2013; Pearson et al. 2015a) has shown that across the site, animals with a large isotope range for their diet are not randomly distributed, but seem to concentrate in certain levels, and perhaps even specific households (Pearson 2012; Pearson et al. 2015a).

*Carbon and nitrogen stable isotope analysis: human*

One of the strengths of the stable isotope data from Çatalhöyük has been the measurement of specimens from both humans and animals across the occupation periods, which has helped to identify changes that occur chronologically due to environmental change or use of different parts of the landscape. The human isotope data from Çatalhöyük are first considered here on a site-wide basis, and then according to area, broad occupation periods (Early, Middle, Late and Final), by building and by building attributes in order to identify environmental versus social differences that might be apparent.



For the final phase of analysis, a further 251 human individuals were sampled, of which 96 failed to yield well-preserved collagen (38% failure rate). The failures were the greatest in the North Area of the site, with 69 of the 96 failed samples originating from this area. Across the site, the mean adult human carbon and nitrogen values are  $-18.8\text{‰}$  and  $12.3\text{‰}$  respectively. For adult males and females, the means remain strikingly similar, with females measuring:  $\delta^{13}\text{C}$   $-18.8\text{‰}$ ;  $\delta^{15}\text{N}$   $12.3\text{‰}$ ;  $n=57$ , and males measuring  $\delta^{13}\text{C}$   $-18.9\text{‰}$ ;  $\delta^{15}\text{N}$   $12.3\text{‰}$ ;  $n=45$ . This suggests the diets were virtually the same across the sexes, although these new data have reduced the mean nitrogen isotope values for both sexes by  $0.4\text{‰}$  relative to Pearson (2013). The adult mean isotope values of  $\delta^{13}\text{C}$   $-18.8\text{‰}$  and  $\delta^{15}\text{N}$   $12.3\text{‰}$  indicate that the average value for food consumed (plants and animals) will be approximately  $8.3\text{‰}$ , with an average carbon isotope value of  $-19.8\text{‰}$  (using  $\Delta^{15}\text{N}_{\text{consumer-diet}}$  value of  $4\text{‰}$  and  $\Delta^{13}\text{C}_{\text{consumer-diet}}$  value of  $1\text{‰}$  trophic level shift discussed above), which would have been generated from a combination of plants and animals. The most common animal protein element of the diet would have been sheep ( $\delta^{13}\text{C}$   $-17.6\text{‰}$ ;  $\delta^{15}\text{N}$   $10.2\text{‰}$ ) and cattle ( $\delta^{13}\text{C}$   $-18.2\text{‰}$ ;  $\delta^{15}\text{N}$   $10.1\text{‰}$ ) (fig. 11.16).

However, since there is still an offset between the values of animals and the expected human diet, this suggests that other resources with lower carbon and nitrogen isotope values likely made up a significant proportion of the diet. As a farming community, cereals

and legumes seem the most likely sources of additional food and would have made a major contribution to the diet. Fish can be ruled out as having been a major resource, since the carbon isotope values for that resource are  $3\text{‰}$  lower than the value expected for the whole diet. However, it should be noted this interpretation is based on measurements from only two samples (although each sample comprised tens of specimens). Aquatic and terrestrial birds cannot be ruled out as dietary contributors. The mean values for these two groups correspond well to the carbon isotope values, in terms of their likely contribution to the human diet, but the relatively higher nitrogen isotope values in the terrestrial birds suggests that these were not a dominant component of the whole diet. The extensive range in nitrogen isotope values amongst the humans indicates that some of the measured fauna would have been more important to some individuals than others. These data suggest the possibility, for instance, that some groups organised either as households or other social groupings consumed significantly more specific resources such as birds, cattle, and the rarer species such as equid, suid and deer. Potential groups or possible environmental effects and their relationship to diet are discussed in more detail below.

Figure 11.17 illustrates adult human diet by age group and sex. Comparing diet in individuals of different age as well as different sex reveals some differentiation in their diets.

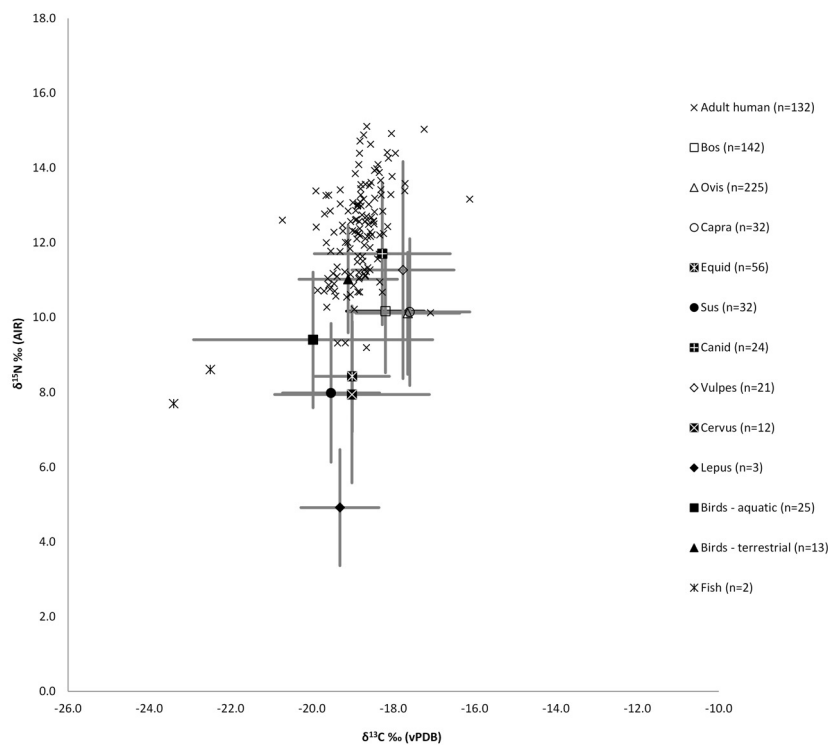


Figure 11.16. All Neolithic faunal species plotted as mean and 1SD error bars against all Neolithic adult humans.

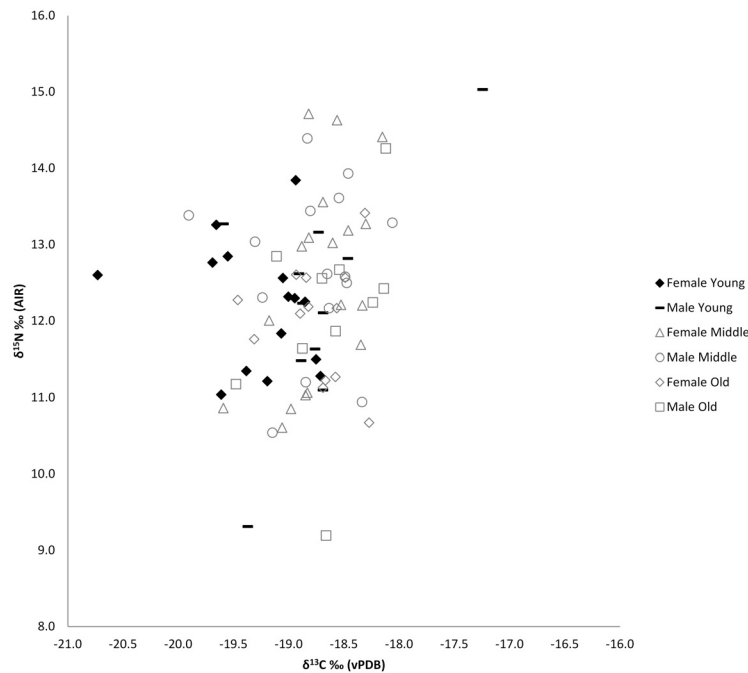


Figure 11.17. Adult humans plotted by age and sex.

These data show a significant shift in carbon isotope values between young and old females ( $p=0.005$ ) and to a lesser (but still significant) extent comparing young females with young males ( $p=0.02$ ), suggesting that age-based diet variations have a greater impact on the isotope evidence of diet than do sex-based variation. However, comparing young females against old males gives the greatest significance ( $p=0.004$ ). This suggests that the main driver in dietary differentiation is age-related, but that a smaller but sustained impact can be attributed to sex and likely was inextricably linked to it. Therefore, the age shift in diet seems to have played out differently according perhaps to gendered foodways. Both groups of younger women and older men had similar mean nitrogen isotope values (12.3‰ versus 12.1‰ respectively), which broadly suggests similar trophic level foods, but the differences in carbon isotope mean values ( $-19.3$ ‰ versus  $-18.6$ ‰ respectively) suggests that younger women would have been more likely to have consumed foods with lower isotope values. Such resources would have been wild animal species including equids, suids and birds, plus plant foods with relatively higher nitrogen isotope values, whereas older men are more likely to have eaten similar foods as the rest of the occupants at the site, since their mean values are close to the site means. A possible biological factor is the difference in isotope values in the tissues of fertile women. However, modern studies of pregnant women show small shifts (up to 1‰ lower) are frequently observed in nitrogen rather than carbon (Fuller et al. 2004; D’Ortenzio et al. 2015), allowing this to be ruled out here.

*Area-specific diets.* A comparison of the groups of individuals living in different parts of the mound, chiefly the North (fig. 11.19) and South (fig. 11.18) Areas, is shown below. The poor preservation in the North Area has somewhat hampered a robust comparison in terms of sample size, but some preliminary data for the North Area suggests large variation in the diets of animals, although the large standard deviation values could be due to small sample sizes in some fauna.

The South and North Area sheep, which are the most statistically robust sample populations, suggest that there is a difference in terms of the diets of the animals from these two areas. However, the North Area animals only span the Early and Middle periods of occupation, whereas sheep for the South Area span Early, Middle, Late and Final periods. Thus, it seems likely that the difference between these two areas is a function of time depth sampling, with the North Area not being represented by the Late and Final period fauna when the  $C_4$  plant ‘reflux’ described above in a number of fauna occurs. Other differences between the two areas appear in the birds; the grey heron mean carbon isotope value for the South Area ( $\delta^{13}C$ :  $-20.0$ ‰) suggests a  $C_3$  diet foundation, in contrast to the North Area ( $\delta^{13}C$ :  $-16.5$ ‰), which suggests some  $C_4$  input in the local food chain (since this species is largely residential). A closer inspection of these data indicates that the South Area animals date to the Early period of the occupation, whereas the North Area animals date to the Late period, suggesting a possible chronological effect. Many of the fauna with the highest nitrogen isotope values seem to occur in the South Area, but again this seems to be

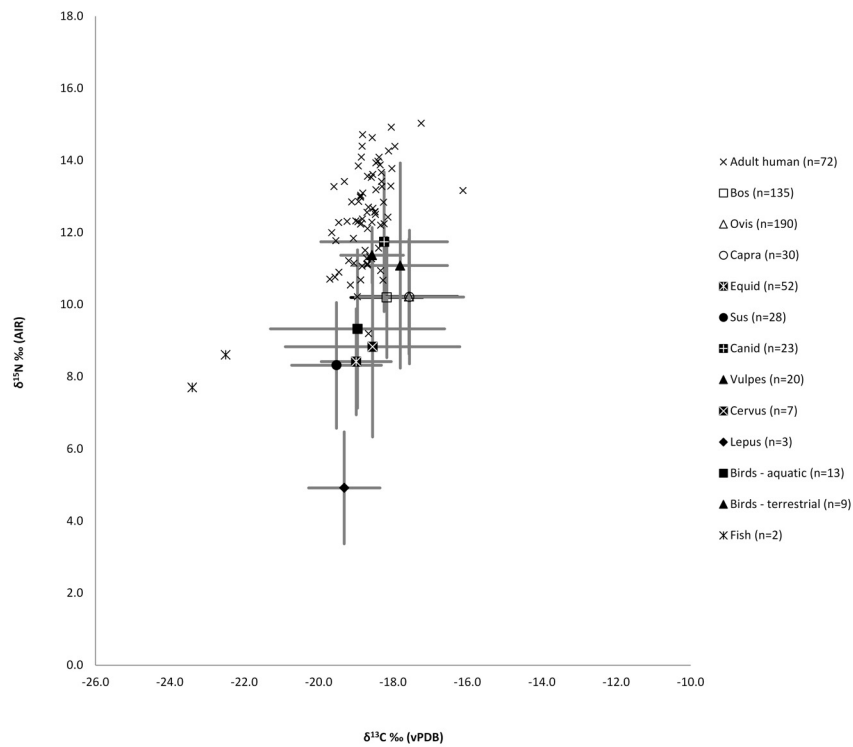


Figure 11.18. South Area faunal species plotted as mean and ISD error bars against South Area Neolithic adult humans ( $n=584$ ).

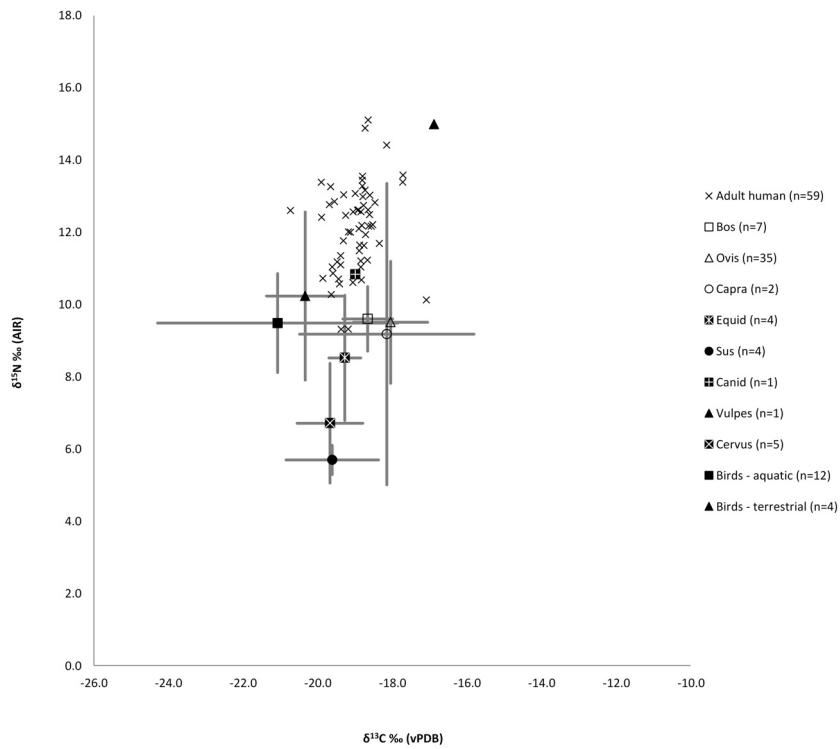


Figure 11.19. North Area faunal species plotted as mean and ISD error bars against North Area Neolithic adult humans ( $n=134$ ).

a feature of sample size and sampling across the different levels of the site, since the adult humans are broadly similar. Statistical analysis using an independent samples t-test of the Middle period of occupation, where the sample population for humans is largest, confirms no significant difference between the diets of humans from these areas ( $p=0.944$ ). The human carbon and nitrogen isotope values are discussed below building by building.

*Period-specific diets.* Figure 11.20 shows the nitrogen element of the ‘reflux’ first identified in the sheep in Pearson (2013) and confirmed above for sheep (fig. 11.4), goat (fig. 11.6), and boar (fig. 11.8), is also present in the human diet, suggesting that this shift likely represents either an environmental impact, or a shift in how the landscape was used for hunting, gathering and farming.

The Middle period witnesses a sizeable shift downwards in nitrogen isotope values, which may indicate a greater focus on plant resources, although what might cause this (that is, population pressure, environmental change) is unclear. However, a stress response concerning availability of resources would normally result in elevated

nitrogen isotope values. These shifts in values, though, are identified in both domestic and wild resources, suggesting a more fundamental shift at the environmental level. There continues to be little impact of  $C_4$  plant consumption in animals on human carbon isotope values. Although many of the elevated nitrogen isotope values in the animals discussed above appear to correlate with increased  $C_4$  plant consumption, that effect does not appear to feature here. One reason for this may be the  $C_4$  plant increase was itself a response to local environment changes. This suggests  $C_4$ -eating animals generally made very little contribution to the lifetime diet of adult humans. This apparent shift in values over time across a number of species also complicates the identification and comparison of building-specific diets and consideration of human diet and its relationship to building attributes discussed below, which can only be compared within occupation periods: Early, Middle, Late and Final.

*Building-specific diets (with contributions by Claudia Engel).* The adult human data in figure 11.21 are plotted according to the building underneath which they were found. It should be noted that these numbers of

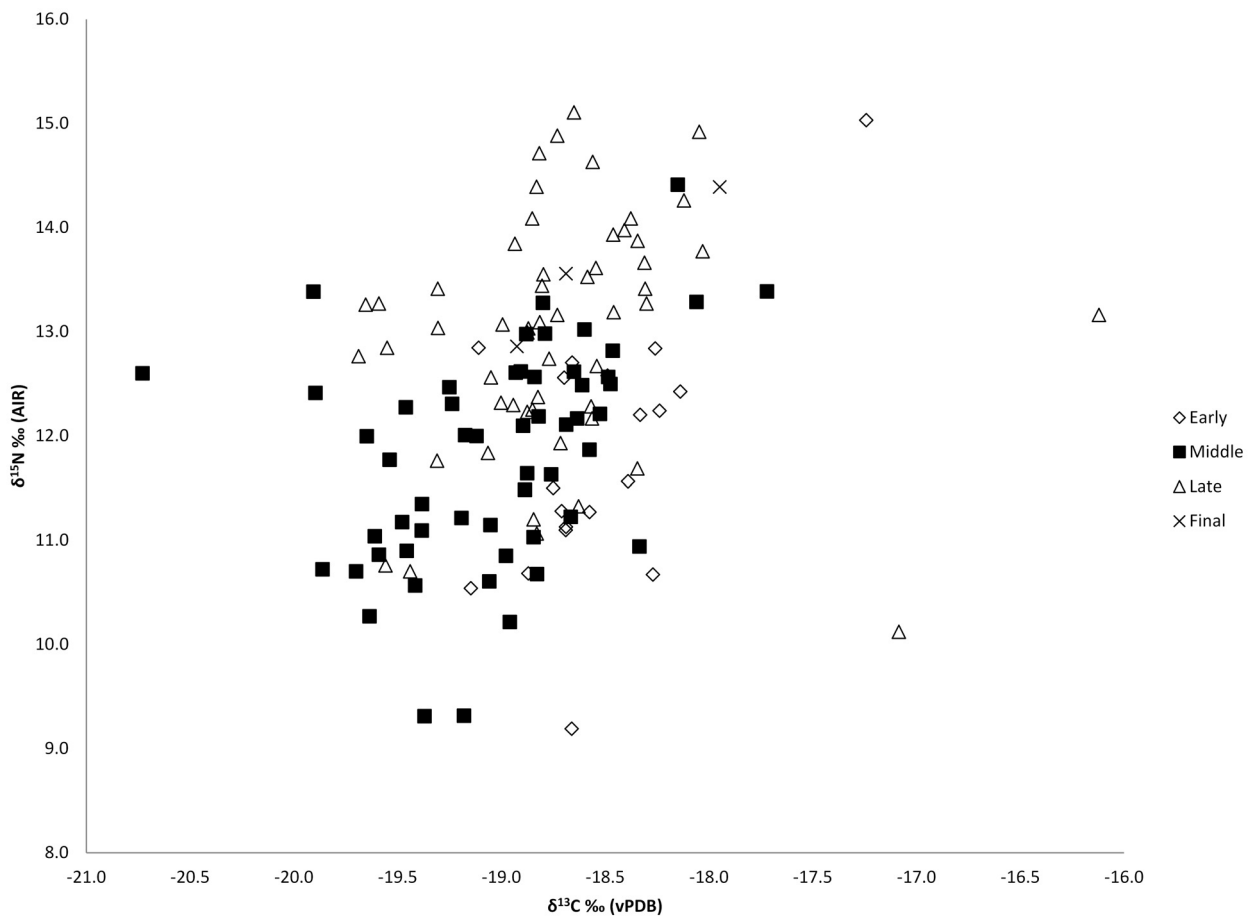


Figure 11.20. Adult humans plotted according to Early, Middle, Late and Final occupation periods.

individuals only represent those that had good collagen preservation, and in most cases there were other adults also buried in the building; therefore, these data do not give a complete picture of the diet of a given building. Only buildings with at least two individuals with well-preserved collagen are included in order to facilitate comparison.

These data show variation in diet within buildings, which is to be expected, as individuals undertook different roles and performed their required tasks as part of the community. Such tasks would have necessitated that individuals spent differing amounts of time away from the site in a range of environments, which would lead to the consumption of different foods where these activities occurred on a regular or even seasonal basis. However, a central question is whether diets within houses are still more similar than across houses in spite of these activities. In other words, are the diets within a house more similar than might be expected if diets (and thus the burying of individuals) were randomly distributed across houses. To test this robustly, considering the small sample size for each house, and given both the likelihood these data are not normally distributed and the need to compare as many as possible, permutational multivariate analysis of variance (PERMANOVA) and permutational analysis of multi-

variate dispersions (PERMDISP) were used to examine the centroids and dispersal. The centroids are of clusters of values relating to a location, in this case a house, and dispersal indicates whether the individuals from one house had widely spread diets in comparison to other houses. Comparing houses with at least four individuals, PERMANOVA was significant at 0.001 across the occupation but PERMDISP was not significant. These tests demonstrate that there is a location (house) effect, which confirms diets differed between houses with no statistical difference in the degree of dispersion within houses (fig. 11.22).

When chronological effects of the major occupation periods are taken into consideration, dietary patterning by house does not reach significance in the Early period ( $p=0.549$ ) but does in the Middle ( $p=0.033$ ) and Late ( $p=0.013$ ) periods, perhaps suggesting increasing clustering over time. Since houses are also part of neighbourhoods, groups of houses were also compared to examine whether there were distinct neighbourhood diets. When six house clusters were compared overall, regardless of period, the groups are significantly different ( $p=0.001$ ). However, when these are further separated into Middle and Late periods, they do not show significant differences within a particular period (fig. 11.23).

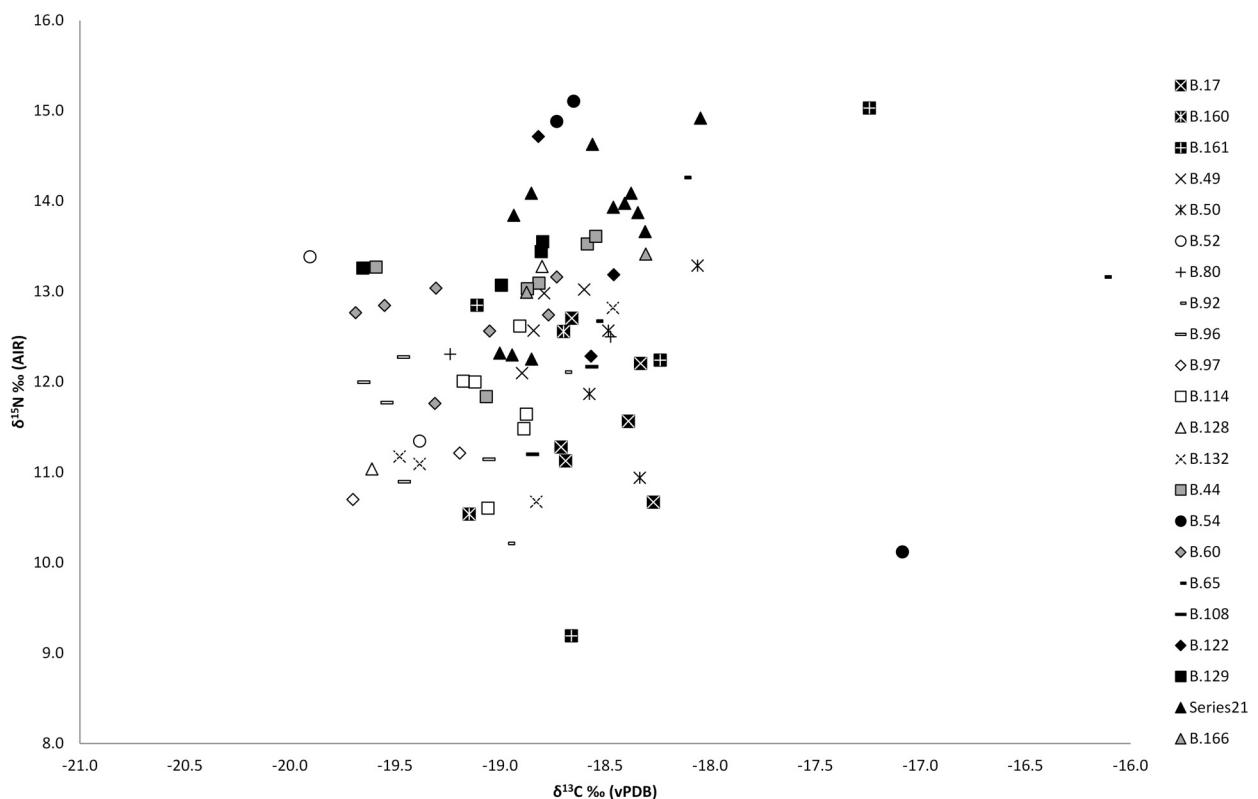


Figure 11.21. Adult humans plotted according to building and occupation period (Early: white on black symbols; Middle: black line/unfilled symbols; Late: filled black and grey symbols).

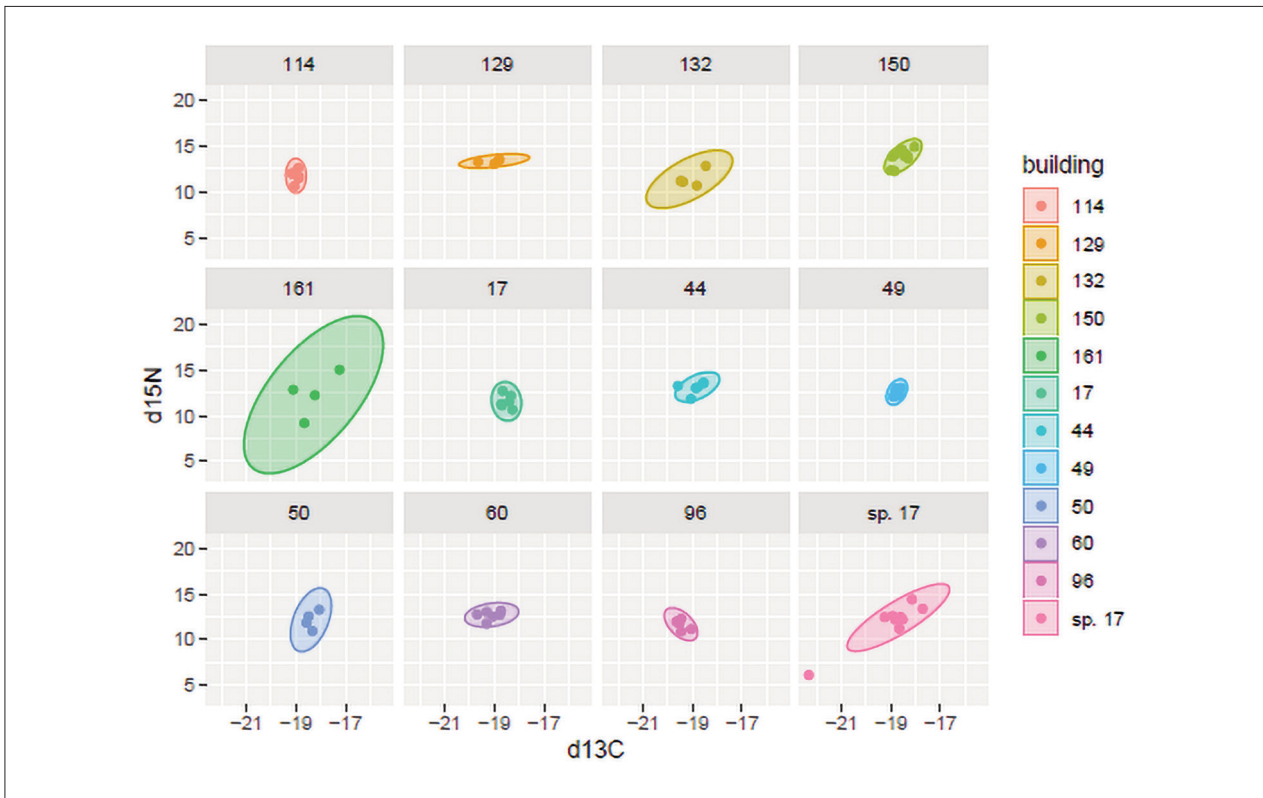


Figure 11.22. Buildings and spaces with >3 individuals with 95% confidence ellipses.

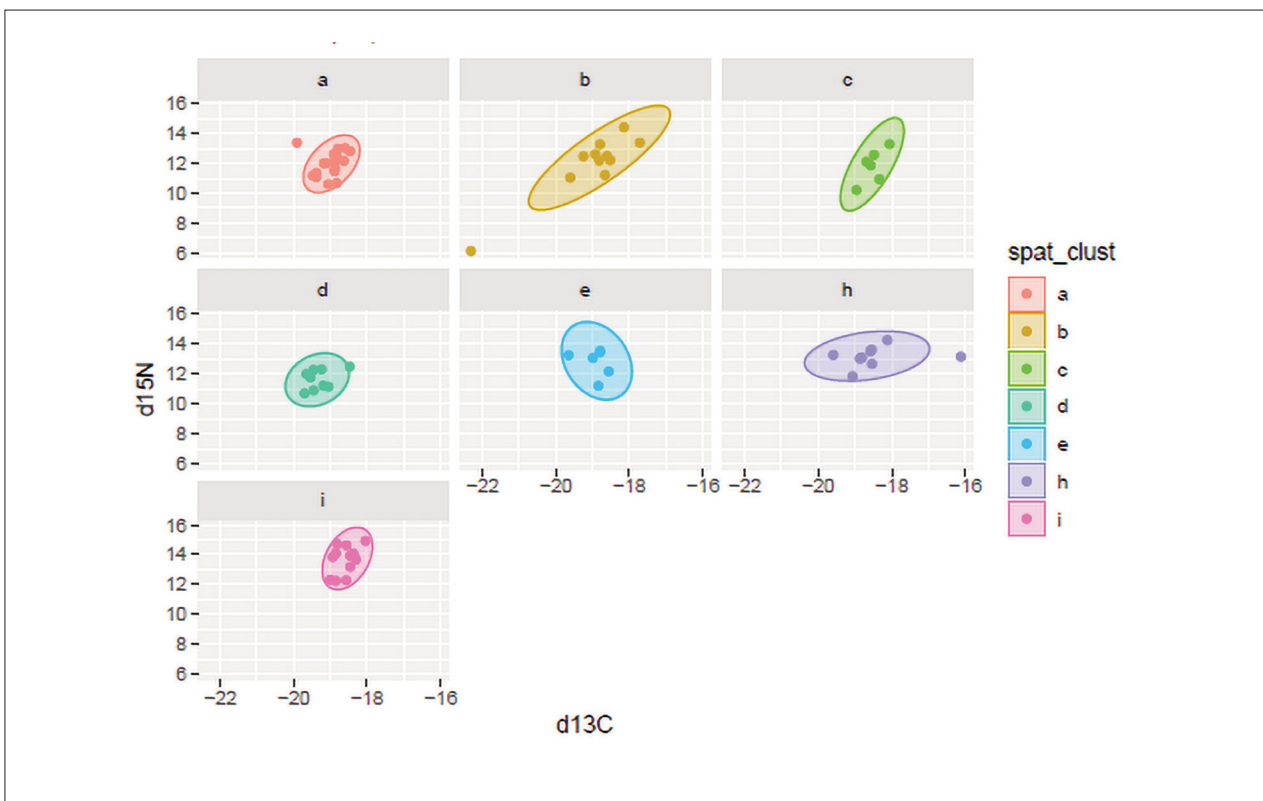


Figure 11.23. Neighbourhood spatial clusters with 95% confidence ellipses: (a) Middle period North (B.132, B.52, B.114, B.49); (b) Middle period North B.128, Sp.17; (c) Middle period South B.92, B.50; (d) Middle period South B.80, B.96, B.97; (e) Late period North B.129, B.108; (f) Late period South B.44, B.65; (g) Late period South B.122, B.150, B.165.

Finally, neonates were compared across houses in an attempt to identify clearer evidence of household diets by hypothesising that neonatal bone provides a short-term summary of female diets as they enter the last trimester of pregnancy. Three buildings (fig. 11.24) had at least four neonatal individuals with well-preserved collagen. These data show significantly different values between the buildings ( $p=0.001$ ) suggesting they may indeed represent evidence of the house-based diets for females. However, there are several caveats that should also be borne in mind: 1) the error margin of neonates is two months in utero to five months post-partum, and older individuals may have had some breastmilk represented in their bone; 2) because pregnancy causes metabolic stress, the isotope values may not reflect true dietary values; and 3) the isotope values of these neonates might also reflect the impact of the pathological condition which they suffered prior to death.

*Human diet and building attributes.* A final source of variation in diet concerns whether specific buildings or areas of buildings were used for particular individuals: specifically, whether the diet of the people of Çatalhöyük correlated according to platforms under which they were buried, or the numbers of burials/elaboration of houses. Platforms in the Early, Middle and Late periods were compared where ages were mixed so as to avoid age-based differences already identified, and no patterning was found. This suggests that individuals under specific platforms were not afforded similar diets. Comparisons were also made using the Elaboration Index (Ei) and Minimum Number of Individuals (MNI) burial data calculated for the site (see Chapter 1). Only buildings where at least 75% of the structure had been excavated were considered. The following linear correlations were explored in order to highlight potential relationships, but since most demonstrated no correlation between any of the building attributes, further statistical analyses were not undertaken (table 11.5).

A total of 29 isolated skulls/crania were also identified for sampling in order to test for a potential difference in diet according to primary and secondary burial. The mean values differ from the overall population by 0.1‰ for carbon and 0.4‰ for nitrogen, suggesting that there was no major difference. Secondary burial treatments of crania and mandibles also feature most prominently in the Late period of occupation, where relatively higher isotope values are seen, suggesting that this difference is not unexpected. Comparisons between the skulls/crania also illustrated there was no dietary difference between the sexes (0.2‰ and 0.1‰ differences were observed in carbon and nitrogen, respectively).

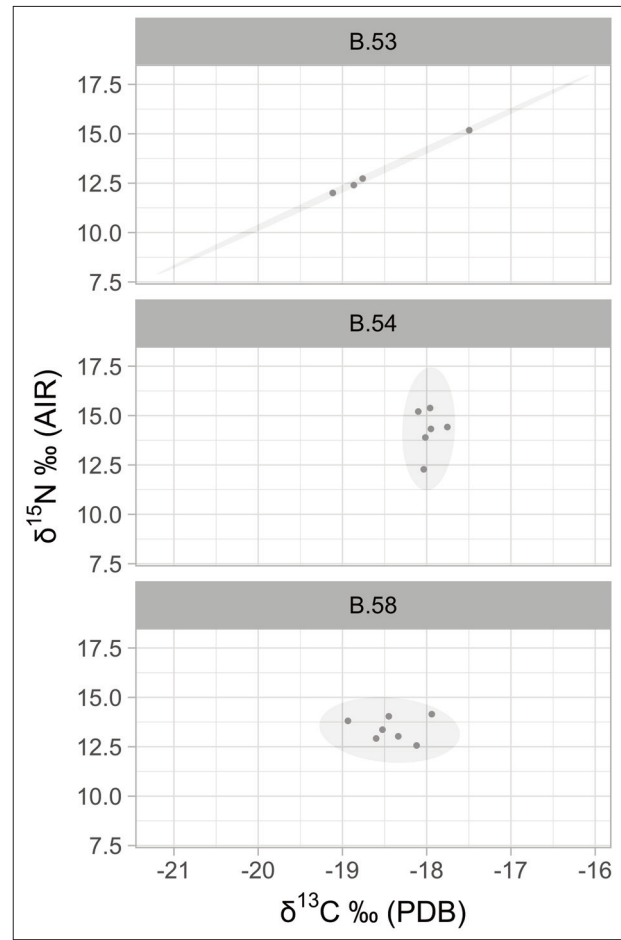


Figure 11.24. Buildings and spaces with 3+ neonatal individuals with 95% confidence ellipses.

Phase	Attribute - Isotope	R <sup>2</sup>
Early	Ei-Carbon	0.4630
Early	MNI-Carbon	0.4630
Early	Ei-Nitrogen	0.0060
Early	MNI-Nitrogen	0.0060
Middle	Ei-Carbon	0.0035
Middle	MNI-Carbon	0.0691
Middle	Ei-Nitrogen	0.0030
Middle	MNI-Nitrogen	0.0526
Late	Ei-Carbon	0.1372
Late	MNI-Carbon	0.0354
Late	Ei-Nitrogen	0.0332
Late	MNI-Nitrogen	<0.0001
ALL	Ei-Carbon	0.0437
ALL	MNI-Carbon	0.0050
ALL	Ei-Nitrogen	0.0139
ALL	MNI-Nitrogen	0.0140

Table 11.5. R<sup>2</sup> data for comparisons of carbon and nitrogen isotope data and building attributes Elaboration Index (Ei) and Minimum Number of Individuals (MNI) burial data.

*Weaning patterns.* In Pearson (2013), using a dataset of 38 subadults aged between birth and age stage five years, the nitrogen isotope data suggested that the first onset of weaning began around 18 months of age, and was complete by three years, giving an overall weaning duration of 18 months. The carbon data were inconclusive.

Adding a further 75 subadults in the interval between birth and five years of age, the nitrogen isotope data now suggest that the start of weaning began before the first year of age (fig. 11.25), much earlier than previously suggested, but that breastfeeding had ceased by three years of age. This shift in the interpretation of these data may have been the result of small sample sizes in the individual age groups. The carbon isotope data also suggest the first introduction of complementary foods began at some point before the first year of age and the wholesale shift to this food was completed by three years of age (fig. 11.26). Some caution should still be exercised, as these new interpretations are based on a small number of individuals with relatively higher values, which may also be a sign of stress in these particular infants.

*Strontium isotope evidence of residential mobility*

In order to identify individuals that did not spend their childhood in the local area, we used a  $^{87}\text{Sr}/^{86}\text{Sr}$  measurement baseline map previously published by Bogaard et al. (2014a) that was constructed using

modern plants sampled from the centre of the Konya Plain alluvial basin across to the nearby limestone terraces. These data showed only a small overlap between the two geological substrates, with the terrace  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios ranging from 0.7069 to 0.7076 and those in the alluvial plain from 0.7076 to 0.7081. Therefore, these data indicate  $^{87}\text{Sr}/^{86}\text{Sr}$  measurement constraints of 0.7076 to 0.7081 as evidence for a childhood spent at Çatalhöyük. The  $^{87}\text{Sr}/^{86}\text{Sr}$  measurements show that the majority (n=72) of the individuals sampled spent their childhood (for most individuals between 2.5 and 8.5 years of age, and for two, 8.5–14.5 years) on the Konya Plain, suggesting they are local individuals that grew up at Çatalhöyük. There are eight individuals that fall outside the range for a childhood spent on the alluvial plain. One individual (14753) has  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios indicative of a childhood spent on the limestone terraces, and seven individuals have  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios indicative of a childhood (or part of a childhood) spent in a more geologically radiogenic zone, likely towards the Taurus Mountains. It is possible that the individuals closest to the higher ratio cut-off for the plain likely spent part of their childhood, perhaps on a seasonal basis, away from the site. Since the Konya Plain alluvium is comprised of soil generated from the Taurus Mountain region (Bogaard et al. 2014a), it is possible that the higher strontium isotope ratios show short-term travel between

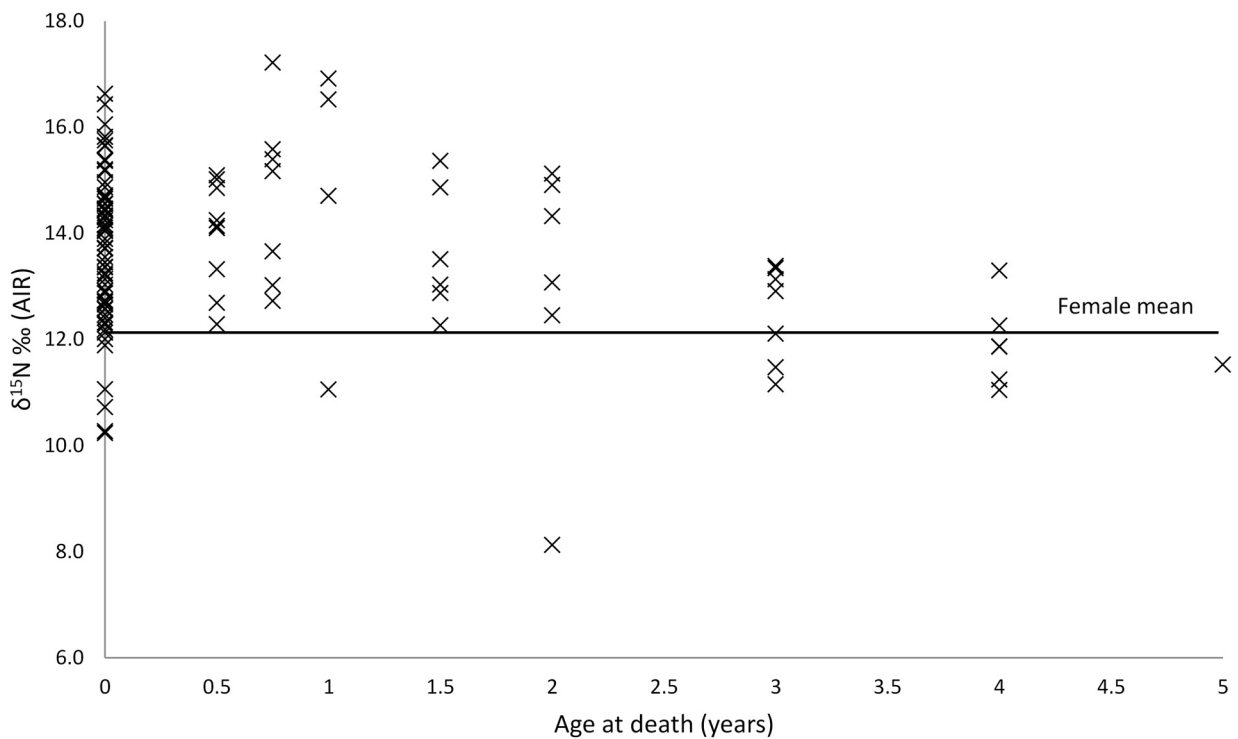


Figure 11.25. Nitrogen isotope values for subadults assigned to age stages birth–5 years age stage. The solid black line indicates the female mean.



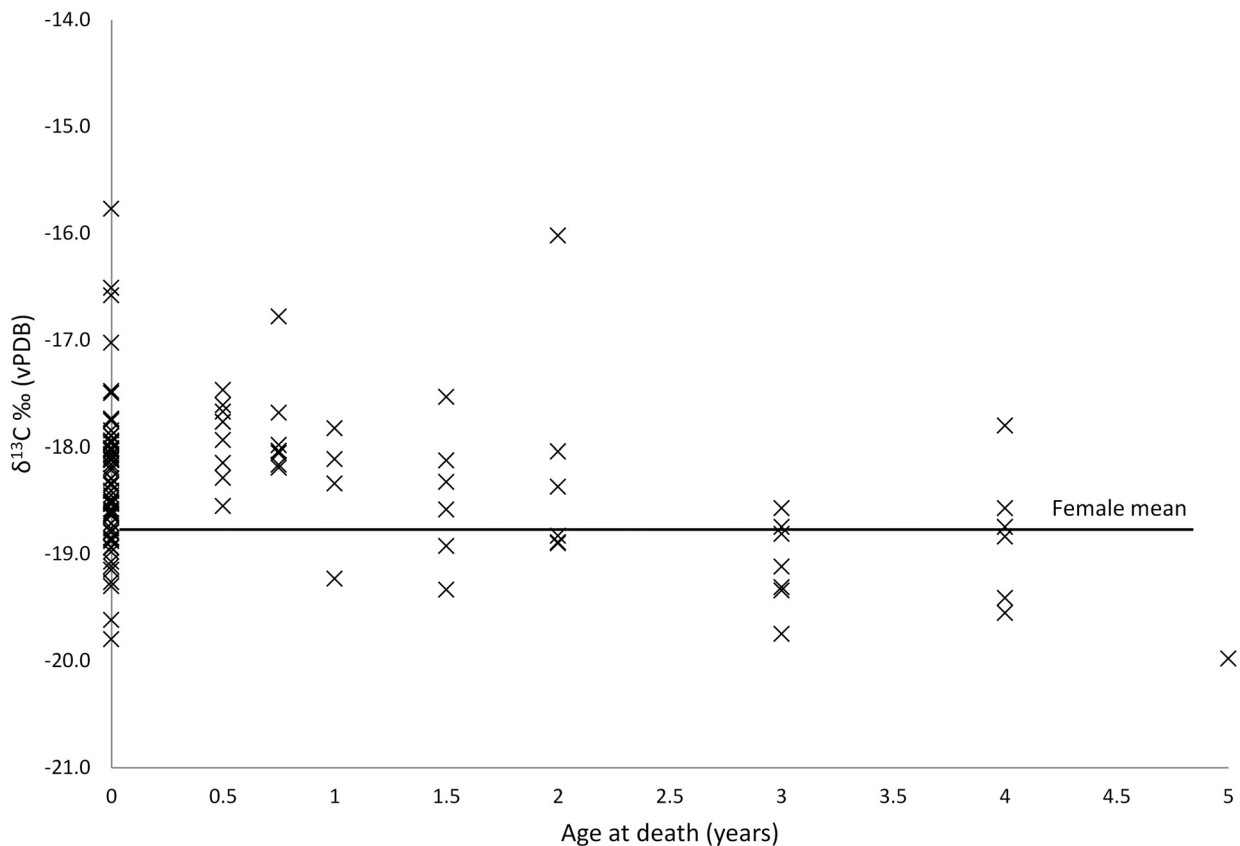


Figure 11.26. Carbon isotope values for subadults assigned to age stages birth–5 years age stage. The solid black line indicates the female mean.

the plain and the Taurus Mountains, rather than originating from elsewhere. The non-local individuals are discussed in more detail below in terms of who they were, when they appeared at the site, and which houses they were buried in.

*Who were the non-local individuals that arrived at Çatalhöyük?* Table 11.6 shows the non-local individuals identified from the strontium isotope measurements. The human individuals that spent their childhood away from the site and the alluvial plain include both males and females and range in age scores from young adult (20–35 years) to old adult (50+ years). There appears to be nothing remarkable about the nature of burial of those with connections to the Taurus, none of the individuals have grave goods or other x-finds included with their grave, and they were not afforded burial in the larger or smaller houses or those that were more or less elaborate. Additionally, some human remains have now been identified as having been curated before burial (see Chapter 15). One example of these was sampled (20830) and was found to have a local, Konya Plain signature, providing no evidence as yet for the curation of outsiders. A comparison with other

biological factors such as non-metric biodistance traits and cross-sectional geometry indicative of logistical mobility, and pathological conditions would be useful to identify any other features that would reveal a pattern among this group of individuals.

*Local and non-local individuals and their relationship to houses.* All individuals measured are plotted in figure 11.27 against building number, illustrating how the individuals that were locals and non-locals are distributed through the site. One important observation here is that most of the individuals buried in these houses were locals, and where non-locals are interred, there is only one per house. Buildings 12, 53, 65, 75, 92, 96 and Sp.620 all contained individuals that spent significant portions all of their childhood away from the site.

*Local and non-local individuals by temporal period.* Figure 11.28 shows that the arrival of non-locals or the mobility of individuals occurs through several temporal periods at the site: in the North Area during Levels North G and H and in the South Area from South M? and again in Levels South O, P and Q, when this

Unit	Sex	Area	Phase	Age score	Deposition	Origin	Other information
14753	Female	N	Middle	5	1	Limestone Terrace	Flexed left side, no grave goods
16411	Female?	N	Late	7	1	Taurus?	Flexed left side, no grave goods
5774	Female?	S	Middle	7	1	Taurus?	Flexed right side, no grave goods
20824	Female	S	Middle	7	1	Taurus?	Flexed right side, no grave goods
16513	Male	S	Late	4	1	Taurus?	Right side, no grave goods
14032	Female	S	Late	5	1	Taurus?	Flexed right side, no grave goods
14805	Male?	S	Late	7	4	Taurus?	Cluster, no grave goods
5795	Sex?	S	Unknown	?	?	Taurus?	redeposited, no grave goods

Table 11.6. Individuals buried at Çatalhöyük that indicate a childhood away from the alluvial plain.

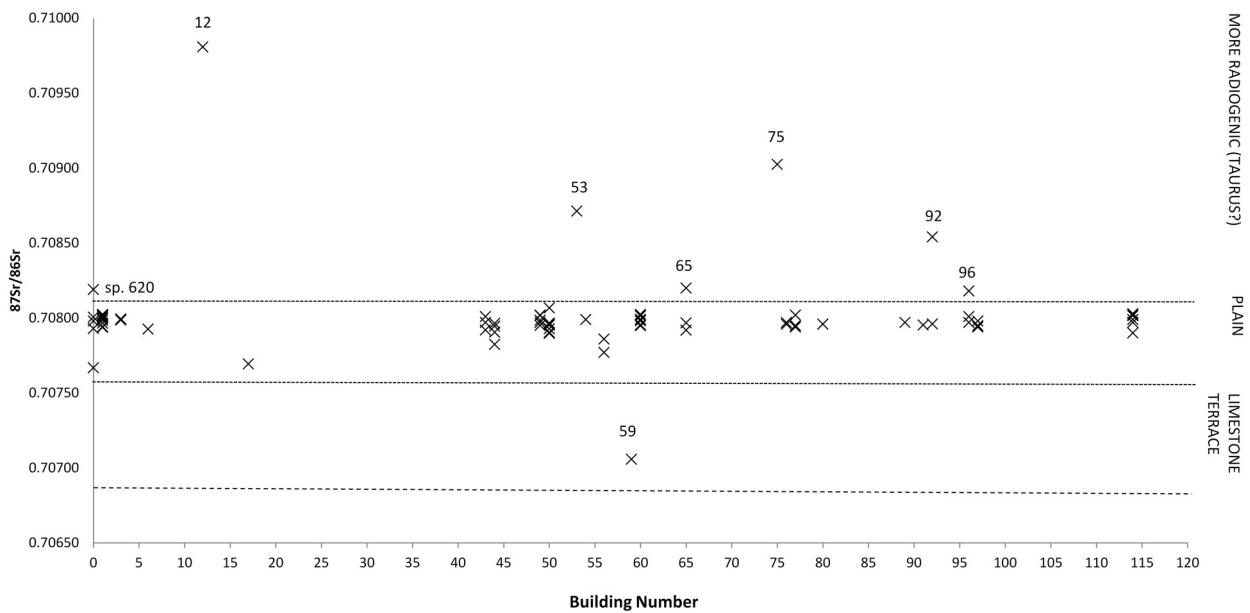


Figure 11.27. Individuals plotted against strontium ratio and building number.

practice seems to stop. It should be borne in mind, however, that although evidence of mobility may be present in a particular level or period, this activity occurred when the individual was a child and, depending on the duration of particular levels and the age of the individual, may in fact be attributed to the previous level.

Figure 11.29 shows that the arrival of non-locals or the mobility of individuals begins in the Middle period and continues through into the Late period. Assuming that the sampled individuals are representative of the site in general, it would seem that the use of the limestone terrace was a relatively short-lived activity during the Middle period of the site’s occupation, or that only a very small number of individuals joined the Çatalhöyük community from this region.

The use of, or connection to, the Taurus Mountains or the influx of individuals from this area seems to

have been a phenomenon that occurred in the Middle period of the site and carried on into the Late period, although figure 11.28 shows that it did not continue into the latest levels of the Late period. This makes for an interesting comparison with the evidence from the Pınarbaşı seventh millennium cal BC rock shelter (6500–6000 cal BC (Watkins 1996)), where the sheep carbon and nitrogen isotope evidence of diet suggests the Çatalhöyük and Pınarbaşı sheep were grazed in similar areas (Baird et al. 2011), perhaps providing evidence of the types of activities that might have been undertaken away from site. However, more recently, the Çatalhöyük sheep have been shown to have made little use of the limestone terraces in the Pınarbaşı locale (Bogaard et al. 2014a) and much of the human mobility is towards a locale with a more radiogenic geological substrate located in the region of the Taurus Mountains.

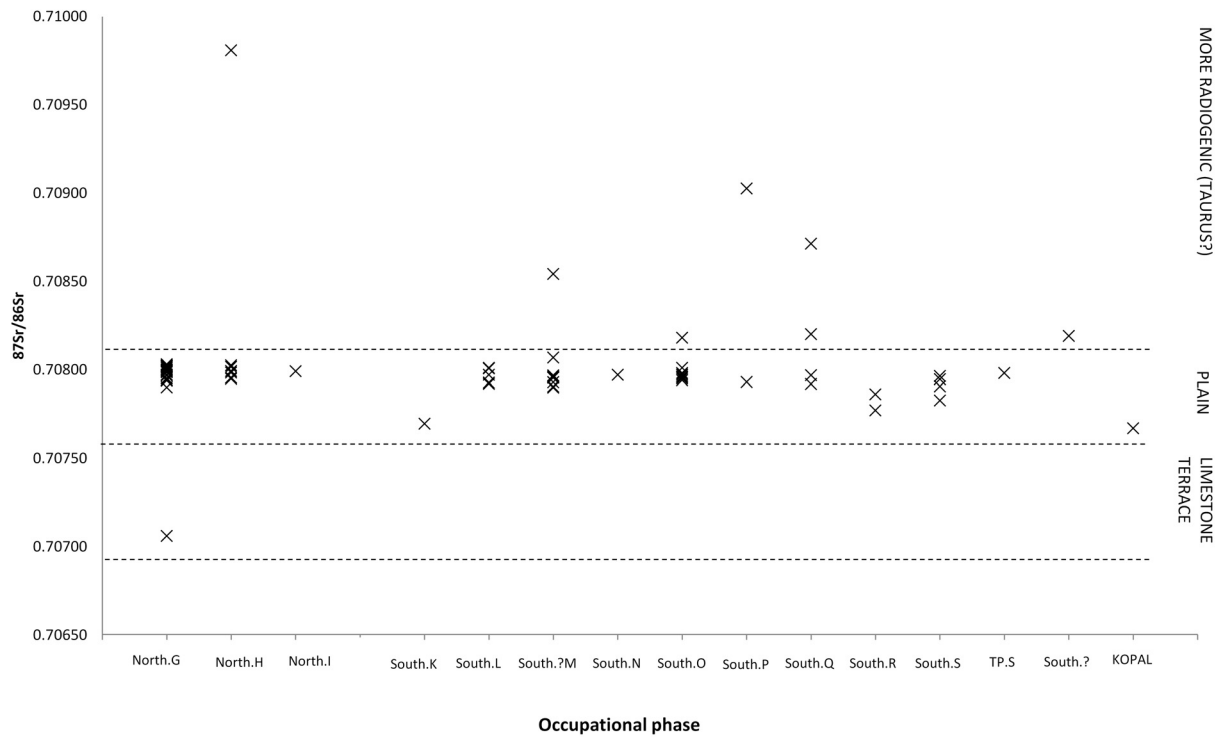


Figure 11.28. Individuals plotted against strontium ratio and occupation level in the North and South Areas.

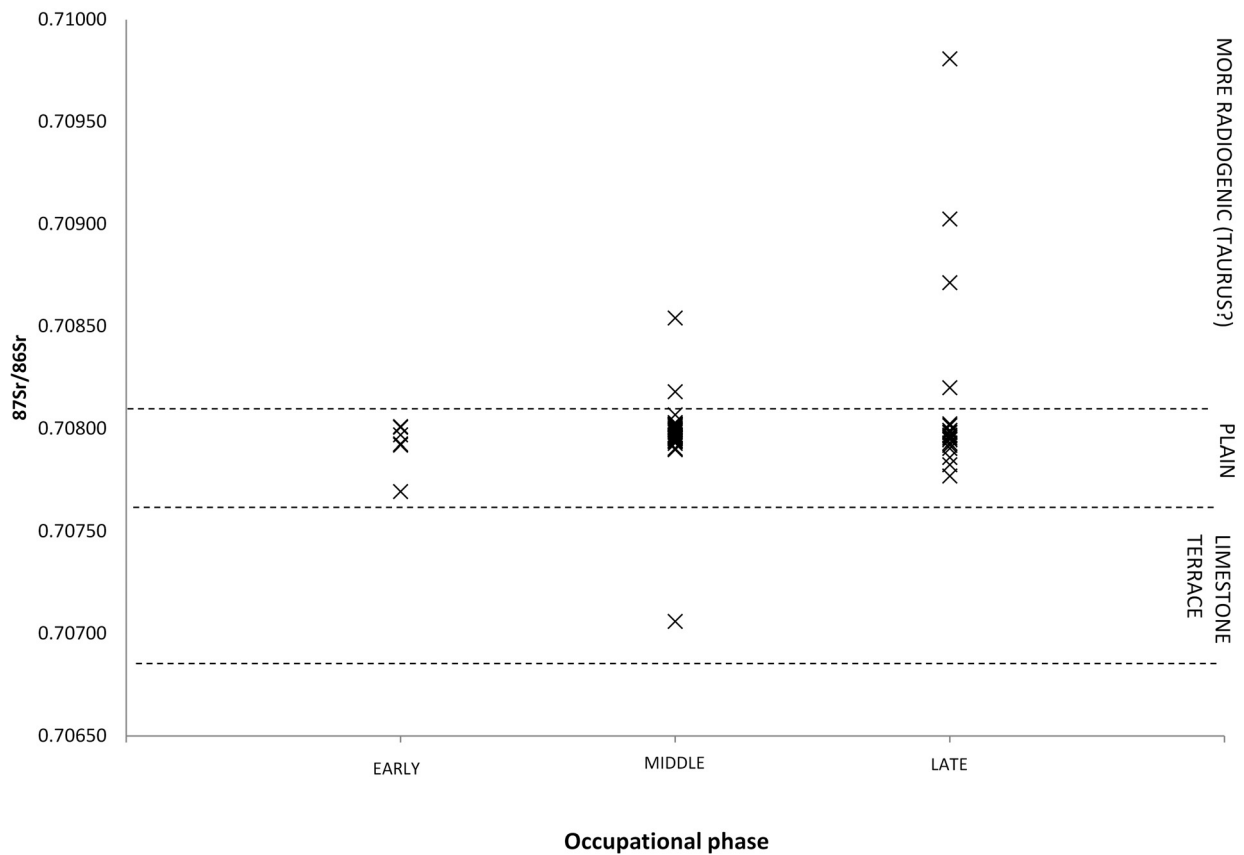


Figure 11.29. Individuals plotted against strontium ratio and Early, Middle and Late periods.

## **Conclusion**

When the stable isotope analysis of animals and humans began at Çatalhöyük in 1998, the method was rarely employed systematically at other sites, and central research questions then and now remained essentially unchanged: what did individuals actually eat, and did this differ according to whether the consumer was male or female, 'high status', or from a particular building or part of a building? And could similarities and differences be accounted for by an influx of outsiders? The 25 years of excavation, and extensive funding from a range of sources, with stable isotope analysis integrated into the overall research aims at the site has enabled an unprecedented volume of material excavated to be measured. This dataset of 987 samples provides data not for the purposes of incremental research, answering the same questions each time, rather it has allowed the formation of more detailed investigation into the nature of food provision and sharing in this large sedentary community from a biosocial perspective, across both space and time. Firstly, the volume of analyses has enabled detailed understanding of what wild, domestic and managed animals ate, through the hypothesis that managed and domesticated animals will have a different diet to animals that were free to roam. Within these managed and domesticated animals, approaches to herding can also be examined (Pearson et al. 2007; Middleton 2014; 2018). These studies also enabled a methodological evaluation of sample size optimisation: using 174 sheep from the site, Pearson and Grove (2013) demonstrated the impact different faunal sample sizes have on the likelihood of a given number of samples providing an estimate of the true mean (the average true diet) for the population. Sample size is important fundamentally to the accuracy provided by stable isotope analysis and the use of faunal animal isotope values to estimate human diet, and the Çatalhöyük fauna isotope data provides a crucial dataset for these parameters to be estimated in ancient assemblages for the first time. Finally, the recent focus on sampling aquatic resources, despite the overwhelming focus on terrestrial farming and agriculture, has enabled the role of birds and fish to be understood for a Neolithic community beyond the usual focus of western and central Europe and to confirm directly for the first time the minor role of these foods in the Neolithic Middle East.

The use of stable isotope analysis to investigate human diet has enabled several other important issues to be addressed: the long-term excavation uncovering the dead

buried beneath more than 100 houses reveals that, overall, men and women buried at Çatalhöyük had the same diet, but that within a single house adults often consumed different food to one another (Pearson 2013; Pearson et al. 2015a), although the individuals within a house tended to be more similar to each other than to individuals in other houses. This adds an extra layer of complexity against the dental biodistance studies (Pilloud, Larsen 2011), which suggests that people within houses organised themselves into practical kin groups predicated on social, economic and political decision-making rather than on biological relationships. Careful assessment of the variation in diet reveals for the first time in the Middle East that age rather than gender is likely to have been a critical structuring principle, with younger adults having a different diet to middle and older age community members (Pearson, Meskell 2013). This supports earlier work on both the figurine corpus and burial assemblage (Nakamura, Meskell 2009; 2013a; 2013b). There is also little evidence that individuals with a particular diet are buried according to the longevity or elaboration of a particular house (see above; Pearson 2013). Finally, the most recent application of strontium isotope analysis has enabled one of the most important issues concerning the unusually large size of the site for this point in prehistory to be addressed: the origins of the people buried here. Although Çatalhöyük is not the first mega-site in the Middle East, it is the first one to appear on this scale in Central Anatolia. Scholars including Baird (2002; 2005) have suggested that the emergence of the site coincides with a reduction in the number of smaller sites. Therefore, identifying whether the size of the site is attributed to aggregation of smaller sites enables this question to be addressed directly. The strontium isotope data discussed above confirm that around 90% of the current dataset (n=80) of sampled adults derive from the Konya Plain, with no evidence of patrilocal or matrilineal kinship practices, suggesting both a local origin for the majority of the population and local (if not site-based) kinship practices for most families. Therefore, the 20+ years of stable isotope research have provided a dataset of crucial importance for understanding key questions not just in Central Anatolia and the Middle East, but for world prehistory: the origins of large villages and the social foundations at the beginning of sedentary life.

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## **Supplementary material**

For supplementary material related to this chapter, please visit <https://doi.org/10.18866/BIAA/e-13>. It comprises colour versions of figures 11.22, 11.23 and 11.24.

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Monograph 53  
Çatalhöyük Research Project Series 13  
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## Online supplementary material

Supplementary material available online (<https://doi.org/10.18866/BIAA/e-13>) comprises additional elements for chapters 5, 8, 12 and 13, and the entirety of chapter 19. Colour versions of selected figures are available for chapters 2, 4, 11, 14, 15 and 16.

5. The archaeobotany of Çatalhöyük: appendix S5.1 (unit-by-unit discussion, with 15 figures: S5.1–S5.15); two tables (S5.1–S5.2)
8. Macromammals of Çatalhöyük: appendix S8.1 (general appendix, with 20 figures: S8.1–S8.20 and 23 tables: S8.1–S8.23); appendix S8.2 (measurements)
12. The fish remains: appendix S12.1; three tables (S12.1–S12.3)
13. The avian remains: one table (S13.1)
19. Gdańsk Area human remains *Michelle Gamble and Belinda Tibbetts*