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Food and Power in Early Medieval England: a Lack of (Isotopic) Enrichment

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ABSTRACT

This work tackles long held assumptions in both archaeology and history surrounding elite diets in early medieval England i.e., that higher status individuals had a more meat-heavy diet and that this was especially true for males. We utilise the largest isotopic dataset on early medieval diets to date to show that not only were high protein diets extremely rare in England before Scandinavian settlement, but that dietary differences cannot be linked to gender or social status from the funerary record. Comparisons with the calculations made in our companion article and the bioarchaeological evidence demonstrate further that the lists of food demanded by eighth-century kings were not the basis for regular elite diet, and that these texts probably represent the supplies for infrequent feasts.

INTRODUCTION

There are long held assumptions in both archaeology and history surrounding elite diets in early medieval England, namely that higher status individuals had a more meat-heavy and therefore protein-rich diet than the lower classes, and that this was especially true for males over females.[1] So closely held are these assumptions that it is commonplace for bioarchaeological studies to actively seek out social differences in diet, comparing variables like numbers and kinds of grave goods with dietary signatures from skeletal remains. These studies have never found biologically meaningful correlations at a cemetery or regional level,[2] yet the

[1] D. Banham, *Food and Drink in Anglo-Saxon England* (Stroud, 2004), pp. 53–70; A. Hagen, *Anglo-Saxon Food & Drink* (Ely, 2010), pp. 444, 460; A. Gautier, *Le Festin dans l'Angleterre anglo-saxonne (Ve-XIe siècle)*, Nouvelle édition [en ligne] (Rennes, 2006), pp. 225–50, DOI: 10.14375/NP.9782753502345.

[2] Yet some studies claim to find differences between the sexes or individuals with different types/quantities of grave goods, however, on closer inspection these differences might be statistically significant but are either within machine/analytical error (and therefore meaningless) or less than one trophic level shift (3–5‰) and therefore cannot be interpreted as a meaningful dietary difference especially when sample sizes are so small e.g. K. L. Privat, T. C. O'Connell and M. P. Richards, 'Stable Isotope Analysis of Human and Faunal Remains from the Anglo-Saxon Cemetery at Berinsfield, Oxfordshire: Dietary and Social Implications', *Jnl of Archaeol. Science* 29 (2002), 779–90, DOI: 10.1006/jasc.2001.0785.

assumptions remain pervasive.[3] To the extent that they are underpinned by evidence, it is not archaeological but textual.

This textual evidence takes the form of a series of lists of foodstuffs written between the late seventh and tenth centuries. Most of these have traditionally been interpreted as part of a system of 'food rents' or 'food renders' (also sometimes known by the Old English term *feorm*), and understood to detail the payments in kind that peasants owed first to kings and later also to non-royal landlords. Since the nineteenth century it has been assumed that these renders were collected regularly by royal households and comprised most of their meals, and that they contributed substantially to the diets of other members of the elite who had been endowed with the right to receive local royal revenues. Ann Hagen summarises the arrangement as follows:

> The holder of large estates could expect to receive a quantity of food, including prestigious items, without working on its production himself. The only food-getting activities the lord was likely to engage in were recreational pursuits … Food was an important component, if not the most important, of the king's revenue. All lands in the realm unless specifically exempted had to contribute food to the king. The unit was the farm of one night, that is the food and drink necessary to support the king and his court for one day … The king, or landowner, went round to his estates in turn with his retinue eating up the provisions gathered for him. He would stay in the main dwelling to which corn, provisions, cattle, and dairy produce were sent from the collecting centres …[4]

As we argue in the companion piece to this article, these assumptions must be questioned. We contend that our food lists and documentary allusions to *feorm* do not refer to renders of general-purpose food supplies used to sustain elite households. The quantities and proportions of different foodstuffs in these texts, and often their contexts, suggest that they are lists of supplies for large and

[3] R. Vidal-Ronchas, P. Rajić Šikanjić, Z. Premužić, A. Rapan Papeša and E. Lightfoot, 'Diet, Sex, and Social Status in the Late Avar Period: Stable Isotope Investigations at Nuštar Cemetery, Croatia', *Archaeol. and Anthropological Sciences* 11 (2019), 1727–37, DOI: 10.1007/s12520-018-0628-4; E. L. Hannah, T. R. McLaughlin, E. M. Keaveney and S. E. Hakenbecka, 'Anglo-Saxon Diet in the Conversion Period: a Comparative Isotopic Study Using Carbon and Nitrogen', *Jnl of Archaeol. Science: Reports* 19 (2018), 24–34, DOI: 10.1016/j.jasrep.2018.02.012; T. C. O'Connell and B. D. Hull, 'Diet: Recent Evidence from Analytical Chemical Techniques', *The Oxford Handbook of Anglo-Saxon Archaeology*, ed. D. A. Hinton, S. Crawford and H. Hamerow, Oxford Handbooks (Oxford, 2011), pp. 667–87, DOI: 10.1093/oxfordhb/9780199212149.013.0034; R. Purcell, 'Social Differentiation through Diet: an Isotopic Study of Anglo-Saxon Lakenheath' (unpubl. PhD dissertation, Cambridge Univ., 2012); B. D. Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England: Stable Isotope Analysis of Archaeological Human and Animal Remains' (unpubl. DPhil dissertation, Oxford Univ., 2007); Privat *et al.*, 'Stable Isotope Analysis of Human and Faunal Remains from the Anglo-Saxon Cemetery at Berinsfield, Oxfordshire'.

[4] Hagen, *Anglo-Saxon Food & Drink*, pp. 304–7.

symbolically significant communal feasts.[5] This conclusion is reinforced in this article, where we demonstrate that these food lists cannot be representative of elite diets because their exceptionally high proportion of animal products is inconsistent with the bioarchaeological evidence, primarily isotopic data. It instead shows that diets were more similar (isotopically) across social groups than previously thought. Most people in pre-Viking Age England ate only low to moderate amounts of animal protein, and there is nothing to suggest that those who consumed more were of higher status. Such dietary variations should be understood to result from differences in environment and agriculture between regions and larger scale chronological changes to foodways.

Assumptions around wealth and social status, and the number and kinds of grave goods are readily made in archaeology; and certain styles of female dress accessories are often taken to be ethnic signifiers.[6] Chris Scull highlights that one of the clearest forms of archaeological evidence for social structure in the fifth to seventh centuries is mortuary ritual, and that the graves of early medieval individuals clearly show socioeconomic hierarchy and inequality.[7] There are of course complexities in drawing social inferences from funerary archaeology, the largest of which is 'the dead don't bury themselves' followed closely by the incompleteness of the archaeological record; however, funerary deposits were clearly socially governed and are a useful tool in investigating how living communities operated, more so than settlement archaeology for this period.[8] The early documentary evidence (principally law codes from seventh-century Kent and Wessex and narrative works from eighth-century Northumbria) suggests a ranked society with slaves at the bottom, a free peasant muiajority, and an increasingly entrenched noble class associated with service to the king.[9] This picture is broadly consistent with that of funerary archaeology until the late

5 Hagen, *Anglo-Saxon Food & Drink*, p. 306; T. Lambert and S. Leggett, 'Food and Power in Early Medieval England: Rethinking *Feorm*', *ASE* 49 (2022), 1–47.

6 H. Geake, *The Use of Grave-Goods in Conversion-Period England, c.600–c.850*, BAR British Series 261 (Oxford, 1997); E. O'Brien, *Post-Roman Britain to Anglo-Saxon England: Burial Practices Reviewed*, BAR British Series 289 (Oxford, 1999); G. R. Owen-Crocker, *Dress in Anglo-Saxon England*, 2nd ed. (Woodbridge, 2010); P. Walton Rogers, 'Cloth, Clothing and Anglo-Saxon Women', *A Stitch in Time: Essays in honour of Lise Bender Jørgensen*, Gotarc Series A., Gothenburg Archaeological Studies 4 (Gothenburg, 2014), 253–80.

7 Christopher Scull, 'Social Transactions, Gift Exchange, and Power in the Archaeology of the Fifth to Seventh Centuries', *The Oxford Handbook of Anglo-Saxon Archaeology*, pp. 848–64.

8 *Ibid.*; M. Parker Pearson, *The Archaeology of Death and Burial*, Texas A & M University Anthropology Series 3 (College Station, 1999).

9 T. Lambert, *Law and Order in Anglo-Saxon England* (Oxford, 2017), pp. 50–51; T. M. Charles-Edwards, 'Social Structure', *A Companion to the Early Middle Ages*, ed. P. Stafford (Oxford, 2009), pp. 107–25, DOI: 10.1002/9781444311020.ch8.

sixth and seventh centuries, when furnished burial declines and clear status identifiers are lost.[10]

In the post-Roman period furnished burial was the norm from the fifth to seventh centuries, not just in England, but generally across much of Western Europe.[11] Ignoring here fifth-century cremation burials due to the challenges they pose for osteology and isotopic analyses,[12] generally, both furnished and unfurnished burials were common in England up to the late seventh and early eighth centuries. Inhumations of this period are highly varied in practice with numbers and kinds of grave goods, orientation, grave furniture, body position and other variables all part of a mutable and dynamic process of death.[13] Grave goods, when present, are often highly gendered, and suggest levels of social stratification, which fluctuate in meaning through time.[14] However, this seems to peter out in the seventh and eighth centuries and in England, at least, this coincides with the shift towards churchyard burials which are more tightly regulated, and most

[10] E. Brownlee, 'Connectivity and Funerary Change in Early Medieval Europe', *Antiquity* 95 (2021), 142–59, DOI: 10.15184/aqy.2020.153; E. Brownlee, 'Grave Goods in Early Medieval Europe: Regional Variability and Decline', *Internet Archaeol.* 56 (2021), DOI: 10.11141/ia.56.11; J. Buckberry, 'On Sacred Ground: Social Identity and Churchyard Burial in Lincolnshire and Yorkshire, c. 700–1100 AD', *Anglo-Saxon Studies in Archaeology and History 14: Early Medieval Mortuary Practices*, ed. S. Semple and H. Williams (Oxford, 2007), pp. 120–32, at 46; E. Craig-Atkins, 'Seeking "Norman Burials": Evidence for Continuity and Change in Funerary Practice Following the Norman Conquest', *The Archaeology of the Eleventh Century: Continuities and Transformations*, Society for Medieval Archaeology Monograph 38 (Abingdon, 2017), 139–58; Geake, *The Use of Grave-Goods*; S. Lucy, *The Anglo-Saxon Way of Death: Burial Rites in Early England* (Stroud, 2000).

[11] Lucy, *The Anglo-Saxon Way of Death*; Brownlee, 'Grave Goods in Early Medieval Europe'.

[12] G. J. Perry, 'Ceramic Hinterlands: Establishing the Catchment Areas of Early Anglo-Saxon Cremation Cemeteries', *World Archaeol.* 52 (2020), 163–82, DOI: 10.1080/00438243.2019.1741438; C. Snoeck, J. Lee-Thorp, R. Schulting, J. de Jong, W. Debouge and N. Mattielli, 'Calcined Bone Provides a Reliable Substrate for Strontium Isotope Ratios as Shown by an Enrichment Experiment: Strontium Isotope Ratios in Calcined Bone', *Rapid Communications in Mass Spectrometry* 29 (2015), 107–14, DOI: 10.1002/rcm.7078; C. Hills, *The Anglo-Saxon Cemetery at Spong Hill, North Elmham, Part I: Catalogue of Cremations*, East Anglian Archaeol. Report 6 (Gressenhall, 1977); J. McKinley, *The Anglo-Saxon Cemetery at Spong Hill, North Elmham, Part VIII: The Cremations* East Anglian Archaeol. Report 69 (Gressenhall, 1994).

[13] Lucy, *The Anglo-Saxon Way of Death*; Brownlee, 'Grave Goods in Early Medieval Europe'; E. C. Brownlee, 'The Dead and their Possessions: the Declining Agency of the Cadaver in Early Medieval Europe', *European Jnl of Archaeol.* 23 (2020), 406–27, DOI: 10.1017/eaa.2020.3.

[14] Lucy, *The Anglo-Saxon Way of Death*; A. Bayliss, J. Hines, K. Høilund Nielsen, G. McCormac and C. Scull, *Anglo-Saxon Graves and Grave Goods of the 6th and 7th Centuries AD: a Chronological Framework*, Soc. for Med. Archaeol. Monograph 33 (London, 2013); Brownlee, 'Grave Goods in Early Medieval Europe'; N. Stoodley, *The Spindle and the Spear: a Critical Enquiry into the Construction and Meaning of Gender in the Early Anglo-Saxon Burial Rite*, BAR British Series 288 (Oxford, 1999); S. Lucy, 'Gender and Gender Roles', *The Oxford Handbook of Anglo-Saxon Archaeology*, pp. 688–703, DOI: 10.1093/oxfordhb/9780199212149.013.0035.

importantly, unfurnished and difficult to date.[15] This means that beyond the mid-to-late-seventh and early eighth centuries determining social status through the funerary record is exceedingly difficult. Therefore, we refrain here from examining closely diet or social status beyond the use of furnished burial aside from broader chronological comparisons. However, dating issues with some sites mean that some later unfurnished individuals are likely to be present in the sample here and are discussed in more detail in analyses below.

As mentioned above, Banham, Franzten, Gautier and Hagen's work (amongst others) on early medieval agriculture and food has suggested that types and quality of food and drink varied with social status and gender roles; most notably that women and younger children were more likely to be hardest hit by food shortages, and there seems to be social precedence for being served at feasts and special occasions, but the assumption of a meat- and alcohol-heavy elite diet is still pervasive.[16] As Alban Gautier puts it '… there were those who had access to the "permanent feast" and those who did not … So, the poor did not eat like the rich, the weak did not drink like the powerful'.[17]

Hence here we analyse the data both in terms of sex and funerary treatment to attempt to tease these variables apart and test these assumptions. We largely remove children from the equation due to issues over the osteological paradox and isotopic complications introduced by studying deceased juveniles.[18]

[15] Bayliss *et al.*, *Anglo-Saxon Graves and Grave Goods*; Brownlee, 'Grave Goods in Early Medieval Europe'.

[16] Banham, *Food and Drink in Anglo-Saxon England*, pp. 71–76; A. J. Frantzen, *Food, Eating and Identity in Early Medieval England*, AS Stud. 22 (Woodbridge, 2014), 34–80; Hagen, *Anglo-Saxon Food & Drink*, pp. 451–62; Z. Knapp, 'The Zooarchaeology of the Anglo-Saxon Christian Conversion: Lyminge, a Case Study' (unpubl. PhD dissertation, Univ. Reading, 2018); C. Lee, 'Earth's Treasures: Food and Drink', *The Material Culture of Daily Living in the Anglo-Saxon World*, ed. M. Clegg Hyer and G. R. Owen-Crocker, Exeter Stud. in Med. Europe (Liverpool, 2013), pp. 142–56; Gautier, *Le Festin dans l'Angleterre anglo-saxonne (Ve-XIe siècle)*.

[17] '… il y avait ceux qui avaient accès au "festin permanent" et ceux qui n'y avaient pas accès … Ainsi, les pauvres ne mangeaient pas comme les riches, les faibles ne buvaient pas comme les puissants', Gautier, *Le Festin dans l'Angleterre anglo-saxonne (Ve-XIe siècle)*, p. 227. The translation is our own.

[18] The osteological paradox is the interpretational issue that arises from studying deceased populations – we cannot study alive 'healthy' individuals from any given time period, only those who are dead and therefore were not healthy, at least at the end of their life. With juveniles this is particularly true as they did not survive into adulthood and therefore do not constitute a 'normal' healthy child of their age group. Bodily stress caused by illness often wreaks havoc on collagen isotope values, nitrogen in particular see: H. Haydock, L. Clarke, E. Craig-Atkins, R. Howcroft and J. Buckberry, 'Weaning at Anglo-Saxon Raunds: Implications for Changing Breastfeeding Practice in Britain over Two Millennia', *Amer. Jnl of Physical Anthropology* 151 (2013), 604–12, DOI: 10.1002/ajpa.22316; J. Beaumont, E.-C. Atkins, J. Buckberry, H. Haydock, P. Horne, R. Howcroft, K. Mackenzie and J. Montgomery, 'Comparing Apples and Oranges: Why Infant Bone Collagen May Not Reflect Dietary Intake in the Same Way as Dentine Collagen', *Amer. Jnl of*

Previous isotopic studies of diet for the period have primarily been site or region specific.[19] Whilst some studies actively hunt for variation in the isotopic evidence and find social differentiation in diet,[20] larger multi-site studies have noted a distinct lack of social differentiation in diet from the fifth to the eighth centuries.[21] Certainly there is a high degree of regional variation in diets and isotopic baselines,[22] and we should not assume isotopic homogeneity across 'England' during a highly dynamic period. However, nor should we actively hunt for variation which may be biologically or socially meaningless as it is a 'statistical sin'.[23] This study will redress that balance by using an Exploratory Data Analysis approach, and analysing the data at various scales, constraining assumptions within the historical evidence analysed above.[24]

Physical Anthropology 167 (2018), 524–40, DOI: 10.1002/ajpa.23682; S. N. DeWitte and C. M. Stojanowski, 'The Osteological Paradox 20 Years Later: Past Perspectives, Future Directions', *Jnl of Archaeol. Research* 23 (2015), 397–450, DOI: 10.1007/s10814-015-9084-1; E. Kendall, A. Millard and J. Beaumont, 'The "Weanling's Dilemma" Revisited: Evolving Bodies of Evidence and the Problem of Infant Paleodietary Interpretation', *Amer. Jnl of Physical Anthropology* 18 (2021), DOI: 10.1002/ajpa.24207; B. T. Fuller, J. L. Fuller, N. E. Sage, D. A. Harris, T. C. O'Connell and R. E. M. Hedges, 'Nitrogen Balance and δ^{15}N: Why You're Not What You Eat during Nutritional Stress', *Rapid Communications in Mass Spectrometry* 19 (2005), 2497–2506, DOI: 10.1002/rcm.2090.

19 For example, F. E. Moore, 'Diet and Subsistence in the Anglo-Saxon Trent Valley: a Stable Isotope Investigation of Broughton Lodge Anglo-Saxon Cemetery, Nottinghamshire' (unpubl. MA dissertation, Univ. Nottingham, 2017); J. Montgomery, J. A. Evans, D. Powlesland and C. A. Roberts, 'Continuity or Colonization in Anglo-Saxon England? Isotope Evidence for Mobility, Subsistence Practice, and Status at West Heslerton', *Amer. Jnl of Physical Anthropology* 126 (2005), 123–38, DOI: 10.1002/ajpa.20111; S. Lucy, R. Newman, N. Dodwell, C. Hills, M. Dekker, T. O'Connell, I. Riddler and P. Walton Rogers, 'The Burial of a Princess? The Later Seventh-Century Cemetery at Westfield Farm, Ely', *Antiquaries Jnl* 89 (2009), 81–141, at 81, DOI: 10.1017/S0003581509990102; Haydock *et al.*, 'Weaning at Anglo-Saxon Raunds'.

20 Privat *et al.*, 'Stable Isotope Analysis of Human and Faunal Remains from the Anglo-Saxon Cemetery at Berinsfield, Oxfordshire'; Purcell, 'Social Differentiation through Diet'; D. Sayer, *Early Anglo-Saxon Cemeteries: Kinship, Community and Identity* (Manchester, 2020), pp. 209–14.

21 Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'; S. Mallet, 'Diets in England: Change, Continuity and Regionality between the Iron Age and Domesday Book (700 BC–1086 AD)' (unpubl. DPhil dissertation, Oxford Univ., 2016); Hannah *et al.*, 'Anglo-Saxon Diet in the Conversion Period'.

22 Mallet, 'Diets in England'; S. A. Leggett, '"Tell Me What You Eat, and I Will Tell You Who You Are": a Multi-Tissue and Multi-Scalar Isotopic Study of Diet and Mobility in Early Medieval England and Its European Neighbours' (unpubl. PhD dissertation, Cambridge Univ., 2020), DOI: 10.17863/CAM.63545; K. Boulden, 'A Bioarchaeological Reassessment of Land-Use Practices from the Neolithic to the Roman Period in Central Southern Britain Using Stable Isotope Analysis and Machine Learning Methods' (unpubl. PhD dissertation, Cambridge Univ., 2016).

23 J. W. Tukey, *Exploratory Data Analysis* (Reading, MA, 1977).

24 *Ibid.*

What is even more elusive are isotopic studies on definitively 'royal' or 'noble' individuals from this period. Whilst 'princely' graves like those at Sutton Hoo, Prittlewell and Benty Grange are likely candidates for such individuals, no skeletal remains survive to analyse.[25] The phenomena of bed burials may be marking out high status women in a special and short-lived way in the seventh century, and whilst these burials are rarely richly furnished in the number of grave goods, their burial on a bed often with select, highly valuable items (like the gold and garnet cross with Grave 1 at Trumpington Meadows) may denote their royal and Christian connections.[26] More skeletons survive from bed burials than they do from 'princely' graves (seven of the fourteen confirmed bed burials have some bone surviving), and four of them have been analysed isotopically, with their data included here.[27] They do not stand out in our dietary analyses, but more work on these fascinating graves is forthcoming. There has also been recent radiocarbon dating and ancient DNA work (and presumably accompanying isotopic analyses) on the funerary chests in Winchester Cathedral, believed to be the remains of late-Saxon and Anglo-Norman royalty, including: Cynegils of Wessex, Bishop Wini, Cynewulf of Wessex, Egbert of Wessex, Æthelwulf of Wessex, Eadred of Wessex, Emma of Normandy, Edmund Ironside, Cnut the Great, Bishop Ælfwyn and William (II) Rufus, and additional unexpected individuals thought to be other members of the royal family of Wessex.[28] Sadly these results are yet to be fully

25 M. O. H. Carver, *Sutton Hoo: Burial Ground of Kings?* (London, 1998); S. M. Hirst, *The Prittlewell Prince: The Discovery of a Rich Anglo-Saxon Burial in Essex* (London, 2004); see the record for the Benty Grange Helmet held at the Sheffield Museums website, Accession Number J93.1189; the site of Benty Grange Hlaew, Monyash is presently a scheduled monument according to the website of Historic England (list entry number 1013767).

26 G. Speake, *A Saxon Bed Burial on Swallowcliffe Down*, Eng. Heritage Archaeol. Report 10 (London, 1989); N. Stoodley and J. Schuster, 'Collingbourne Ducis, Wiltshire: an Early Saxon Cemetery with Bed Burial', *Glaube, Kult und Herrschaft: Phänomene des Religiösen im 1. Jahrtausend n. Chr. in Mittel- und Nordeuropa ; Akten des 59. Internationalen Sachsensymposions und der Grundprobleme der frühgeschichtlichen Entwicklung im Mitteldonauraum*, ed. U. von Freeden, H. Friesinger and E. Wamers, Kolloquien zur Vor- und Frühgeschichte 12 (Bonn, 2009), 489–96; J. Watson, *Smythes Corner (Shrublands Quarry), Coddenham, Suffolk: the Examination and Reconstruction of an Anglo-Saxon Bed Burial* (Portsmouth, 2006); C. Evans, S. Lucy and R. Patten, 'Chapter 5 – Anglo-Saxon Burials and Settlement', *Riversides: Neolithic Barrows, a Beaker Grave, Iron Age and Anglo-Saxon Burials and Settlement at Trumpington, Cambridge*, ed. C. Evans, S. Lucy and R. Patten, CAU Landscape Archives: New Archaeologies of the Cambridge Region 2 (Cambridge, 2018), 307-32; S. Lucy, 'The Trumpington Cross in Context', *ASE* 45 (2016), 7–37, DOI: 10.1017/S0263675100080200.

27 Leggett *et al.*, 'Multi-Tissue and Multi-Isotope (δ^{13}C, δ^{15}N, δ^{18}O and $^{87/86}$Sr) Data for Early Medieval Human and Animal Palaeoecology'; Evans *et al.*, 'Chapter 5 – Anglo-Saxon Burials and Settlement'.

28 'Winchester Cathedral's Mortuary Chests Unlocked', University of Bristol website, 16 May 2019, https://www.bristol.ac.uk/news/2019/may/winchester-cathedral-chests.html; 'The Riddle of Winchester Cathedral's Skeletons', *BBC News*, 18 May 2019, sec. Hampshire & Isle of Wight, https://www.bbc.com/news/uk-england-hampshire-48300450.

published, but could give definite answers about what English rulers were eating and drinking, and if their diet changed much between the seventh and twelfth centuries.

This article will first tackle dietary evidence and social status from across early medieval England as a whole and then look specifically at cemeteries from Wessex to minimise the impact of regional variation on the data.

BACKGROUND

'FOOD RENDERS' AND ELITE CONSUMPTION

We point readers to the companion article to this one for a more in-depth discussion on our assessment of the food list texts and their context;[29] however, it is useful here to discuss the calculations and assumptions carried through into the analysis of the isotopic data below. This is clause 70.1 of the laws of King Ine of Wessex (r. 688–726): 'From ten hides as *fostre*: ten *fata* of honey, 300 loaves, twelve *ambra* of Welsh ale, thirty of clear ale, two full-grown cattle or ten wethers, ten geese, twenty hens, ten cheeses, an *amber* full of butter, five salmon, twenty *pundwæge* of fodder and 100 eels'.[30] We estimated the volume, weight, and calorie content of each of the food stuffs listed here, and in the handful of broadly comparable lists, using a range of historical and zooarchaeological evidence in conjunction with information on modern livestock and the nutritional composition of foods. Our calculations suggest that the foods listed by Ine were disproportionately skewed towards animal products. A 'loaf' in this context is likely to mean a small round bun, an individual portion at most and highly unlikely to weigh more than the 300 grams we have assumed. For each such loaf, Ine's list includes 1.2 kg of meat, fish, and cheese, as well as approximately 2.1 litres of ale. A remarkable fifty-five per cent of the list's total calories derive from animal products, and if (as is likely) each loaf represents a single imagined diner, an individual meal was 4,140 kcal. None of these figures can be relied on precisely, of course, but the estimates underlying them have robust bases for the bread and livestock, where it matters most. The impression they provide of the scale and proportions of the foods demanded can be trusted.[31] Moreover, as we show, the scale and proportions of Ine's list is broadly consistent with those of the food lists contained in a range of other texts, dating from the late eighth to the late tenth

29 Lambert and Leggett, 'Food and Power in Early Medieval England: Rethinking *Feorm*'.

30 'Æt x hidum to fostre x fata hunies, ccc hlafa, xii ambra wilisc ealað, xxx hluttres, tu eald hriðeru oððe x weðeras, x gees, xx henna, x cesas, amber fulne buteran, v leaxas, xx pundwæga foðres 7 hundteontig æla,' S. Jurasinski and L. Oliver, *The Laws of Alfred: the* Domboc *and the Making of Anglo-Saxon Law* (Cambridge, 2021), pp. 430–31; F. Liebermann, *Die Gesetze der Angelsachsen*, 3 vols. (Halle, 1903–16) I, 118–19. The translation is our own.

31 Lambert and Leggett, 'Food and Power in Early Medieval England: Rethinking *Feorm*'.

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centuries, from Gloucestershire, Kent, and Hertfordshire, which hail from royal and ecclesiastical contexts.[32] These similarities have long been noted and have sometimes been assumed to reflect a degree of institutional continuity, with ecclesiastical food renders representing privatised versions of the king's 'farm of one night'.[33] Our contention is that this is a misunderstanding and that these food lists have similar proportions because they are all lists of provisions for a specific sort of meal, a lavish feast typically involving several hundred guests. These were not the lists of general-purpose food supplies that the literature has widely assumed them to be. Rather, they constituted feasting food for special occasions with implications for community building and politics. This is not to downplay the key economic role of food and animals, especially cattle, in early medieval England – far from it. However, as we demonstrate below, the easy assumption that these texts provide evidence for what day-to-day meals looked like for elite households must be rejected, as the direct evidence from skeletons shows.

STABLE ISOTOPE BACKGROUND

Light stable isotope analysis has become a regularly used technique in archaeological science to help answer questions surrounding diet and mobility in the past. Carbon and nitrogen stable isotope analysis for dietary reconstruction in archaeological contexts is a well-established methodology which is based on the principle that different foods differ in their isotopic compositions and that these can be quantified in the foods themselves and in the tissues of consumers. The core premise is 'you are what you eat (and drink)' plus or minus a few permille (‰).[34] The foods and beverages you consume are incorporated into your bodily tissues and thus a chemical signature of diet for the period that tissue was formed is preserved. Different tissues remodel at different rates, giving archaeologists different windows into diet across an individual's life if samples are chosen wisely. Bones preserve a much longer isotopic average of the food consumed for an

32 Lambert and Leggett, 'Food and Power in Early Medieval England: Rethinking *Feorm*'.

33 C. Wickham, *Framing the Early Middle Ages: Europe and the Mediterranean, 400—800* (Oxford, 2005), p. 321, DOI: 10.1093/acprof:oso/9780199264490.001.0001.

34 Stable isotope measurements are reported as a ratio of the heavy to the light isotope in relation to internationally defined standards in units permille (‰) – VPDB ($\delta^{13}C$) and AIR ($\delta^{15}N$). Where $\delta^{15}N_{AIR} = [(^{15/14}N_{sample}/^{15/14}N_{AIR})\text{-}1]$, and $\delta^{13}C_{VPDB} = [(^{13/12}C_{sample}/^{13/12}C_{VPDB})\text{-}1]$. T. Brown and K. Brown, *Biomolecular Archaeology: an Introduction* (Chichester, 2011); T. B. Coplen, 'Guidelines and Recommended Terms for Expression of Stable-Isotope-Ratio and Gas-Ratio Measurement Results', *Rapid Communications in Mass Spectrometry* 25 (2011), 2538–60, DOI: 10.1002/rcm.5129; J. Hoefs, *Stable Isotope Geochemistry*, 6th ed. (Berlin, 2009); T. Douglas Price and J. H. Burton, *An Introduction to Archaeological Chemistry* (New York, 2012).

individual, with long bones such as femurs estimated to have a turnover rate of several decades, whilst ribs represent approximately up to one decade before death. Dentine from tooth roots has tighter constraints, with dentine not remodelling once formed; so for third molars (wisdom teeth) for instance the roots start forming at approximately twelve to sixteen years old and finish between eighteen to twenty-five years, and so represent consumption during adolescence and early adulthood, whereas a permanent (adult) first molar crown begins forming at birth, with roots capturing dietary signatures from two-and-a-half to ten years old.[35]

Isotopic composition in the biosphere is highly variable and is affected by a variety of different processes depending on the element in question.[36] Isotope fractionation is the term that describes these processes which cause the relative abundance of difference in isotopes between substances, or the partitioning of the heavier and lighter isotopes.[37] The ratios of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ in the environment and the food chain are therefore changeable and depend on many different variables. These natural variations in isotope ratios in the ecosystem form the basis of isotope analysis in archaeology and ecology, as measurable differences can be associated with human/animal behaviours.

Plants are the base of most terrestrial food chains and the isotopic variation in them will be passed on to consumers, be they herbivores or humans.[38] Carbon in plant tissues is a product of photosynthesis where atmospheric carbon dioxide is turned into oxygen (expelled) and glucose (stored for the plant to use), and isotopic fractionation occurs during this process.[39] There are three photosynthetic pathways – C_3, C_4 and CAM – each fixes carbon in a different way which results in ^{13}C value differences between plant types.[40] As this study focuses on early medieval England, only C_3 (most cereals and vegetables) and C_4 plants are of interest here (CAM plants being desert species such as cacti and

35 R. C. Scheid, *Woelfel's Dental Anatomy: its Relevance to Dentistry*, 7th ed. (Baltimore, 2007), pp. 327–29.

36 Hoefs, *Stable Isotope Geochemistry*, pp. 334–82.

37 M. Tiwari, A. K. Singh and D. K. Sinha, 'Chapter 3 – Stable Isotopes: Tools for Understanding Past Climatic Conditions and their Applications in Chemostratigraphy', *Chemostratigraphy*, ed. M. Ramkumar (Oxford, 2015), pp. 65–92, DOI: 10.1016/B978-0-12-419968-2.00003-0.

38 G. D. Farquhar, J. R. Ehleringer and K. T. Hubick, 'Carbon Isotope Discrimination and Photosynthesis', *Ann. Rev. of Plant Physiology and Plant Molecular Biology* 40 (1989), 503–37, DOI: 10.1146/annurev.pp.40.060189.002443; M. H. O'Leary, 'Carbon Isotopes in Photosynthesis', *BioScience* 38 (1988), 328–36, DOI: 10.2307/1310735; L. L. Tieszen, T. W. Boutton, K. G. Tesdahl and N. A. Slade, 'Fractionation and Turnover of Stable Carbon Isotopes in Animal Tissues: Implications for $\delta^{13}C$ Analysis of Diet', *Oecologia* 57 (1983), 32–37, DOI: 10.1007/BF00379558.

39 Farquhar *et al.*, 'Carbon Isotope Discrimination and Photosynthesis'; O'Leary, 'Carbon Isotopes in Photosynthesis'.

40 Farquhar *et al.*, 'Carbon Isotope Discrimination and Photosynthesis'; O'Leary, 'Carbon Isotopes in Photosynthesis'; Hoefs, *Stable Isotope Geochemistry*, p. 52.

succulents). Millet, sago and amaranth are the only known C_4 plants to be consumed in Continental Europe in the early Middle Ages, but were not known in Britain until the later Middle Ages.[41] C_3 plants have a possible $\delta^{13}C$ range of between –38 to –22‰, and C_4 plants between –21 to –9‰, when analysed as a whole plant, with some variation between species and plant tissues.[42] Therefore when we find relatively elevated $\delta^{13}C_{coll}$ values in early medieval England, a possible interpretation could be that these individuals were migrants from regions where C_4 plants were consumed (e.g. Croatia or Italy).[43] However, a more plausible explanation in this context, as we explain below, is marine resource consumption.

41 K. W. Alt, C. Knipper, D. Peters, W. Müller, A.-F. Maurer, I. Kollig, N. Nicklisch, C. Müller, S. Karimnia, G. Brandt, C. Roth, M. Rosner, B. Mende, B. R. Schöne, T. Vida and U. von Freeden, 'Lombards on the Move – an Integrative Study of the Migration Period Cemetery at Szólád, Hungary', ed. L. Bondioli, *PLoS ONE* 9 (2014), e110793, DOI: 10.1371/journal.pone.0110793; G. Ganzarolli, M. Alexander, A. Chavarria Arnau and O. E. Craig, 'Direct Evidence from Lipid Residue Analysis for the Routine Consumption of Millet in Early Medieval Italy', *Jnl of Archaeol. Science* 96 (2018), 124–30, DOI: 10.1016/j.jas.2018.06.007; Hagen, *Anglo-Saxon Food & Drink*, pp. 23, 33, 38–39; S. E. Hakenbeck, J. Evans, H. Chapman and E. Fóthi, 'Practising Pastoralism in an Agricultural Environment: an Isotopic Analysis of the Impact of the Hunnic Incursions on Pannonian Populations', *PLoS ONE* 12 (2017), DOI: 10.1371/journal.pone.0173079.

42 Hoefs, *Stable Isotope Geochemistry*, p. 52; O'Leary, 'Carbon Isotopes in Photosynthesis'; L. L. Tieszen, 'Natural Variations in the Carbon Isotope Values of Plants: Implications for Archaeology, Ecology, and Paleoecology', *Jnl of Archaeol. Science* 18 (1991), 227–48, DOI: 10.1016/0305-4403(91)90063-U; N. J. van der Merwe, 'Carbon Isotopes, Photosynthesis, and Archaeology: Different Pathways of Photosynthesis Cause Characteristic Changes in Carbon Isotope Ratios that Make Possible the Study of Prehistoric Human Diets', *Amer. Scientist* 70 (1982), 596–606. Photosynthesis and thus stable isotope ratios in plants (of both carbon and nitrogen) are inextricably linked with the plant's growing environment – water availability, light, altitude, heat, the canopy effect, salinity and plant physiology can all impact on plant stable isotope ratios. Farquhar *et al.*, 'Carbon Isotope Discrimination and Photosynthesis'; E. Lightfoot, N. Przelomska, M. Craven, T. C. O'Connell, Lu He, H. V. Hunt and M. K. Jones, 'Intraspecific Carbon and Nitrogen Isotopic Variability in Foxtail Millet (*Setaria Italica*)', *Rapid Communications in Mass Spectrometry* 30 (2016), 1475–87, DOI: 10.1002/rcm.7583; E. Lightfoot, M. Cemre Ustunkaya, N. Przelomska, T. C. O'Connell, H. V. Hunt, M. K. Jones and C. A. Petrie, 'Carbon and Nitrogen Isotopic Variability in Foxtail Millet (*Setaria Italica*) with Watering Regime', *Rapid Communications in Mass Spectrometry* 34 (2020), DOI: 10.1002/rcm.8615; O'Leary, 'Carbon Isotopes in Photosynthesis'; Tieszen, 'Natural Variations in the Carbon Isotope Values of Plants'; van der Merwe, 'Carbon Isotopes, Photosynthesis, and Archaeology'.

43 For example, C. E. G. Amorim, S. Vai, C. Posth, A. Modi, I. Koncz, S. Hakenbeck, M. C. La Rocca, B. Mende, D. Bobo, W. Pohl, L. Pejrani Baricco, E. Bedini, P. Francalacci, C. Giostra, T. Vida, D. Winger, U. von Freeden, S. Ghirotto, M. Lari, G. Barbujani, J. Krause, D. Caramelli, P. J. Geary and K. R. Veeramah, 'Understanding 6th-Century Barbarian Social Organization and Migration through Paleogenomics', *Nature Communications* 9 (2018), 1–11, DOI: 10.1038/s41467-018-06024-4; Vidal-Ronchas *et al.*, 'Diet, Sex, and Social Status in the Late Avar Period: Stable Isotope Investigations at Nuštar Cemetery, Croatia'.

Diversity in aquatic plants and extended food webs in both freshwater and marine ecosystems means that isotopic signatures of plants and animals in these environments are highly variable with large intra- and inter-species variations observed, particularly in freshwater fish.[44] Carbon isotopic signatures in these ecosystems are particularly complex. This complexity is highlighted by the high degree of overlap between freshwater fish bone collagen δ^{13}C and δ^{15}N values and those of terrestrial and marine species.[45]

Marine δ^{13}C values are higher in comparison with terrestrial environments due to their long and complex food chains and carbon reservoir effect. This means they are easily isotopically distinguished in the tissues of producers and consumers.[46] However, there is an interpretational problem due to the overlap between δ^{13}C values of C_4 consumers, marine consumers, and consumers of mixed plant or terrestrial/marine diets.[47] Therefore isotopically separating these consumption patterns is extremely difficult without good baseline evidence or other contextual dietary information (archaeological or historical) to constrain interpretations.

Many of the causes of δ^{15}N variation in nature are the same as δ^{13}C described above – water availability, heat, the canopy effect *etc*. Differences in ecosystems are

[44] A. Ervynck, M. Boudin and W. Van Neer, 'Assessing the Radiocarbon Freshwater Reservoir Effect for a Northwest-European River System (the Schelde Basin, Belgium)', *Radiocarbon* 60 (2018), 395–417, DOI: 10.1017/RDC.2017.148; E. Guiry, 'Complexities of Stable Carbon and Nitrogen Isotope Biogeochemistry in Ancient Freshwater Ecosystems: Implications for the Study of Past Subsistence and Environmental Change', *Frontiers in Ecology and Evolution* 7 (2019), DOI: 10.3389/fevo.2019.00313; R. E. M. Hedges and L. M. Reynard, 'Nitrogen Isotopes and the Trophic Level of Humans in Archaeology', *Jnl of Archaeol. Science* 34 (2007), 1240–51, DOI: 10.1016/j.jas.2006.10.015; Hoefs, *Stable Isotope Geochemistry*, p. 153.

[45] J. I. Jones and S. Waldron, 'Combined Stable Isotope and Gut Contents Analysis of Food Webs in Plant-Dominated, Shallow Lakes', *Freshwater Biology* 48 (2003), 1396–1407, DOI: 10.1046/j.1365-2427.2003.01095.x; O. Nehlich, D. Borić, S. Stefanović and M. P. Richards, 'Sulphur Isotope Evidence for Freshwater Fish Consumption: a Case Study from the Danube Gorges, SE Europe', *Jnl of Archaeol. Science* 37 (2010), 1131–39, DOI: 10.1016/j.jas.2009.12.013; Guiry, 'Complexities of Stable Carbon and Nitrogen Isotope Biogeochemistry in Ancient Freshwater Ecosystems'.

[46] B. S. Chisholm, D. E. Nelson and H. P. Schwarcz, 'Stable-Carbon Isotope Ratios as a Measure of Marine Versus Terrestrial Protein in Ancient Diets', *Science* 216 (1982), 1131–32, DOI: 10.1126/science.216.4550.1131; G. Müldner, 'Marine Fish Consumption in Medieval Britain: the Isotope Perspective from Human Skeletal Remains', *Cod and Herring: the Archaeology and History of Medieval Sea Fishing*, ed. J. H. Barrett and D. C. Orton (Oxford, 2016), pp. 239–49; M. J. Schoeninger and M. J. DeNiro, 'Nitrogen and Carbon Isotopic Composition of Bone Collagen from Marine and Terrestrial Animals', *Geochimica et Cosmochimica Acta* 48 (1984), 625–39, DOI: 10.1016/0016-7037(84)90091-7; H. Tauber, '13 C Evidence for Dietary Habits of Prehistoric Man in Denmark', *Nature* 292 (1981), 332–33, DOI: 10.1038/292332a0.

[47] Chisholm *et al.*, 'Stable-Carbon Isotope Ratios as a Measure of Marine Versus Terrestrial Protein in Ancient Diets'; M. C. Lewis and J. C. Sealy, 'Coastal Complexity: Ancient Human Diets Inferred from Bayesian Stable Isotope Mixing Models and a Primate Analogue', *PLoS ONE* 13 (2018), DOI: 10.1371/journal.pone.0209411; van der Merwe, 'Carbon Isotopes, Photosynthesis, and Archaeology'.

as apparent in δ^{15}N values as they are in δ^{13}C, aiding in the distinction between terrestrial and marine resource consumption. In animal tissues δ^{15}N increases stepwise up the food chain so that carnivores have higher values than omnivores and omnivores higher than herbivores, with each step called a 'trophic level', with δ^{15}N assumed to increase between 3–5‰ between each level.[48]

Terrestrial plants assimilate nitrogen from decaying organic matter and the atmosphere via two pathways – direct nitrogen (N_2) fixation, and assimilation with help from soil microbes or commensal microbes living in the plant's roots (e.g. legumes).[49] The differences in these pathways causes fractionation giving direct nitrogen fixers δ^{15}N values similar to atmospheric values (0‰).[50] Whereas nitrogen assimilators (non-fixers), the majority of terrestrial plants, have δ^{15}N values ranging from 2–10‰ due to variation in soil isotopic values which can be altered through processes such as manuring or water logging.[51]

In marine ecosystems nitrogen is fixed by both algae and phytoplankton and can also enter food chains from decomposing organic matter in the oceans.[52] The main cause of denitrification in marine systems is from water evaporation, which favours the lighter isotope, leaving these ecosystems isotopically enriched in ^{15}N. This evapo-concentration combined with the longer marine food chains described above, leads to marine organisms having higher δ^{15}N values compared to their terrestrial counterparts.[53] Long aquatic food chains are also the main

48 S. H. Ambrose, 'Stable Carbon and Nitrogen Isotope Analysis of Human and Animal Diet in Africa', *Jnl of Human Evolution* 15 (1986), 707–31, DOI: 10.1016/S0047-2484(86)80006-9; S. H. Ambrose, 'Effects of Diet, Climate and Physiology on Nitrogen Isotope Abundances in Terrestrial Foodwebs', *Jnl of Archaeol. Science* 18 (1991), 293–317, DOI: 10.1016/0305-4403(91)90067-Y; Hedges, 'On Bone Collagen?'; Hedges and Reynard, 'Nitrogen Isotopes and the Trophic Level of Humans in Archaeology'.

49 Hoefs, *Stable Isotope Geochemistry*, pp. 54–55.

50 *Ibid.*; D. Robinson, 'δ^{15}N as an Integrator of the Nitrogen Cycle', *Trends in Ecology & Evolution* 16 (2001), 153–62, DOI: 10.1016/S0169-5347(00)02098-X.

51 A. Bogaard, T. H. E. Heaton, P. Poulton and I. Merbach, 'The Impact of Manuring on Nitrogen Isotope Ratios in Cereals: Archaeological Implications for Reconstruction of Diet and Crop Management Practices', *Jnl of Archaeol. Science* 34 (2007), 335–43, DOI: 10.1016/j.jas.2006.04.009; Hoefs, *Stable Isotope Geochemistry*, 55; Lightfoot *et al.*, 'Intraspecific Carbon and Nitrogen Isotopic Variability in Foxtail Millet (*Setaria Italica*)'; Lightfoot *et al.*, 'Carbon and Nitrogen Isotopic Variability in Foxtail Millet (*Setaria Italica*) with Watering Regime'; Schoeninger and DeNiro, 'Nitrogen and Carbon Isotopic Composition of Bone Collagen from Marine and Terrestrial Animals'.

52 N. Gruber, 'The Dynamics of the Marine Nitrogen Cycle and Its Influence on Atmospheric CO_2 Variations', *The Ocean Carbon Cycle and Climate*, ed. M. Follows and T. Oguz, NATO Science Series 40 (Dordrecht, 2004), 97–148, DOI: 10.1007/978-1-4020-2087-2_4; N. Gruber, 'The Marine Nitrogen Cycle: Overview and Challenges', *Nitrogen in the Marine Environment*, ed. D. C. Capone and E. J. Carpenter, 2nd ed. (London, 2008), pp. 1–50.

53 M. P. Richards and R. E. M. Hedges, 'Stable Isotope Evidence for Similarities in the Types of Marine Foods Used by Late Mesolithic Humans at Sites Along the Atlantic Coast of Europe', *Jnl*

driving factor for freshwater ^{15}N enrichment, as mentioned above with carbon in these ecosystems.[54]

Another important factor to consider with nitrogen, especially in humans, is nitrogen balance. It is the equilibrium in our bodies between protein intake (from diet) and loss (through metabolism and excretion). If this equilibrium is thrown out then the body might start to self-metabolise, breaking down its own tissues for fuel. This balance between energy intake and expenditure can be disturbed by illness or nutritional stress causing isotopic changes in bodily tissues. Research also suggests that in otherwise healthy individuals, lactation, pregnancy and growth during puberty where the energy demands of the body exceed dietary input, likely cause isotopic changes similar to periods of illness.[55] The impact of stress on δ^{15}N values is exemplified by work on Irish famine populations where a 'stress bubble' can be seen in incremental dentine slices of people who survived the famine.[56]

of Archaeol. Science 26 (1999), 717–22, DOI: 10.1006/jasc.1998.0387; Schoeninger and DeNiro, 'Nitrogen and Carbon Isotopic Composition of Bone Collagen from Marine and Terrestrial Animals'.

54 Guiry, 'Complexities of Stable Carbon and Nitrogen Isotope Biogeochemistry in Ancient Freshwater Ecosystems'; Hoefs, *Stable Isotope Geochemistry*, p. 154; Jones and Waldron, 'Combined Stable Isotope and Gut Contents Analysis of Food Webs in Plant-Dominated, Shallow Lakes'; Privat *et al.*, 'The Distinction between Freshwater- and Terrestrial-Based Diets'.

55 C. T. Clark, A. H. Fleming, J. Calambokidis, N. M. Kellar, C. D. Allen, K. N. Catelani, M. Robbins, N. E. Beaulieu, D. Steel and J. T. Harvey, 'Heavy with Child? Pregnancy Status and Stable Isotope Ratios as Determined from Biopsies of Humpback Whales', *Conservation Physiology* 4 (2016), DOI: 10.1093/conphys/cow050; Fuller *et al.*, 'Nitrogen Balance and δ^{15}N'; Haydock *et al.*, 'Weaning at Anglo-Saxon Raunds'; E. K. Nitsch, L. T. Humphrey and R. E. M. Hedges, 'The Effect of Parity Status on δ^{15}N: Looking for the "Pregnancy Effect" in 18th and 19th Century London', *Jnl of Archaeol. Science* 37 (2010), 3191–99, DOI: 10.1016/j.jas.2010.07.019; L. J. Reitsema, 'Beyond Diet Reconstruction: Stable Isotope Applications to Human Physiology, Health, and Nutrition', *Amer. Jnl of Human Biology* 25 (2013), 445–56, DOI: 10.1002/ajhb.22398; J. Beaumont and J. Montgomery, 'The Great Irish Famine: Identifying Starvation in the Tissues of Victims Using Stable Isotope Analysis of Bone and Incremental Dentine Collagen', *PLoS ONE* 11 (2016), DOI: 10.1371/journal.pone.0160065.

56 A 'stress bubble' on an incremental dentine chart occurs when the ^{15}N values go up and the ^{13}C values more or less remain constant around the nutritional stress event thus creating co-occurring anomalies and a 'bubble' on the chart is formed. Isotopic analysis of incremental dentine, a technique not used here, uses fine slices along a cross-section of the tooth root to look at diet through the period of that tissue's formation. Beaumont *et al.*, 'Comparing Apples and Oranges'; Julia Beaumont *et al.*, 'Infant Mortality and Isotopic Complexity: New Approaches to Stress, Maternal Health, and Weaning', *Amer. Jnl of Physical Anthropology* 157 (2015), 441–57, DOI: 10.1002/ajpa.22736; Beaumont and Montgomery, 'The Great Irish Famine'; J. Beaumont, A. Gledhill, J. Lee-Thorp and J. Montgomery, 'Childhood Diet: a Closer Examination of the Evidence from Dental Tissues Using Stable Isotope Analysis of Incremental Human Dentine', *Archaeometry* 55 (2013), 277–95; E. Craig-Atkins, J. Towers and J. Beaumont, 'The Role of Infant Life Histories in the Construction of Identities in Death: an Incremental Isotope Study of Dietary and Physiological Status among Children Afforded Differential Burial', *Amer. Jnl of Physical Anthropology* 167 (2018), 644–55, DOI: 10.1002/ajpa.23691; C. L. King, A. R. Millard, D. R.

Nutritional stress and breastfeeding are therefore also isotopically visible in tissues of mothers and infants, making early life health events traceable using this methodology.[57]

When there is not sufficient protein in someone's diet (either through starvation or by choice, e.g., veganism) the body routes carbon from whole diet (carbohydrates, lipids and any residual protein from plants) into collagen which is usually skewed towards protein intake. So, whilst no 'stress bubble' is seen in δ^{13}C values, δ^{15}N values will appear low, and this re-routing can impact interpretations of isotopic values. Conversely, the more protein there is in the diet, the more carbon will be sourced from that portion of the diet.[58] Therefore modern veganism is isotopically identifiable in δ^{15}N values and looks like other herbivorous mammals. Controlled dietary studies show significant differences between people with no animal protein intake compared with those who have various levels of omnivory (whether it be secondary animal products like milk, cheese or eggs, or meat).[59]

Gröcke, V. G. Standen, B. T. Arriaza and S. E. Halcrow, 'A Comparison of Using Bulk and Incremental Isotopic Analyses to Establish Weaning Practices in the Past', *STAR: Science & Technology of Archaeol. Research* 3 (2017), 126–34, DOI: 10.1080/20548923.2018.1443548.

57 Beaumont *et al*., 'Infant Mortality and Isotopic Complexity'; Beaumont *et al*., 'Comparing Apples and Oranges'; K. D. Crowder, J. Montgomery, D. R. Gröcke and Kori L. Filipek, 'Childhood "Stress" and Stable Isotope Life Histories in Transylvania', *International Jnl of Osteoarchaeol.* 29 (2019), 644–53, DOI: 10.1002/oa.2760; Fuller *et al*., 'Nitrogen Balance and δ^{15}N'; B. T. Fuller *et al*., 'Isotopic Evidence for Breastfeeding and Possible Adult Dietary Differences from Late/Sub-Roman Britain', *Amer. Jnl of Physical Anthropology* 129 (2006), 45–54, DOI: 10.1002/ajpa.20244; Haydock *et al*., 'Weaning at Anglo-Saxon Raunds'.

58 D. Codron, M. Sponheimer, J. Codron, I. Newton, J. L. Lanham and M. Clauss, 'The Confounding Effects of Source Isotopic Heterogeneity on Consumer-Diet and Tissue-Tissue Stable Isotope Relationships', *Oecologia* 169 (2012), 939–53, DOI: 10.1007/s00442-012-2274-3; Daryl Codron, M. Clauss, J. Codron and T. Tütken, 'Within Trophic Level Shifts in Collagen-Carbonate Stable Carbon Isotope Spacing Are Propagated by Diet and Digestive Physiology in Large Mammal Herbivores', *Ecology and Evolution* 8 (2018), 3983–95, DOI: 10.1002/ece3.3786; S. Jim, S. H. Ambrose and R. P. Evershed, 'Stable Carbon Isotopic Evidence for Differences in the Dietary Origin of Bone Cholesterol, Collagen and Apatite: Implications for their Use in Palaeodietary Reconstruction', *Geochimica et cosmochimica acta* 68 (2004), 61–72; S. Jim, V. Jones, S. H. Ambrose and R. P. Evershed, 'Quantifying Dietary Macronutrient Sources of Carbon for Bone Collagen Biosynthesis Using Natural Abundance Stable Carbon Isotope Analysis', *Brit. Jnl of Nutrition* 95 (2006), 1055–62, DOI: 10.1079/BJN20051685.

59 M. A. Katzenberg and H. R. Krouse, 'Application of Stable Isotope Variation in Human Tissues to Problems in Identification', *Canadian Soc. of Forensic Science Jnl* 22 (1989), 7–19, DOI: 10.1080/00085030.1989.10757414; M. Minagawa, 'Reconstruction of Human Diet from σ^{13}C and σ^{15}N in Contemporary Japanese Hair: a Stochastic Method for Estimating Multi-Source Contribution by Double Isotopic Tracers', *Applied Geochemistry* 7 (1992), 145–58, DOI: 10.1016/0883-2927(92)90033-Y; T. C. O'Connell, C. J. Kneale, N. Tasevska and G. G. C. Kuhnle, 'The Diet-Body Offset in Human Nitrogen Isotopic Values: a Controlled Dietary Study', *Amer. Jnl of Physical Anthropology* 149 (2012), 426–34, DOI: 10.1002/ajpa.22140; T. C. O'Connell and R. E. M. Hedges, 'Investigations into the Effect of Diet on Modern Human Hair Isotopic Values', *Amer. Jnl of Physical Anthropology* 108 (1999), 409–25, DOI: 10.1002/(SICI)1096-8644(

OTHER BIOARCHAEOLOGICAL EVIDENCE

For our purposes, the great benefit of stable isotope analysis is that, despite the range of possible confounding factors, it can yield insights into the relative significance of different foodstuffs within early medieval diets. There are of course other forms of bioarchaeological evidence for diet which can enrich our understanding of foodway economics in early medieval England by providing finer-grained detail on the types of food that were eaten, even if it is more difficult to bring them to bear on questions about their overall significance in ordinary diets. These include zooarchaeology, archaeobotany, biomolecular studies of residues in pottery (lipids and proteins) and dental calculus (calcified dental plaque/tartar which can be studied in a variety of ways to look at what food has been preserved within it – light microscopy to identify visibly distinctive food remnants, isotope

199904)108:4<409::AID-AJPA3>3.0.CO;2-E; K. J. Petzke, H. Boeing and C. C. Metges, 'Choice of Dietary Protein of Vegetarians and Omnivores Is Reflected in Their Hair Protein ^{13}C and ^{15}N Abundance', *Rapid Communications in Mass Spectrometry* 19 (2005), 1392–1400, DOI: 10.1002/rcm.1925; L. Ellegård, L. Ellegård, T. Alstad, T. Rütting, P. Hammarström Johansson, H. M. Lindqvist and A. Winkvist, 'Distinguishing Vegan-, Vegetarian-, and Omnivorous Diets by Hair Isotopic Analysis', *Clinical Nutrition* 38 (2019), 2949–51, DOI: 10.1016/j.clnu.2018.12.016. Beyond breastfeeding and weaning, it has been suggested that differences in metabolism at different life stages or between the sexes causes isotopic fractionation. There is evidence from non-humans for age stages causing isotopic shifts, but the data for humans seems to suggest any age-related isotopic differences are culturally mediated beyond breastfeeding, however more experimental work needs to be done. I. Bădescu, M. A. Katzenberg, D. P. Watts and D. W. Sellen, 'A Novel Fecal Stable Isotope Approach to Determine the Timing of Age-Related Feeding Transitions in Wild Infant Chimpanzees', *Amer. Jnl of Physical Anthropology* 162 (2017), 285–99, DOI: 10.1002/ajpa.23116; A. Borrell, A. Velásquez Vacca, A. M. Pinela, C. Kinze, C. H. Lockyer, M. Vighi and A. Aguilar, 'Stable Isotopes Provide Insight into Population Structure and Segregation in Eastern North Atlantic Sperm Whales', *PLoS ONE* 8 (2013), DOI: 10.1371/journal.pone.0082398; M. A. Katzenberg, S. R. Saunders and W. R. Fitzgerald, 'Age Differences in Stable Carbon and Nitrogen Isotope Ratios in a Population of Prehistoric Maize Horticulturists', *Amer. Jnl of Physical Anthropology* 90 (1993), 267–81, DOI: 10.1002/ajpa.1330900302; K. M. MacKenzie, C. N. Trueman, M. R. Palmer, A. Moore, A. T. Ibbotson, W. R. C. Beaumont and I. C. Davidson, 'Stable Isotopes Reveal Age-Dependent Trophic Level and Spatial Segregation during Adult Marine Feeding in Populations of Salmon', *ICES Jnl of Marine Science* 69 (2012), 1637–45, DOI: 10.1093/icesjms/fss074; A. J. Waterman, R. H. Tykot and A. M. Silva, 'Stable Isotope Analysis of Diet-Based Social Differentiation at Late Prehistoric Collective Burials in South-Western Portugal', *Archaeometry* 58 (2016), 131–51, DOI: 10.1111/arcm.12159; Kendall, Millard and Beaumont, '"Weanling's Dilemma" Revisited'; Beaumont *et al.*, 'Comparing Apples and Oranges'; M. Minagawa and E. Wada, 'Stepwise Enrichment of ^{15}N along Food Chains: Further Evidence and the Relation between δ^{15}N and Animal Age', *Geochimica et Cosmochimica Acta* 48 (1984), 1135–40.

As yet there is no experimental evidence for differences between male and female ^{13}C and ^{15}N values (excluding pregnancy and nursing effects) however some differences have been observed and it has been suggested these are due to physiology rather than culturally defined. Minagawa, 'Reconstruction of Human Diet from σ^{13}C and σ^{15}N in Contemporary Japanese Hair'; Leggett, 'Tell Me What You Eat, and I Will Tell You Who You Are', pp. 242–45.

analysis, lipids, proteomics, and DNA). Pottery residues and dental calculus work are rapidly evolving and as yet have limited usage in the early medieval period.

The majority of the zooarchaeological literature on our period is focused on East Anglia due to the extraordinary excavations at West Stow, however there are multitudes of site-specific studies on early medieval animal bones in site reports and grey literature from commercial archaeology with recent efforts attempting some synthesis.[60] Recent studies suggest that with Romanisation in Britain came animal 'improvement' (enlargement for meat) for major domesticates such as sheep, cattle and pigs, but with the collapse of control in the fringes of the Empire these larger meat-heavy animals and an emphasis on these kinds of animal surplus for meat seem to have disappeared in fifth-century Britain.[61] Kill patterns (age and sex of butchered animals), animal pathologies (e.g. foot bone disease from use as traction animals) and butchery marks on bones also give insight into animal husbandry practices, meat cuts and processing of animals for other secondary products.[62] Zooarchaeologists have suggested that in the post-Roman period domestic livestock were killed predominantly as either part of herd management (e.g. killing younger males earlier in life so as to keep females for dairy and breeding) or later in life after their utility for traction, breeding or secondary products like dairy or wool was at an end, rather than the meat-heavy emphasis of the Roman period.[63] Recent work from Zoe Knapp on the high-status site of Lyminge in Kent shows feasting layers rich in red meat which changes over time with Christianisation to a larger emphasis on chickens and fish, which she related back to the laws of Wihtred of Kent which imposes fines for those found to be

60 D. Stansbie and S. Mallet, 'Big, Bad (?) Data: New Approaches to the Study of Food, Identity and Landscape in Early Medieval England', *Medieval Settlement Research* 30 (2015), 16–24; P. J. Crabtree, 'Production and Consumption in an Early Complex Society: Animal Use in Middle Saxon East Anglia', *World Archaeol.* 28 (1996), 58–75, DOI: 10.1080/00438243.1996.9980331; P. J. Crabtree, 'Animal Husbandry and Farming in East Anglia from the 5th to the 10th Centuries CE', *Quaternary International: Agrarian Archaeol. in Early Med. Europe* 346 (2014), 102–8, DOI: 10.1016/j.quaint.2013.09.015; P. J. Crabtree, *Middle Saxon Animal Husbandry in East Anglia*, East Anglian Archaeology 143 (Bury St Edmunds, 2012).

61 M. Rizzetto, P. J. Crabtree and U. Albarella, 'Livestock Changes at the Beginning and End of the Roman Period in Britain: Issues of Acculturation, Adaptation, and "Improvement"', *European Jnl of Archaeol.* 20 (2017), 535–56, DOI: 10.1017/eaa.2017.13; M. Holmes, 'Does Size Matter? Changes in the Size of Animals throughout the English Saxon Period (AD 450–1066)', *Jnl of Archaeol. Science* 43 (2014), 77–90, DOI: 10.1016/j.jas.2013.12.007.

62 Holmes, 'Does Size Matter?'

63 Knapp, 'Zooarchaeology of the Anglo-Saxon Christian Conversion: Lyminge, a Case Study'; Holmes, 'Does Size Matter?'; Rizzetto *et al.*, 'Livestock Changes at the Beginning and End of the Roman Period in Britain'; Crabtree, 'Animal Husbandry and Farming in East Anglia from the 5th to the 10th Centuries CE'; P. J. Crabtree, 'Agricultural Innovation and Socio-Economic Change in Early Medieval Europe: Evidence from Britain and France', *World Archaeol.* 42 (2010), 122–36, DOI: 10.1080/00438240903430373.

eating meat during fasting periods.[64] Knapp's identification of feasting deposits, distinct from other midden material, implies that consumption of pigs, sheep/goat and cattle, whilst consumed in higher quantities at Lyminge, may have been reserved for distinctive special feasting events rather than regular day-to-day consumption, and that what was acceptable or in fashion to consume at feasts changed throughout the early medieval period. This suggests that meat from livestock was not a regular occurrence, even at high-status sites.

The archaeobotany of early medieval England suggests that there were indeed shifts in agriculture from the Roman period into the fifth and sixth centuries; however, the major agricultural transitions occurred in the seventh and eighth centuries onwards.[65] The shifts are in the species and cultivars of cereal crops grown, and their relative proportions to one another, as well as changes in plough technology and therefore the kinds of soils cultivated. It appears some of these changes in how cereals were grown may have impacted the crop isotopic values, namely by enriching δ^{15}N values due to fertilisation and/or physiological stress from non-ideal soil conditions. Therefore, these agricultural transitions may have impacted δ^{15}N values up the food chain passing ^{15}N enrichment onto human consumers making them look like they were eating more protein when in fact the whole food chain has been enriched.[66] A full exploration of this is forthcoming and outside the scope of this article but poses interesting questions about dietary shifts in the later part of the early medieval period in England.

Other biomolecular approaches such as genomics, proteomics, metabolomics, and lipid residue analyses can also shed light on early medieval diets, and these techniques are showing great promise but remain underutilised for our period, with specialists primarily focussing on prehistoric contexts. Genetics studies in particular are still very much intent on human population studies and hunting down pathogens rather than what plants and animals are left behind in peoples'

64 Knapp, 'The Zooarchaeology of the Anglo-Saxon Christian Conversion: Lyminge, a Case Study'; D. Whitelock, 'The Laws of Wihtred, King of Kent (695)', *English Historical Documents c. 500–1042*, ed. D. Whitelock, Eng. Hist. Documents 1, 2nd ed. (London, 1979) [hereafter *EHD*], 396–8.

65 M. J. McKerracher, *Anglo-Saxon Crops and Weeds: a Case Study in Quantitative Archaeobotany*. (Oxford, 2019); M. McKerracher, *Farming Transformed in Anglo-Saxon England: Agriculture in the Long Eighth Century* (Bollington, 2018); H. Hamerow, A. Bogaard, M. Charles, E. Forster, M. Holmes, M. McKerracher, S. Neil, C. Bronk Ramsey, E. Stroud and R. Thomas, 'An Integrated Bioarchaeological Approach to the Medieval "Agricultural Revolution": a Case Study from Stafford, England, *c.* AD 800–1200', *European Jnl of Archaeol.* 23 (2020), 585–609, DOI: 10.1017/eaa.2020.6.

66 Hamerow *et al.*, 'An Integrated Bioarchaeological Approach to the Medieval "Agricultural Revolution"'; Leggett, 'Tell Me What You Eat, and I Will Tell You Who You Are'.

https://doi.org/10.1017/S0263675122000072 Published online by Cambridge University Press

fossilised food.[67] There has been interesting work on medieval dental calculus in the past few years, but these studies are few and far between, and tend towards the exceptional rather than every day.[68] New work on dental calculus from early medieval cemeteries in Cambridgeshire may indicate social differentiation in diet

[67] J. Hendy, 'Ancient Protein Analysis in Archaeology', *Science Advances* 7 (2021), DOI: 10.1126/sciadv.abb9314; J. Hendy, C. Warinner, A. Bouwman, M. J. Collins, S. Fiddyment, R. Fischer, R. Hagan, C. A. Hofman, M. Holst, E. Chaves, L. Klaus, G. Larson, M. Mackie, K. McGrath, A. Z. Mundorff, A. Radini, H. Rao, C. Trachsel, I. M. Velsko and C. F. Speller, 'Proteomic Evidence of Dietary Sources in Ancient Dental Calculus', *Proceedings of the R. Soc. B: Biological Sciences* 285 (2018), DOI: 10.1098/rspb.2018.0977; S. Leslie, B. Winney, G. Hellenthal, D. Davison, A. Boumertit, T. Day, K. Hutnik, E. C. Royrvik, B. Cunliffe, Wellcome Trust Case Control Consortium 2, International Multiple Sclerosis Genetics Consortium, D. J. Lawson, D. Falush, C. Freeman, M. Pirinen, S. Myers, M. Robinson, P. Donnelly and W. Bodmer, 'The Fine-Scale Genetic Structure of the British Population', *Nature* 519 (2015), 309–14, DOI: 10.1038/nature14230; A. Boumertit, T. Day, D. Davison, C. Echeta, I. Evseeva, K. Hutnik, S. Leslie, K. Nicodemus, E. C. Royrvik, S. Tonks, Xiaofeng Yang, J. Cheshire, P. Longley, P. Mateos, A. Groom, C. Relton, D. T. Bishop, K. Black, E. Northwood, L. Parkinson, T. M. Frayling, A. Steele, J. R. Sampson, T. King, R. Dixon, D. Middleton, B. Jennings, R. Bowden, P. Donnelly and W. Bodmer, 'People of the British Isles: Preliminary Analysis of Genotypes and Surnames in a UK-Control Population', *European Jnl of Human Genetics* 20 (2012), 203–10, DOI: 10.1038/ejhg.2011.127; L. Seifert, S. Hänsch, D. M. Wagner, D. Birdsell, K. L. Parise, I. Wiechmann, G. Grupe, A. Thomas, P. Keim, L. Zöller, B. Bramanti, J. M. Riehm and H. C. Scholz, 'Yersinia Pestis DNA from Skeletal Remains from the 6th Century AD Reveals Insights into Justinianic Plague', *PloS Pathogens* 9 (2013), DOI: 10.1371/journal.ppat.1003349; M. Keller, M. A. Spyrou, C. L. Scheib, G. U. Neumann, A. Kröpelin, B. Haas-Gebhard, B. Päffgen, J. Haberstroh, A. Ribera I Lacomba, C. Raynaud, C. Cessford, R. Durand, P. Stadler, K. Nägele, J. S. Bates, B. Trautmann, S. A. Inskip, J. Peters, J. E. Robb, T. Kivisild, D. Castex, M. McCormick, K. I. Bos, M. Harbeck, A. Herbig and J. Krause, 'Ancient *Yersinia Pestis* Genomes from across Western Europe Reveal Early Diversification during the First Pandemic (541–750)', *Proceedings of the National Academy of Sciences* 116 (2019), 12,363–372, DOI: 10.1073/pnas.1820447116; M. Roffet-Salque, J. Dunne, D. T. Altoft, E. Casanova, L. J. E. Cramp, J. Smyth, H. L. Whelton and R. P. Evershed, 'From the Inside Out: Upscaling Organic Residue Analyses of Archaeological Ceramics', *Jnl of Archaeol. Science: Reports* 16 (2017), 627–40, DOI: 10.1016/j.jasrep.2016.04.005; E. Cappellini, A. Prohaska, F. Racimo, F. Welker, M. Winther Pedersen, M. E. Allentoft, P. de Barros Damgaard, P. Gutenbrunner, J. Dunne, S. Hammann, M. Roffet-Salque, M. Ilardo, J. V. Moreno-Mayar, Yucheng Wang, M. Sikora, L. Vinner, J. Cox, R. P. Evershed and E. Willerslev, 'Ancient Biomolecules and Evolutionary Inference', *Annual Rev. of Biochemistry* 87 (2018), 1029–60, DOI: 10.1146/annurev-biochem-062917-012002.

[68] One of the handful of dental calculus studies on a (later) medieval individual reported lapis lazuli in the dental plaque of a religious woman, suggesting she was involved in the production of manuscripts, see A. Radini, M. Tromp, A. Beach, E. Tong, C. Speller, M. McCormick, J. V. Dudgeon, M. J. Collins, F. Rühli, R. Kröger and C. Warinner, 'Medieval Women's Early Involvement in Manuscript Production Suggested by Lapis Lazuli Identification in Dental Calculus', *Science Advances* 5 (2019), DOI: 10.1126/sciadv.aau7126. But as yet the more detailed findings on this skeleton and other medieval individuals and the implications for diet have not yet been published or made accessible, e.g. A. Radini, 'Particles of Everyday Life. Past Diet and Living Conditions as Evidenced by Micro- Debris Entrapped in Human Dental Calculus: A Case Study from Medieval Leicester and Surrounding' (unpubl. PhD dissertation, Univ. York, 2016).

through the species meat and dairy are sourced from but these results are not yet published, and more work needs to be done.[69]

The handful of studies on early medieval pottery and other cooking residues have demonstrated that foodways may indeed shift across the first millennium AD, and certainly after the Norman Conquest, with a homogenising of dietary signatures related to marketisation.[70] Sherds from pre-Conquest Oxford pottery shows vessels were used for cooking beef, lamb and possibly also goat, with some limited dairy processing, but this shifted in the post-Conquest period away from dairy, as pork and chicken meat processing became predominant. In both periods these vessels also showed plant biomarkers, with leafy greens such as brassicas being particularly clear in the residues. Similarly, residue analyses from West Cotton Raunds (*c.* 950–1450 AD) show specialisation in pottery types for certain kinds of food processing and storage, with evidence for animal meat consumption in the forms of stews or pottages, dairy processing, some porcine fats, mixing of animal products and plants in cookery and even some honey/beeswax signatures.[71] However, the picture is largely of meat and carcass fats being cooked with dairy as an additional or supplemental protein depending on social status reflected in the type of site and pottery styles. These studies are several centuries later than our period of focus here, however they also rely on these long-held assumptions of a meat-focussed diet, particularly for elites, with the protein of choice changing in post-Conquest England (i.e. pork).

However, some exciting new work has very recently been done on *c.* fifth-to-seventh-century 'roasting pits' in Suffolk. Residue analysis on burnt stones from these pits implies they were used for cooking whole ruminant animals (cattle, sheep, or goats but not horses or pigs), and the archaeological evidence in and around these structures suggest they were used for periodic feasting events.[72] This in combination with the zooarchaeological evidence for feasting, and perhaps less

[69] C. Scheib, pers comm.

[70] E. Craig-Atkins, B. Jervis, L. Cramp, S. Hammann, A. J. Nederbragt, E. Nicholson, A. R. Taylor, H. Whelton and R. Madgwick, 'The Dietary Impact of the Norman Conquest: a Multiproxy Archaeological Investigation of Oxford, UK', *PLoS ONE* 15 (2020), DOI: 10.1371/journal.pone.0235005.

[71] J. Dunne, A. Chapman, P. Blinkhorn and R. P. Evershed, 'Reconciling Organic Residue Analysis, Faunal, Archaeobotanical and Historical Records: Diet and the Medieval Peasant at West Cotton, Raunds, Northamptonshire', *Jnl of Archaeol. Science* 107 (2019), 58–70, DOI: 10.1016/j.jas.2019.04.004; J. Dunne, A. Chapman, P. Blinkhorn and R. P. Evershed, 'Fit for Purpose? Organic Residue Analysis and Vessel Specialisation: the Perfectly Utilitarian Medieval Pottery Assemblage from West Cotton, Raunds', *Jnl of Archaeol. Science* 120 (2020), DOI: 10.1016/j.jas.2020.105178.

[72] J. Caruth, 'Revealing Lipid Analysis at Anglo-Saxon Sites in Suffolk', *Cotswold Archaeology* (blog), 20 January 2021, http://cotswoldarchaeology.co.uk/revealing-lipid-analysis-at-anglo-saxon-sites-in-suffolk/.

regular daily consumption of meat adds further weight to our argument and supports the isotopic evidence explored below.

MATERIALS AND METHODS

The data used to explore social status and diet here are pulled from the datasets collated in the 2021 research article by Leggett *et al*, 'Multi-Tissue and Multi-Isotope (δ^{13}C, δ^{15}N, δ^{18}O and $^{87/86}$Sr) Data for Early Medieval Human and Animal Palaeoecology'.[73] Those databases consist of 8,910 isotopic data points for human and animal diet and mobility in the first millennium AD from across western Europe. Here we have used a subset of that data consisting of bone collagen data from early medieval England and the associated contextual information including osteological sex, grave goods and chronological designations for those burials which is also available within the datasets.[74]

Statistical analyses and graphics were conducted using Free and Open-Source R version 4.0.4 and Rstudio version 1.4.1106.[75] The code is freely available as part of the supplementary material and data available as part of the article, 'Multi-Tissue and Multi-Isotope (δ^{13}C, δ^{15}N, δ^{18}O and $^{87/86}$Sr) Data'.[76] For DetectingDeviatingCells (DDC) analysis the data had to be re-organised for the package algorithm and the spreadsheet is available in the supplementary material. For further details on DDC analysis see below in the regional specific analysis for Wessex.

We investigated links between diet, social status, and funerary practices by looking for correlations between several funerary variables with possible relevance to social status (number of grave goods, number of foreign grave goods, body position and grave orientation) and dietary signatures as measured from bone collagen $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values. Some funerary variables were not analyzed here but are included in the databases. For instance, interment style had too many variants that are not easily standardised for visualisation or statistical analyses. Number of grave goods is a rough measure of wealth and status, so too are the number of foreign grave goods as their rarity in graves and having the means to obtain items from overseas (or bring them with you) could be an additional

[73] S. Leggett, A. Rose, E. Praet and P. Le Roux, 'Multi-Tissue and Multi-Isotope (δ^{13}C, δ^{15}N, δ^{18}O and $^{87/86}$Sr) Data for Early Medieval Human and Animal Palaeoecology', *Ecology* 102 (2021), DOI: 10.1002/ecy.3349.

[74] *Ibid.*

[75] R Development Core Team, *R: a Language and Environment for Statistical Computing*, version 4.0.4 'Lost Library Book', MacOS, R, 2021, http://www.r-project.org/; RStudio Team, *RStudio: Integrated Development Environment for R*, version 1.4.1106 'Tiger Daylily', MacOS, R (Boston, MA: RStudio, 2021), http://www.rstudio.com/.

[76] Leggett *et al*., 'Multi-Tissue and Multi-Isotope (δ^{13}C, δ^{15}N, δ^{18}O and $^{87/86}$Sr) Data'.

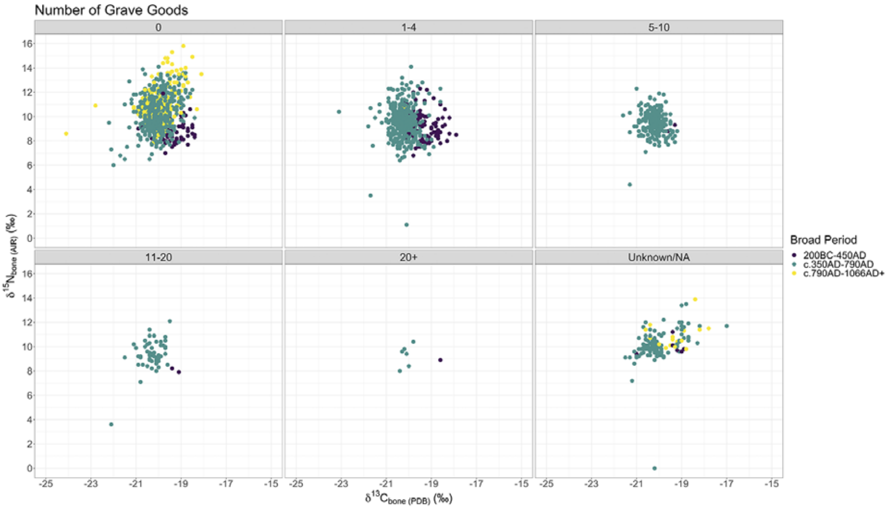

Figure 1: Scatterplots of human bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values from England by number of grave goods, coloured by period.

signifier of status.[77] Grave orientation and body position become standardised over time with earlier variability linked to social status and religious practices, so differences in diet and cultural change are tentatively investigated through these variables.[78]

First this was done using bone at a whole England level from the Roman through to the Anglo-Norman period (n = 2023, fig. 1), with individuals coloured on plots by broad period to make broad chronological patterns in both diet and funerary treatment more readily discernible. Figs 1–4 highlight these larger chronological trends in both funerary and dietary change in England in the first millennium AD. We then focused more tightly on gender and number of grave goods for adult burials dating roughly from the fifth to the eighth century AD (n = 1463, fig. 5 and fig. 6), both because this is the period during which the prevalence of grave goods gives us the most information on the social status of individual burials and because it predates the shift towards greater use of marine

[77] Geake, *Use of Grave-Goods*; J. M. King, 'Grave-Goods as Gifts in Early Saxon Burials (ca. AD 450–600)', *Jnl of Soc. Archaeol* 4 (2004), 214–38, DOI: 10.1177/1469605304041076; Lucy, *The Anglo-Saxon Way of Death*.

[78] Brownlee, 'Connectivity and Funerary Change in Early Medieval Europe'; Brownlee, 'Grave Goods in Early Medieval Europe'; Brownlee, 'The Dead and Their Possessions'; E. James, 'Burial and Status in the Early Medieval West', *TRHS* 39 (1989), 23–40, DOI: 10.2307/3678976; S. Mui, 'Dead Body Language: Deciphering Corpse Positions in Early Anglo-Saxon England' (unpubl. PhD dissertation, Durham Univ., 2018).

resources associated with the arrival of Scandinavian migrants. To further reduce the noise in the data, we then analyse adult diet in Wessex (n = 321) to compare contemporary and regionally appropriate adult burials more directly with the royal food render specified in the Laws of Ine (figs 7 and 8), and end with DDC analysis of both adult and juvenile data from Wessex (n = 517) to look for overall outliers in the region (fig. 9).

Since isotopic analyses are used here to infer dietary intake, especially of animal protein, and therefore trophic position (how high you sit up the food chain), we need to consider the isotopic variability of the animals theoretically being consumed. This can differ greatly due to environmental factors and animal husbandry practices, despite sitting at the same trophic level, and can cause problems when we then try to make interpretations of human consumption without comparison with said animals. This is usually referred to as constructing an isotopic baseline, and allows for less erroneous estimations of dietary protein intake and trophic level relative to appropriate food sources.[79] Animal isotopic baselines were obtained by averaging species group bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values from England from the faunal data in the article 'Multi-Tissue and Multi-Isotope ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ and $^{87/86}Sr$) Data'.[80] Not all species were available for all regions analysed, so England-wide averages were used as broad proxies for trophic level. The values for the groups are summarised in Table 1.

Another helpful benchmark is isotopic data from modern hair samples with defined diets (see Table 2).[81] These values should be used with some caution, as comparing across tissues (i.e. here from hair keratin to bone collagen) and across time and space comes with many caveats.[82] From the background information

[79] M. M. Casey and D. M. Post, 'The Problem of Isotopic Baseline: Reconstructing the Diet and Trophic Position of Fossil Animals', *Earth-Science Reviews* 106 (2011), 131–48, DOI: 10.1016/j.earscirev.2011.02.001.

[80] Leggett *et al.*, 'Multi-Tissue and Multi-Isotope ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ and $^{87/86}Sr$) Data'.

[81] O'Connell and Hedges, 'Investigations into the Effect of Diet on Modern Human Hair Isotopic Values'; Ellegård *et al.*, 'Distinguishing Vegan-, Vegetarian-, and Omnivorous Diets by Hair Isotopic Analysis'; T. C. O'Connell, 'Comment on Ellegård *et al.* Clinical Nutrition 2019 "Distinguishing Vegan-, Vegetarian-, and Omnivorous Diets by Hair Isotopic Analysis"', *Clinical Nutrition* 40 (2021), 4912–13, DOI: 10.1016/j.clnu.2021.07.006.

[82] Beaumont *et al.*, 'Comparing Apples and Oranges'; Tieszen *et al.*, 'Fractionation and Turnover of Stable Carbon Isotopes in Animal Tissues'; L. L. Tieszen and T. Fagre, 'Effect of Diet Quality and Composition on the Isotopic Composition of Respiratory CO_2, Bone Collagen, Bioapatite, and Soft Tissues', *Prehistoric Human Bone: Archaeology at the Molecular Level*, ed. J. B. Lambert and G. Grupe (Berlin, 1993), pp. 121–55, DOI: 10.1007/978-3-662-02894-0_5; T. C. O'Connell, 'The Isotopic Relationship between Diet and Body Proteins: Implications for the Study of Diet in Archaeology' (unpubl. DPhil dissertation, Oxford Univ., 1996); O'Connell *et al.*, 'Diet-Body Offset in Human Nitrogen Isotopic Values'; Webb *et al.*, 'Influence of Varying Proportions of Terrestrial and Marine Dietary Protein on the Stable Carbon-Isotope Compositions of Pig Tissues from a Controlled Feeding Experiment'.

TABLE 1:
Isotopic averages of major faunal species groups in Early Medieval England, calculated from data in Leggett *et al.*, 'Multi-Tissue and Multi-Isotope ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$ and $^{87/86}Sr$) Data'.

Species Group	$\delta^{13}C_{coll}$ average (‰)	$\delta^{15}N_{coll}$ average (‰)
Marine Fish	−13.37	15.03
Freshwater Fish	−22.52	11.38
Companion Animals (Cats and Dogs)	−19.84	9.63
Domestic Fowl	−20.20	8.99
Pigs	−21.31	6.90
Large Domestic Herbivores (Cattle and Equids)	−21.87	5.38
Medium Domestic Herbivores (Ovicaprids)	−21.54	5.57
Wild Herbivores	−22.59	5.08

TABLE 2:
Modern human hair sample $\delta^{13}C$ and $\delta^{15}N$ values for vegan, ovo-lacto vegetarian and omnivore diets and frequency of animal protein intake. Daily is defined as once or more per day, frequent as more than twice a week and intermediate consumption as once or twice weekly.[83]

		O'Connell and Hedges (1999)		Ellegård *et al.* (2019)	
Diet	Animal Protein Frequency	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
Vegan	None	−20.9±0.8	6.9±0.5	−21.3±0.4	5.6±1.2
Ovo-lacto vegetarian	Average	−21.0±0.3	8.7±0.5	−21.0±0.4	7.6±1.0
	Intermediate		8.3±0.2		
	Frequent		8.9±0.4		
	Daily		9.4		
Omnivore	Average	−20.2±0.7	8.8±0.6	−20.9±0.5	8.9±0.9
	Intermediate		8.3±0.2		
	Frequent		8.7±0.1		
	Daily		9.5±0.1		

83 Data from: O'Connell and Hedges, 'Investigations into the Effect of Diet on Modern Human Hair Isotopic Values' and Ellegård *et al.*, 'Distinguishing Vegan-, Vegetarian-, and Omnivorous Diets by Hair Isotopic Analysis'.

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given about the samples, the individuals in these studies do not appear to be on a diet comparable to what has been imagined for early medieval elites but are nonetheless a useful guide for where these early medieval individuals may sit within the nutritional literature.

As our reference point for a possible 'elite' diet, we took the food list given in clause 70.1 of the laws of King Ine of Wessex. In our companion article, we estimate that fifty-five per cent of the calories contained in Ine's list derived from animal protein, and if we assume a single loaf represents a single meal (which is probable) an individual portion would have been 4,140kcal. As noted above, the scale and proportions of these food lists lead us to believe that these texts should be understood as lists of provisions for occasional grand feasts, and not as the general food supplies that sustained itinerant royal households. But if they were what royal households routinely ate – and what was consumed in the many other elite households endowed with rights to royal 'food renders' – then we might expect to see more nutritionally related pathologies in high status individuals. We would also expect $\delta^{15}N_{coll}$ values from collagenous tissues well in excess of 11‰ if these foods were eaten more than once a day, or even once daily alongside more simplistic plant-based meals for the majority of these individuals' lives given modern and Late Medieval dietary data.[84]

THE ISOTOPIC EVIDENCE FOR DIET AND SOCIAL STATUS IN *C.* FIFTH-TO-ELEVENTH CENTURY ENGLAND

We start here with total number of grave goods per grave from across England from the late Roman to Anglo-Norman period in fig. 1, and what is apparent is that not only are graves with over ten grave goods relatively rare among those that have

[84] Ellegård *et al.*, 'Distinguishing Vegan-, Vegetarian-, and Omnivorous Diets by Hair Isotopic Analysis'; Petzke *et al.*, 'Choice of Dietary Protein of Vegetarians and Omnivores Is Reflected in Their Hair Protein ^{13}C and ^{15}N Abundance'; O'Connell and Hedges, 'Investigations into the Effect of Diet on Modern Human Hair Isotopic Values'; Minagawa, 'Reconstruction of Human Diet from $\sigma^{13}C$ and $\sigma^{15}N$ in Contemporary Japanese Hair'; P. S. Patel, A. J. M. Cooper, T. C. O'Connell, G. G. C. Kuhnle, C. K. Kneale, A. M. Mulligan, R. N. Luben, S. Brage, K.-T. Khaw, N. J. Wareham and N. G. Forouhi, 'Serum Carbon and Nitrogen Stable Isotopes as Potential Biomarkers of Dietary Intake and Their Relation with Incident Type 2 Diabetes: the EPIC-Norfolk Study', *Amer. Jnl of Clinical Nutrition* 100 (2014), 708–18, DOI: 10.3945/ajcn.113.068577; Hedges and Reynard, 'Nitrogen Isotopes and the Trophic Level of Humans in Archaeology'; 'Reference Intakes Explained', article on the NHS website: https://www.nhs.uk/live-well/eat-well/what-are-reference-intakes-on-food-labels/; A. L. Lamb, J. E. Evans, R. Buckley and J. Appleby, 'Multi-Isotope Analysis Demonstrates Significant Lifestyle Changes in King Richard III', *Jnl of Archaeol. Science* 50 (2014), 559–65, DOI: 10.1016/j.jas.2014.06.021; G. Müldner and M. P. Richards, 'Stable Isotope Evidence for 1500 Years of Human Diet at the City of York, UK.', *Amer. Jnl of Physical Anthropology* 133 (2007), 682–97; O'Connell, 'Comment on Ellegård *et al.* Clinical Nutrition 2019 "Distinguishing Vegan-, Vegetarian-, and Omnivorous Diets by Hair Isotopic Analysis"'.

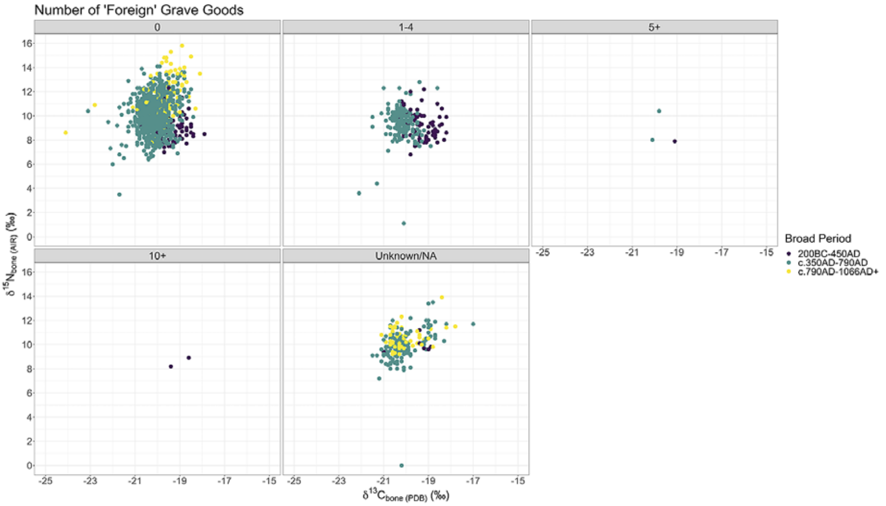

Figure 2: Scatterplots of human bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values by number of 'foreign' grave goods, coloured by period.

been studied isotopically, but also that the trends in diet are more chronological than wealth based. There are shifts from the Roman to Early Medieval period, and from the late eighth century onwards, but this seems to have nothing to do with grave provisioning, and therefore possible wealth during life.

Fig. 2 shows the number of 'foreign' grave goods as designated by the original site reports. As mentioned above such items are relatively rare and could therefore be an additional indicator of status through the ability to obtain luxury items from overseas, or by having the means to travel distances with said items. Fig. 2 shows a very similar, but reduced, pattern to fig. 1 – mostly chronological shifts in diet, and nothing to suggest people with more grave goods or more exotic artefacts had higher $\delta^{15}N_{coll}$ values, and therefore ate more animal protein.

The individuals that do have higher $\delta^{15}N_{coll}$ values, and potentially also indicate some marine resource consumption, are generally those coloured yellow in fig. 1 and fig. 2. These individuals either have no grave goods or are part of the 'unknown/NA individuals' group who are mostly from the commingled and mass grave contexts of St John's College Oxford and Ridgeway Hill, Weymouth; these individuals have been identified by the original investigators as of probable Scandinavian origin.[85]

[85] C. A. Chenery, J. A. Evans, D. Score, A. Boyle and S. R. Chenery, 'A Boat Load of Vikings?', *Jnl of the North Atlantic* 7 (2014), 43–53, DOI: 10.3721/037.002.sp704; L. Loe, A. Boyle, H. Webb and D. Score, *'Given to the Ground': a Viking Age Mass Grave on Ridgeway Hill, Weymouth*, Dorset Nat. Hist. and Archaeol. Soc. Monograph Series 22 (Dorchester, 2014); A. M. Pollard, P. Ditchfield, E. Piva,

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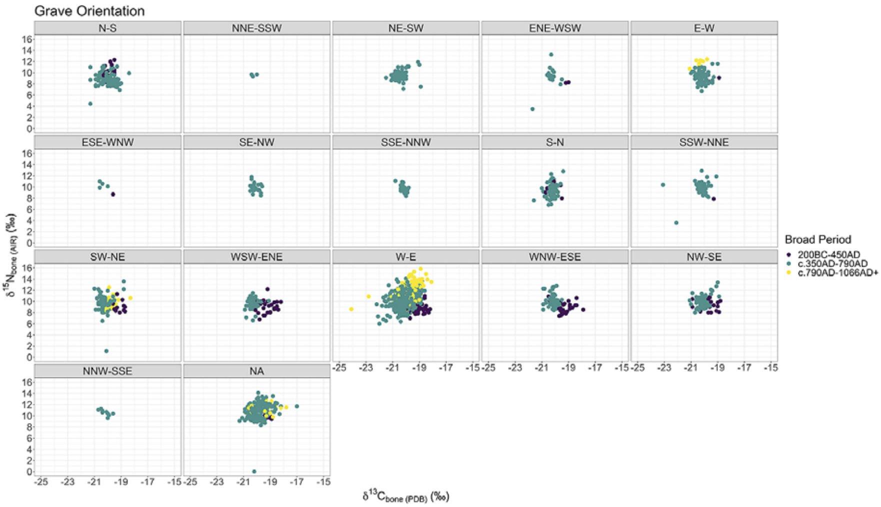

Figure 3: Scatterplots of human bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values by grave orientation, coloured by period.

This suggests that diets in England were not dictated by social status or changed by the *Fish Event Horizon* in the Early Middle Ages,[86] but the high trophic level and marine dietary signatures evident above are the result of incoming people. Further work on re-investigating the *Fish Event Horizon* using human isotopic evidence is forthcoming and outside the scope of this work here.

As with grave goods above, fig. 3 and fig. 4 demonstrate the same trends but with grave orientation and body position as well. The trends appear to be, once again,

S. Wallis, C. Falys and S. Ford, '"Sprouting Like Cockle Amongst the Wheat": the St Brice's Day Massacre and the Isotopic Analysis of Human Bones from St John's College, Oxford', *Oxford Jnl of Archaeol.* 31 (2012), 83–102, DOI: 10.1111/j.1468-0092.2011.00380.x.

86 The *Fish Event Horizon* is a phenomenon which builds over the course of the ninth and tenth centuries, reaching its peak in the year 1000 AD, whereby increasing amounts of marine fish bones have been found on archaeological sites in Britain, suggesting an increasing demand for and consumption of marine fish, which goes on to be a major economic shift in North Sea fisheries in the central and later Middle Ages. Outside of Scandinavia, the main isotopic evidence for this from human bones comes from Orkney and York, and Scandinavian settlers, and still proves elusive in the rest of Early Medieval human isotopic data. See: J. H. Barrett and M. P. Richards, 'Identity, Gender, Religion and Economy: New Isotope and Radiocarbon Evidence for Marine Resource Intensification in Early Historic Orkney, Scotland, UK', *European Jnl of Archaeol.* 7 (2004), 249–71, DOI: 10.1177/1461957104056502; J. H. Barrett, A. M. Locker and C. M. Roberts, '"Dark Age Economics" Revisited: the English Fish Bone Evidence AD 600–1600', *Antiquity* 78 (2004), 618–36, DOI: 10.1017/S0003598X00113262; Müldner, 'Marine Fish Consumption in Medieval Britain: the Isotope Perspective from Human Skeletal Remains'; J. Barrett and D. Orton, *Cod and Herring – the Archaeology and History of Medieval Sea Fishing* (Oxford, 2016).

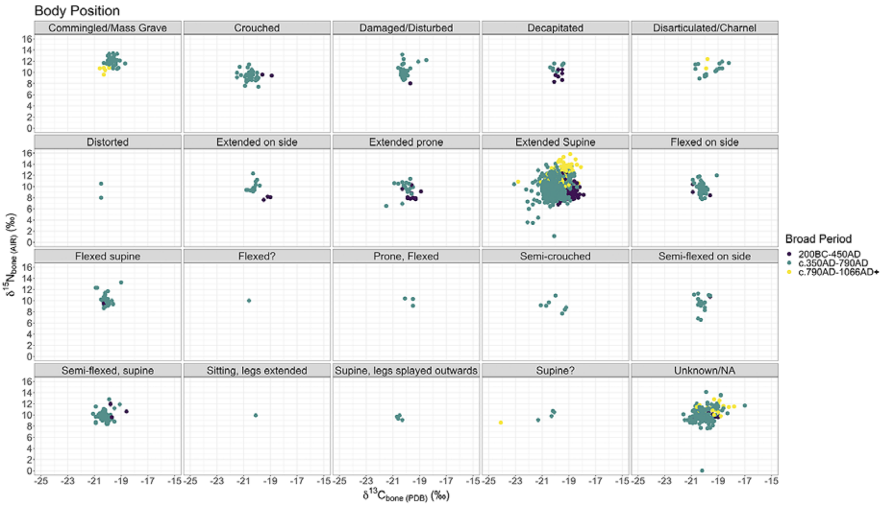

Figure 4: Scatterplots of human bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values by body position, coloured by period.

chronological, and not easily linked to any one aspect of burial practice. Other aspects of burial practices are too nuanced and variable to easily compare with the isotopic evidence as it currently stands and were therefore outside the scope of this current work (e.g. burial plot within a cemetery, or how close a burial is to the altar, internment type – stone-lined, ash-halo, *in-the-green*, various types of wooden structures, coffins, barrows *etc.*). This approach does not include some high-status graves such as bed burials as separate categories, which are marked out as exceptional by the quality rather than quantity of grave goods. However, as mentioned above, the isotopic evidence we have for these four burials does not indicate they had higher proportional intake of animal protein than other contemporary burials.[87] These are a rare phenomenon, and in the absence of definitively royal data, these proxies are our best starting point for furnished cemeteries.

HEALTH AND DIET

If members of England's early medieval elite ordinarily consumed the rich diet implied by food lists such as the one in Ine's laws, we would perhaps expect to find evidence of associated health complications. People eating red-meat and animal-fat heavy diets, accompanied by regular alcohol consumption, are prone to

[87] These are the burials at Trumpington Meadows, Edix Hill (x2) and Coddenham, and their $\delta^{15}N_{coll}$ values range from 9.4–11.4‰, with the average being 10.5‰.

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develop conditions such as gout, type 2 diabetes, cardio-vascular disease, and cancer, generally decreasing their overall life expectancy.[88] Some of these health implications would only affect soft-tissue and are thus archaeologically invisible, however gout and excess protein should show up osteologically and isotopically respectively. Gout in particular is associated with purine-rich diets and excessive alcohol consumption and has been found to be associated with 'rich' diets in later medieval individuals.[89] Certainly early medieval people knew of gout and had remedies for it, with Gregory the Great and other early medieval 'celebrities' suffering from the condition, although diet was not always seen as a contributing factor in antiquity.[90] Constipation and other gut related issues might also be attributed to unbalanced diets, and as with gout, there are remedies for these in the leech books and other medical texts, however linking them to the diets described in the food renders is difficult as the causes for the ailments are rarely given.[91]

We checked the dataset for correlations between pathological data, age at death, number of grave goods and ^{15}N enrichment and could not find any clear links between these variables as the data stands. Of the 561 adults in England with bone

[88] C. L. Ranabhat, M.-B. Park and C.-B. Kim, 'Influence of Alcohol and Red Meat Consumption on Life Expectancy: Results of 164 Countries from 1992 to 2013', *Nutrients* 12 (2020), 459, DOI: 10.3390/nu12020459; K. Papier, G. K. Fensom, A. Knuppel, P. N. Appleby, T. Y. N. Tong, J. A. Schmidt, R. C. Travis, T. J. Key and A. Perez-Cornago, 'Meat Consumption and Risk of 25 Common Conditions: Outcome-Wide Analyses in 475,000 Men and Women in the UK Biobank Study', *BMC Medicine* 19 (2021), 53, DOI: 10.1186/s12916-021-01922-9; E. Battaglia Richi, B. Baumer, B. Conrad, R. Darioli, A. Schmid and U. Keller, 'Health Risks Associated with Meat Consumption: a Review of Epidemiological Studies', *International Jnl for Vitamin and Nutrition Research* 85 (2015), 70–78, DOI: 10.1024/0300-9831/a000224; F. Qian, M. C. Riddle, J. Wylie-Rosett and F. B. Hu, 'Red and Processed Meats and Health Risks: How Strong Is the Evidence?', *Diabetes Care* 43 (2020), 265–71, DOI: 10.2337/dci19-0063; G. Ragab, M. Elshahaly and T. Bardin, 'Gout: an Old Disease in New Perspective – a Review', *Jnl of Advanced Research* 8 (2017), 495–511, DOI: 10.1016/j.jare.2017.04.008.

[89] J. M. Dittmar, P. D. Mitchell, P. M. Jones, B. Mulder, S. A. Inskip, C. Cessford and J. E. Robb, 'Gout and "Podagra" in Medieval Cambridge, England', *International Jnl of Paleopathology* 33 (2021), 170–81, DOI: 10.1016/j.ijpp.2021.04.007; Ragab *et al.*, 'Gout'; G. Fornaciari, S. Marinozzi, D. Messineo, C. Caldarini, F. Zavaroni, S. Iorio, L. Sveva, S. Capuani, P. Catalano and V. Gazzaniga, 'A Remarkable Case of Gout in the Imperial Rome: Surgery and Diseases in Antiquity by Osteoarchaeological, Paleopathological, and Historical Perspectives', *International Jnl of Osteoarchaeol.* 29 (2019), 797–807, DOI: 10.1002/oa.2792.

[90] J. D. Hosler, 'Gregory the Great's Gout: Suffering, Penitence, and Diplomacy in the Early Middle Ages', *Where Heaven and Earth Meet: Essays on Medieval Europe in honor of Daniel F. Callahan*, ed. M. Frassetto, J. Hosler and M. Gabriele, Studies in the Hist. of Christian Traditions 174 (Leiden, 2014), 9–32, DOI: 10.1163/9789004274167_003.

[91] 'Bald's Leechbook' (London, British Library, Royal MS 12 D XVII (Winchester, s. x med.)); F. Watkins, B. Pendry, O. Corcoran and A. Sanchez-Medina, 'Anglo-Saxon Pharmacopoeia Revisited: a Potential Treasure in Drug Discovery', *Drug Discovery Today* 16 (2011), 1069–75, DOI: 10.1016/j.drudis.2011.07.002; C. T. Doyle, 'Anglo-Saxon Medicine and Disease: a Semantic Approach' (unpubl. PhD dissertation, Cambridge Univ., 2011).

$\delta^{15}N_{coll}$ values above 10.3‰, 286 had pathological data recorded. The one individual with a possible gout diagnosis has a $\delta^{15}N_{coll}$ value of 10.8‰ which is slightly above the 5‰ upper limit of trophic enrichment from faunal baselines (see below), but this is not sufficiently high to suggest an excess of protein compared to their contemporaries.[92] Since this case is medically inconclusive it is therefore hard to extrapolate from. Similarly, there were fifteen cases of osteomas (bone cancer) and they averaged $\delta^{15}N_{coll}$ values of 9.5‰ (range of 7.5–13.5‰), again with no discernible link between social status (most individuals with osteomas had no grave goods), although twice as many women suffered from osteomas than men (ten females, five males). This is not to say that those with protein-heavy diets did not suffer from other forms of cancer, but unless it reached their skeleton it is invisible to this study. As diet is linked to oral health, we also searched for oral pathologies and links with $\delta^{15}N_{coll}$ values.[93] Out of the full adult dataset for England (n = 1793) there are 209 individuals with caries recorded and 232 individuals with dental calculus (often on the same individual). 54 of the 209 individuals with caries (25.84%) showed some ^{15}N enrichment; similarly, 62 of the 232 individuals (26.72%) with dental calculus had $\delta^{15}N_{coll}$ values above 10.3‰. This suggests these oral pathologies cannot strictly be linked to ^{15}N enrichment.

Sulphur or amino acid specific isotopic studies would help to distinguish between different causes for ^{15}N enrichment (e.g. stress, excess protein and different protein sources) more effectively but these kinds of analyses are less common than carbon and nitrogen studies, however in coming years more light may be shed on this.[94] As the data currently stands there is no palaeopathological evidence for many individuals suffering from diseases associated with rich diets as those described in the food render texts, as were experienced by other early and later Medieval individuals eating excessively rich diets;[95] nor can we link any such pathologies with isotopic enrichment or funerary status.

DIET AND SOCIAL STATUS IN C. FIFTH-TO-EIGHTH CENTURY ENGLAND: THE ISOTOPIC EVIDENCE

Removing the Roman and definitively Viking Age and Anglo-Scandinavia/Norman individuals produces fig. 5. This demonstrates that for the whole of

[92] This is a twenty-six- to thirty-five-year-old male, grave 26 at Stanton in Suffolk with 2 grave goods – a knife and a belt buckle.

[93] P. Moynihan, 'The Interrelationship between Diet and Oral Health', *Proceedings of the Nutrition Soc.* 64 (2005), 571–80, DOI: 10.1079/PNS2005431.

[94] Reitsema, 'Beyond Diet Reconstruction'; Nehlich, 'Application of Sulphur Isotope Analyses in Archaeological Research'.

[95] Dittmar *et al.*, 'Gout and "Podagra" in Medieval Cambridge'; Hosler, 'Gregory the Great's Gout'.

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England between the fifth and eighth centuries AD there is a tighter range in bone δ^{13}C and δ^{15}N values relative to the figures above, as evidenced by the marginal box plots, with tails of individuals for both elements in higher and lower values beyond the interquartile ranges. There is a spread of over 14‰ in δ^{15}N values, which is much larger than we would expect if everyone was consuming at roughly the same trophic level. As this dataset spans several hundred years and from the southwest of England up to the northeast, variation could be due to any number of factors such as regional variation in isotopic baselines (different geologies or grazing grasses, sea spray etc.), regional variation in foodways, and diachronic changes to diets and farming techniques altering baselines (e.g. manuring). We try to filter out some of these effects at the end of this section by focusing on just Wessex, but this larger dataset remains valuable for its size (n = 1463). It just requires careful interpretation.

Given our assumptions about elite diets drawn from the literature and food render texts themselves, we should consider not only animal baselines but also as a point of comparison animal protein variation in modern diets as outlined in Table 1 and Table 2 above. Figs 5–8 have the faunal nitrogen averages from England from Table 1 overlaid, and there are several key observations we can draw from this.

This suggests that domestic fowl, cats, and dogs during the period are being fed broadly similar diets to humans, with possibly some supplementary scavenging/

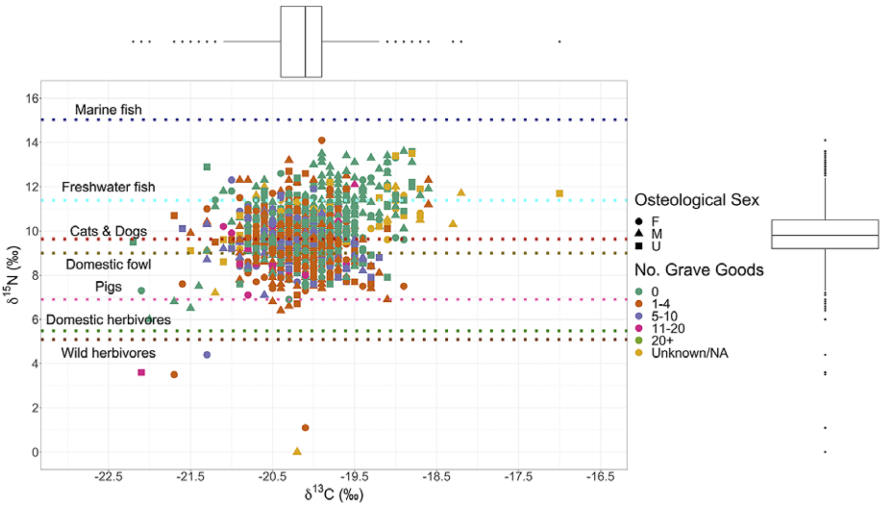

Figure 5: Scatterplot with marginal boxplots of bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values of *c.* fifth-to-eighth century individuals in England with animal base lines as labelled horizontal lines.

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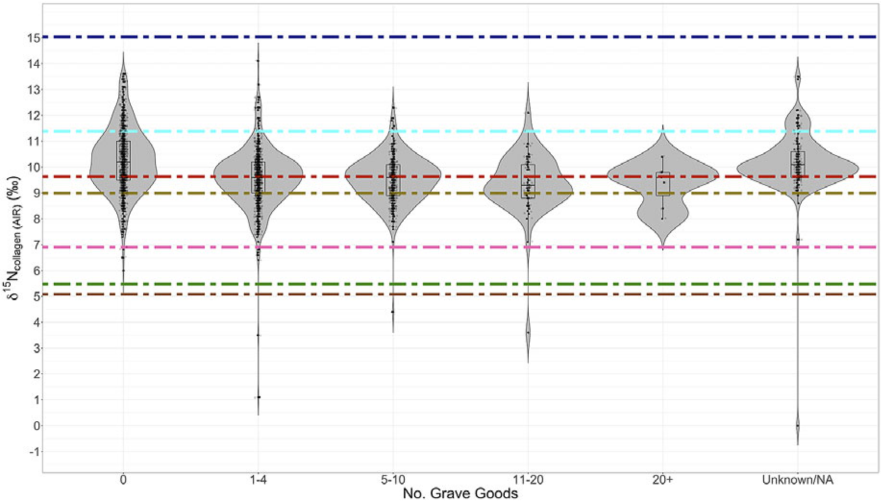

Figure 6: Violin plot of bone $\delta^{15}N_{coll}$ values of *c.* fifth-to-eighth century individuals in England, animal base lines top-bottom: marine fish, freshwater fish, domestic cats and dogs, domestic fowl, domestic pigs, domestic herbivores (cattle, sheep/goats), and wild herbivores as per Figure 5 above.

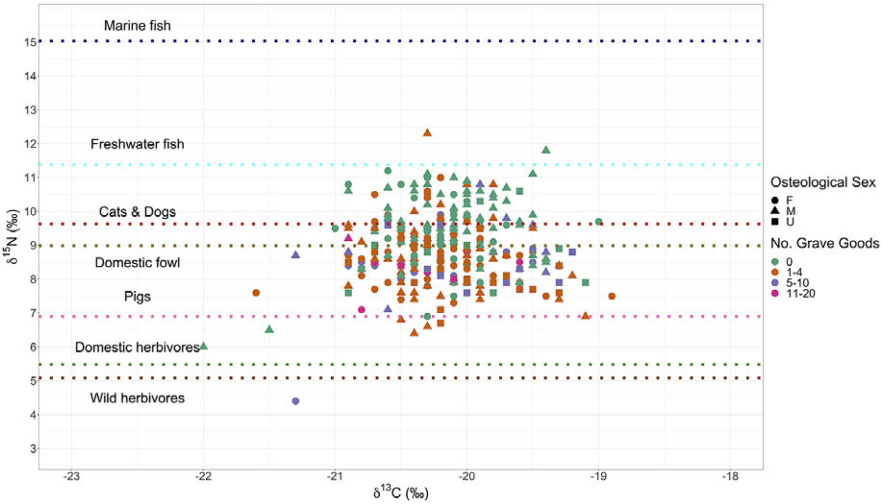

Figure 7: Scatterplot of bone $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ of *c.* fifth-to-eighth century individuals in the region of Wessex with animal base lines as labelled horizontal lines.

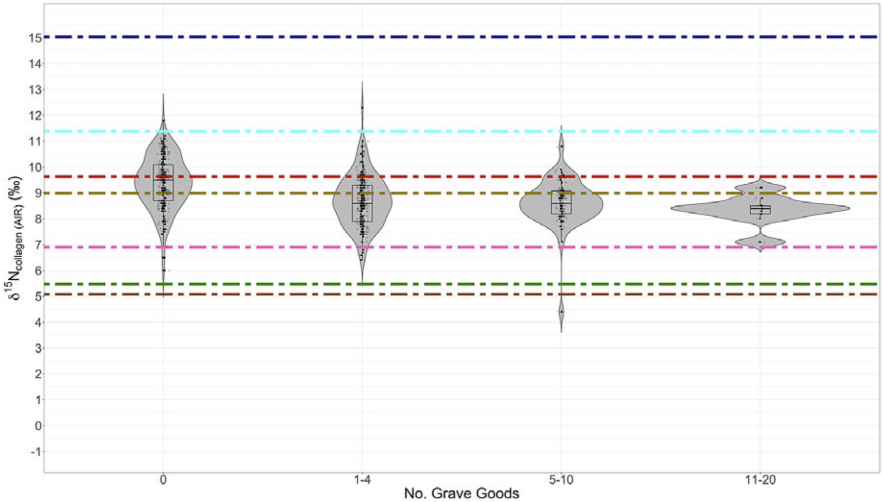

Figure 8: Violin plot of bone $\delta^{15}N_{coll}$ values of *c.* fifth-to-eighth century individuals in the region of Wessex, animal base lines top-bottom: marine fish, freshwater fish, cats and dogs, domestic fowl, pigs, domestic herbivores (cattle, sheep/goats), and wild herbivores as per Figures 5-7 above.

hunting due to the similarity in their isotopic signatures which is supported by other studies.[96] This means that these animals are poor indicators of higher trophic levels but useful for understanding aspects of companion animals and farming practices. Comparing the human values to the herbivore baselines and given the 14.1‰ spread in $\delta^{15}N_{coll}$ values, it appears that there is a wide variety of diets being consumed across England in this period, with significant differences in animal protein consumption.

We took the assumed 5‰ upper limit of trophic level enrichment (the maximum increase you might expect to see when you step up the food chain, see above) for $\delta^{15}N_{coll}$[97] and applied it to the combined herbivore average here

[96] Crabtree, *Middle Saxon Animal Husbandry in East Anglia*; J. A. Evans, S. Tatham, S. R. Chenery and C. A. Chenerya, 'Anglo-Saxon Animal Husbandry Techniques Revealed Though Isotope and Chemical Variations in Cattle Teeth', *Applied Geochemistry* 22 (2007), 1994–2005, DOI: 10.1016/j.apgeochem.2007.03.059; Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'; Müldner and Richards, 'Stable Isotope Evidence for 1500 Years of Human Diet at the City of York'; Knapp, 'Zooarchaeology of the Anglo-Saxon Christian Conversion'; P. J. Crabtree, 'A Note on the Role of Dogs in Anglo-Saxon Society: Evidence from East Anglia', *International Jnl of Osteoarchaeol.* 25 (2015), 976–80, DOI: 10.1002/oa.2358.

[97] Bocherens and Drucker, 'Trophic Level Isotopic Enrichment of Carbon and Nitrogen in Bone Collagen'; Minagawa and Wada, 'Stepwise Enrichment of 15N along Food Chains'; Hedges and Reynard, 'Nitrogen Isotopes and the Trophic Level of Humans in Archaeology'.

(5.34‰) we get a rough benchmark of 10.34‰ above which we can be satisfied people are eating moderate to high levels of animal protein in their diets. For the overall adult dataset this gives us 418 individuals (28.6% of the total). Conversely this means over seventy per cent of individuals are eating negligible to moderate animal protein. The temptation at this point might be to assume that the 418 individuals with high $\delta^{15}N_{coll}$ values represent a social elite, defined in part by their privileged access to animal-based foodstuffs.

However, when we look more closely it becomes apparent that this interpretation is not viable. Of these 418 individuals 191 are from East Anglia, which is known to have ^{15}N enrichment compared with the rest of the country, presumably due to a mixture of the wetter Fenland environments causing isotopic enrichment at the base of the food chain and a regional preference for freshwater fish given said environs (e.g. Westfield Farm Ely[98]), amongst other factors.[99] This regional ^{15}N enrichment seems to have been what skewed Hull and O'Connell's original conclusions of early medieval diet in England consisting of moderate to high protein intake,[100] since the majority of Hull's data was from East Anglia with little comparative data to draw on at the time.[101] It is probable that many of the other burials with $\delta^{15}N_{coll}$ values over this threshold are actually from after this period, appearing in this dataset because of issues with dating. Ninety-nine burials are either definite or probable Scandinavians or individuals who likely date to the eighth-to-eleventh centuries but were included here due to the ambiguity of dates (either there are none, they have very broad radiocarbon estimations or there is a very broad chronological designation for the site). These include thirty-eight skeletons from St John's College Oxford (Scandinavian origins),[102] ten burials from Repton (predominantly war dead from the Viking Great Army but some possible earlier monastic skeletons),[103] twenty-nine skeletons from the cemetery at Black Gate Newcastle (presumed to date to the eleventh-to-thirteenth centuries but some burials date to the seventh-to-ninth),[104] and twenty-two individuals

98 Lucy *et al.*, 'The Burial of A Princess?'

99 Boulden, 'Bioarchaeological Reassessment of Land-Use Practices from the Neolithic to the Roman Period in Central Southern Britain'; Mallet, 'Diets in England'; Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'.

100 O'Connell and Hull, 'Diet: Recent Evidence'.

101 Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'.

102 Pollard *et al.*, 'Sprouting Like Cockle Amongst the Wheat'.

103 C. L. Jarman, M. Biddle, T. Higham and C. B. Ramsey, 'The Viking Great Army in England: New Dates from the Repton Charnel', *Antiquity* 92 (2018), 183–99, DOI: 10.15184/aqy.2017.196.

104 D. L. Mahoney Swales, 'Life and Stress: a Bio-Cultural Investigation into the Later Anglo-Saxon Population of the Black Gate Cemetery, Newcastle-upon-Tyne' (unpubl. PhD dissertation, Univ. Sheffield, 2012); D. M. Swales, 'A Biocultural Analysis of Mortuary Practices in the Later Anglo-Saxon to Anglo-Norman Black Gate Cemetery, Newcastle-upon-Tyne, England', *International Jnl of Osteoarchaeol.* 29 (2019), 198–219, DOI: 10.1002/oa.2729; J. Nolan, 'The Early

from Priory Orchard Godalming which has a similar date range and lack of chronological resolution to Black Gate.[105] Five interesting burials in this group are from Bishopstone in East Sussex.[106] Bishopstone, whilst within our chronological range, is definitively Christian (it is an early churchyard cemetery) and the burials lack grave goods, but they are assumed to be elites or their retainers based in and around the manor. Zooarchaeological evidence from Bishopstone and its contemporary in Kent (Lyminge) suggests that fish became a larger part of these elite sites after Christianisation, around the same time burial started in the churchyard, and the manor moved location.[107] So it is therefore hard to attribute the ^{15}N enrichment at Bishopstone purely to status, although undoubtedly that played a role, when there is a clear shift in all aspects of life there in the late-seventh to early-eighth century linked to Christianisation. The other burials above this trophic boundary are scattered across wide ranging sites with no particular patterns in their chronology or gender (ignoring the Viking or monastic sites with majority males) and most of these individuals have no or very few grave goods which is clear in fig. 5 and fig. 6.

Those individuals at the very top of the tight splurge in fig. 5 above the freshwater fish line at 11.38‰ account for 9.8% (n = 143/1463) of the total adult data for England dated to roughly the fifth-to-eighth centuries. Many of these individuals have already been accounted for above with the major cemeteries contributing to this group being Westfield Farm Ely (n = 19), St John's College Oxford (n = 32), Caister-by-Yarmouth (n = 16) and Black Gate Newcastle (n = 11). Westfield Farm, being on the isle of Ely, is presumed to have such high $\delta^{15}N_{coll}$ values due to high freshwater fish (eels included) consumption;[108] Caister-by-Yarmouth is assumed to be an early monastic centre with adherents consuming more aquatic resources than the laity;[109] and Black Gate and St John's Oxford were mentioned in more detail above. The other burials which are probable or definite incoming Scandinavians with 'fishy' diets in this group are five individuals from Repton, one from Coppergate in York and one burial from Masham in Yorkshire.[110] Like Caister-by-Yarmouth the interred people at South

Medieval Cemetery at the Castle, Newcastle upon Tyne', *Archaeol. Aeliana*, 5th ser., 39 (2010), 147–287.

105 Leggett *et al.*, 'Multi-Tissue and Multi-Isotope (δ^{13}C, δ^{15}N, δ^{18}O and $^{87/86}$Sr) Data for Early Medieval Human and Animal Palaeoecology'.

106 G. Thomas, *The Later Anglo-Saxon Settlement at Bishopstone: a Downland Manor in the Making*, CBA Research Report 163 (York, 2010).

107 Knapp, 'Zooarchaeology of the Anglo-Saxon Christian Conversion'; Thomas, *The Later Anglo-Saxon Settlement at Bishopstone*.

108 Lucy *et al.*, 'The Burial of A Princess?'

109 Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'.

110 J. Buckberry, J. Montgomery, J. Towers, G. Müldner, M. Holst, J. Evans, A. Gledhill, N. Neale and J. Lee-Thorp, 'Finding Vikings in the Danelaw', *Oxford Jnl of Archaeol.* 33 (2014), 413–34,

Acre (n = 7) and Burgh Castle (n = 8) are also assumed to be early Christian monastic adherents.[111] For the rest of the individuals with $\delta^{15}N_{coll}$ values above 11.38‰ we could find no common attributes in their demography or funerary treatment to suggest a link between social status and diet as seen through stable isotope analysis. If anything, regionality and chronology play more of a role with ^{15}N enrichment in Early Medieval England.

Fig. 6 demonstrates more clearly the lack of relationship between ^{15}N enrichment and wealth/social status as defined through grave good provisioning. The mean $\delta^{15}N_{coll}$ values for the grave good groups are within 1‰ of each other (less than one trophic level which is generally assumed to be 3–5‰) with the highest being 10.3‰ and the lowest at 9.3‰. What is even more apparent here is that the individuals with the highest $\delta^{15}N_{coll}$ values have at most 4 grave goods.

These averages are similar to the daily protein consumption data for both ovo-lacto vegetarians and omnivores in Table 2. As mentioned above, it is therefore likely that most individuals, regardless of social status, ate some form of animal protein daily but this does not equate to one or more meals a day at over fifty per cent animal protein of the kind suggested by Ine's laws and similar texts.

CASE STUDY: EARLY MEDIEVAL WESSEX

We then focused on one region to eliminate some of the noise in the data (such as regional variation) and chose Wessex both because it is the origin of our earliest food list in Ine's laws and because it saw fewer Scandinavian settlers in the ninth and tenth centuries, reducing the risk of our sample including misdated later burials that reflect imported foodways. Wessex is defined here as early medieval cemeteries clustering in the modern counties of Dorset, Hampshire, Somerset, Surrey, West Sussex, and Wiltshire. Fig. 7 shows a more constrained cluster than the whole of England in Fig. 5. Diets in Wessex show less ^{15}N enrichment than the larger dataset with most individuals having $\delta^{15}N_{coll}$ values between the herbivore baselines and the fowl/cat/dog base lines, indicating negligible to moderate animal protein consumption. There are thirty-five individuals with $\delta^{15}N_{coll}$ values above the trophic benchmark of 10.34‰, twenty-two of which are buried at Priory Orchard Godalming, three at Beckery Chapel, three at Worthy Park Kingsworthy, three at Winnall II (Winchester), two at Alton, and one each at Droxford and Portway Andover. Only one of these burials, grave 50 at Worthy Park, has more than four grave goods (five to be exact). One of these items is a spear, and he is the only weapons burial in this higher $\delta^{15}N_{coll}$ range.

DOI: 10.1111/ojoa.12045; Müldner and Richards, 'Stable Isotope Evidence for 1500 Years of Human Diet at the City of York'; Jarman *et al.*, 'The Viking Great Army in England'.

[111] Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'.

Palaeopathological data was not available for all individuals but aside from caries and other oral pathologies which are relatively common in this period, there is nothing particularly unusual or striking to link these thirty-five individuals in their pathologies. What is striking is that in Wessex most of these individuals are men, with little to suggest that they are incomers importing more protein rich diets with them as for some of the sites mentioned above. However, Beckery Chapel and Priory Orchard Godalming are both Christian burial grounds associated with churches. Therefore, they might be reflecting Christianised diets with fish consumption (probably freshwater given their $\delta^{13}C_{coll}$ values) causing ^{15}N enrichment. Furthermore, these men with ^{15}N enrichment could be ecclesiastics, or perhaps this suggests some social differentiation in diet in Wessex based on gender. Of these thirty-five individuals only two have $\delta^{15}N_{coll}$ values above the freshwater fish line (11.38‰) – grave 17B from Worthy Park and skeleton 1023 from Priory Orchard Godalming. Both are osteologically male and the Priory Orchard individual has no grave goods, whereas the Worthy Park individual has three (knife, key/girdle hanger and a Roman coin); this with the chronological distance between the two (500–570AD for Worthy Park and 770–1150AD for Priory Orchard) suggests their isotopic enrichment is due to different factors and not a straightforward interpretation of status.

Fig. 8 shows a clear drop in $\delta^{15}N_{coll}$ values with increasing numbers of grave goods which adds further weight to our hypothesis that the driving factor for ^{15}N enrichment in early medieval England is not (purely) social status as viewed through funerary treatment. Changes through time to do with Christianisation and other socio-economic factors are instead probable driving factors.

Finally, we sifted the Wessex burials dataset for outliers. Rather than doing this subjectively, risking unconsciously introducing selection biases, we used the DetectingDeviatingCells (DDC) algorithm to detect outlying cells in the numeric data available (e.g. isotopic values or number of grave goods) not excluding children and infants here as we did above to avoid selection bias in the algorithm. DDC was run using the R package cellWise.[112] DDC as run by cellWise can only be used on numeric data, and it excludes individuals from analysis who have over fifty per cent missing data as well as any variables which do not have much variation. It uses the whole of the data matrix to establish what cells have higher or lower values than expected given all the other data for an observation (here an individual burial). It produces a graphic called a cell map (see Fig. 9) with red cells indicating higher than predicted values, blue cells lower than predicted, yellow cells

112 J. Raymaekers, P. Rousseeuw, W. Van den Bossche and M. Hubert, *CellWise: Analyzing Data with Cellwise Outliers*, version 2.1.1, 2020, https://CRAN.R-project.org/package=cellWise; P. Rousseeuw and W. Van Den Bossche, 'Detecting Deviating Data Cells', *Technometrics* 60 (2018), 135–45, DOI: 10.1080/00401706.2017.1340909.

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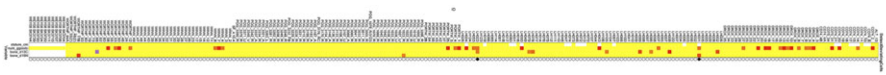

Figure 9: Detecting deviating cells cellmap for Wessex. Cells which are red have higher values than expected, blue are lower than expected, yellow are 'normal' and white are missing values for that variable.

are as predicted, and orange and purple cells are scales between the extremes. White cells indicate missing values. If individuals are flagged with black or grey dots this signals them as an outlier for the whole matrix due to having a high number of flagged cells. Therefore, DDC can tell us which burials stand out for one or more variables given the data for, in this case, their region.

The DDC cellmap presented in fig. 9 further demonstrates the lack of correlation between number of grave goods and diet (and stature) for Wessex. Rarely are individuals flagged by the algorithm with unexpected values for more than one variable. The two individuals who have higher than expected numbers of grave goods for their contexts and unexpected dietary values are LH023 (grave 1640) and LH031 (grave 118) – burials from the Late Roman cemetery at Lankhills, Winchester.[113] Grave goods are uncommon in this cemetery, and more generally in Late Roman graves, so these two individuals having four objects each is noteworthy. LH023 is an older female with significant pathologies throughout her skeleton, who was buried in a coffin with four different Roman coins of fourth-century date. Her bone $\delta^{13}C_{coll}$ value (but not $\delta^{15}N_{coll}$) is flagged as being higher than expected at –18.4‰ and might suggest she consumed marine and/or C_4 resources during life which stands out amongst the rest of the region with predominantly C_3 signals. LH031 is an infant who was buried in a coffin with two bone bracelets, a copper alloy bracelet and a necklace of glass and amber beads. This infant's $\delta^{15}N_{coll}$ values are flagged as being higher than expected at 12.2‰. Due to the age of the individual (*c.* 1–1.5 years old) ^{15}N enrichment is likely due to one or more factors including breastfeeding (i.e. trophic enrichment as well as ^{15}N enrichment of breast milk), physiological differences in infant metabolism, and physiological stress (nutritional or otherwise) which is linked to the osteological paradox of a dead infant – they were clearly not a healthy baby to be deceased in infancy.[114] Therefore despite their relatively rich funerary treatment

113 *The Late Roman Cemetery at Lankhills, Winchester: Excavations 2000–2005*, ed. P. Booth, A. Simmonds, A. Boyle, S. Clough, H. E. M. Cool and D. Poore, Oxford Archaeol. Monograph 10 (Oxford, 2010).

114 Fuller *et al.*, 'Nitrogen Balance and $\delta^{15}N$'; Beaumont *et al.*, 'Infant Mortality and Isotopic Complexity'; Haydock *et al.*, 'Weaning at Anglo-Saxon Raunds'; Fuller *et al.*, 'Isotopic Evidence for Breastfeeding and Possible Adult Dietary Differences from Late/Sub-Roman Britain'; Kendall *et al.*, 'The "Weanling's Dilemma" Revisited'; T. Siek, 'The Osteological Paradox and

TABLE 3:
Individuals from fig. 9 flagged by the DDC algorithm for only dietary results.

Site	Grave/ Skeleton	Sex	Number of Grave Goods	Flagged For?	$\delta^{13}C_{coll}$ (‰)	$\delta^{15}N_{coll}$ (‰)
Worthy Park	17B	Male	3	High nitrogen	−20.28	12.31
Worthy Park	68	Female	1	Low carbon	−21.61	7.58
Priory Orchard Godalming	1023	Male	0	High nitrogen	−19.41	11.81
Lankhills	LH002/Gr 25	Male	1	High carbon	−18.20	9.90
Lankhills	LH008/Gr 451	Male	1	High carbon	−17.90	8.50
Lankhills	LH078/Gr 1223	Male?	1	High carbon	−18.30	8.00
Lankhills	LH079/Gr 1227	Female	2	High carbon	−18.40	9.30
Lankhills	LH096/Gr 554	Male	0	High carbon	−18.40	8.50
Lankhills	LH099/Gr 616	Male	1	High carbon	−18.20	8.60
Lankhills	LH105/Gr 914	Female	0	High carbon	−18.40	8.30

we cannot take their ^{15}N enrichment at face value due to these complicating biological factors.

Other individuals flagged by DDC with unexpected isotopic signatures are listed in Table 3. None of these individuals were flagged for other variables, and most are late Roman individuals with similar suggestions of marine and/or C_4 resource consumption as for LH023. Worthy Park grave 17B and Priory Orchard skeleton 1023 have been discussed above. Worthy Park grave 68 is interesting due to her lower $\delta^{13}C_{coll}$ value combined with a relatively low $\delta^{15}N_{coll}$ value which is similar to the pig, vegan and some of the ovo-lacto vegetarian values in Table 1 and Table 2 above, suggesting she had a diet more reliant on plant-based protein.

The upshot of this is that no post-Roman burials (highly furnished or otherwise) from the Wessex region were flagged for both number of grave goods and nitrogen isotope values, and the majority of dietary deviation flagged was

Issues of Interpretation in Paleopathology', *Vis-à-Vis: Explorations in Anthropology* 13 (2013), 92–101; DeWitte and Stojanowski, 'The Osteological Paradox 20 Years Later'.

C_4/marine consumption signals from the Roman period. DDC flagged many burials with higher-than-expected grave goods but there was no statistical association between rich grave provisioning and diet in these data.

CONCLUSIONS

What we have demonstrated here is a general lack of elite isotopic differentiation in $\delta^{13}C_{coll}$ and $\delta^{15}N_{coll}$ values. From the data available it is implausible that the individuals with the highest $\delta^{15}N_{coll}$ values represent early medieval elites. No matter how this was investigated (gender, grave goods, body position *etc.*) there was a lack of correlation between social status in death and isotopic signals for diet. There is some suggestion that, regionally, gender differences might be more pronounced, as we have found with Wessex; however, excavation and sampling biases cannot be ruled out due to uneven numbers of females and males with available isotopic data.

There are certainly many caveats to be aware of here: sampling issues, problems with chronology, difficulties with identifying elites archaeologically, to name a few. But despite these caveats none of the analyses showed any clear relationships between funerary practices, social status and diet. Some chronological differences are, however, visible where more than one time period is present for a funerary variable. This suggests that social status and wealth as judged by funerary practice does not correlate with significantly higher protein consumption or eating different resources (e.g. marine fish), in the periods where furnished burial was still the norm. The well-known changes in burial practice from the end of the Roman period to churchyard burials in the eighth/ninth centuries are clearly shown in this smaller subset of burials with stable isotope data.[115] It supports and expands the findings of Hannah and Hull that there is no link between social identity/status and dietary isotopes for this period but contradicts the smaller scale correlations seen at sites such as Berinsfield, which reflect researchers actively hunting for variation in samples too small to sustain their conclusions.[116] We suggest that the social hierarchy seen in early medieval cemeteries and the foodways of these communities may be biochemically ephemeral, played out through politics, material culture and specific kinds of food (e.g. special cuts or types of animal,

[115] Brownlee, 'Connectivity and Funerary Change in Early Medieval Europe'; H. Geake, 'Persistent Problems in the Study of Conversion-Period Burial in England', *Burial in Early Medieval England and Wales*, ed. S. Lucy and A. Reynolds, Soc. for Med. Archaeol. Monograph 17 (London, 2002), 144–55; H. Geake, 'The Control of Burial Practice in Anglo-Saxon England', *The Cross Goes North: Processes of Conversion in Northern Europe, AD 300–1300*, ed. M. O. H. Carver (Woodbridge, 2003), pp. 259–70; Geake, *Use of Grave-Goods*; Lucy, *Anglo-Saxon Way of Death*.

[116] Hannah *et al.*, 'Anglo-Saxon Diet in the Conversion Period'; Hull, 'Social Differentiation and Diet in Early Anglo-Saxon England'; O'Connell and Hull, 'Diet: Recent Evidence from Analytical Chemical Techniques'; Privat *et al.*, 'Stable Isotope Analysis of Human and Faunal Remains from the Anglo-Saxon Cemetery at Berinsfield, Oxfordshire'.

fruits *etc.*) rather than an increased amount of protein or environmentally different resources (e.g. marine foods) that would show up in isotopic data. There is some zooarchaeological evidence from high status sites of marine fish (Bishopstone and Lyminge), which it is believed are linked to the Christianisation of these sites, as well as their higher social status (in the case of Lyminge moving from great hall complex to a minster).[117] The fact that decline in furnished burial, the increase in fish consumption, calendarisation of Christian feast days all coincide makes it nearly impossible to link burial practice, social status and diet for these sites – especially when we often cannot associate a cemetery with any given settlement.[118] It is a case of correlation does not equal causation.

The isotopic evidence as it stands gives a picture of fifth-to-eighth-century diets which are more homogeneous than has commonly been supposed, where what people ate was more dictated by regional trends (environmental differences as well as regionally different foodways) and seasonality than purely by social status. This is perhaps unsurprising in many ways, yet narratives of social stratification causing drastically different diets have been persistent in the literature.

Across these two companion articles, we have demonstrated both the power of a multi-disciplinary approach and the potential for further bioarchaeological research which will only add to our knowledge of the interaction between foodways and social status, and the broader socio-economic implications thereof. With improvements in methodology, technology, statistics and physiological research, reassessments of the isotopic data on a broader scale with more nuanced interpretations are possible.

Palaeoproteomics is now coming of age, and alongside aDNA and lipids, these emerging data are beginning to fill the gaps in our archaeological knowledge of agriculture, food, cookery, cuisine, and diet in this period. It is now possible to look at the cookery contexts and food crusts themselves to add more dimensions to the story.[119] As these datasets grow, our understanding of the social and economic implications of food will only deepen.

117 Knapp, 'Zooarchaeology of the Anglo-Saxon Christian Conversion'; G. Thomas, 'Life before the Minster: the Social Dynamics of Monastic Foundation at Anglo-Saxon Lyminge, Kent', *The Antiquaries Jnl* 93 (2013), 109–45, DOI: 10.1017/S0003581513000206; G. Thomas and A. Knox, 'A Window on Christianisation: Transformation at Anglo-Saxon Lyminge, Kent, England', *Antiquity Bulletin* 86 (2012), http://www.antiquity.ac.uk/projgall/thomas334/; Thomas, *Later Anglo-Saxon Settlement at Bishopstone*.

118 Knapp, 'Zooarchaeology of the Anglo-Saxon Christian Conversion'; R. V. Reynolds, 'Food for the Soul: the Dynamics of Fishing and Fish Consumption in Anglo-Saxon England: *c.* AD 410–1066' (unpubl. PhD dissertation, Univ. Nottingham, 2015); Hagen, *Anglo-Saxon Food & Drink*; Banham, *Food and Drink in Anglo-Saxon England*; Whitelock, 'The Laws of Wihtred, King of Kent (695)'.

119 Hendy, 'Ancient Protein Analysis in Archaeology'; Cappellini *et al.*, 'Ancient Biomolecules and Evolutionary Inference'; Dunne *et al.*, 'Reconciling Organic Residue Analysis, Faunal, Archaeobotanical and Historical Records'.

The cautious conclusion we draw here is that we need to rethink the idea that the food lists we find in the laws of Ine and associated texts represent the institutionalised 'expropriation of the poor to feed the powerful'.[120] The assumption that the food supplies listed constitute blueprints for everyday elite diets is not consistent with the bioarchaeological evidence as it currently stands. People were eating animal protein to varying degrees, but those with the highest $\delta^{15}N_{coll}$ values seem to be eating more fish because they were Scandinavian incomers or observing religious dietary restrictions, and not because they were routinely eating the remarkably meat-heavy diets those texts imply.[121]

SUPPLEMENTARY MATERIALS

To view supplementary material for this article, please visit http://doi.org/10.1017/S0263675122000072.

[120] R. Faith, *The Moral Economy of the Countryside: Anglo-Saxon to Anglo-Norman England* (Cambridge: Cambridge University Press, 2020), p. 50, DOI: 10.1017/9781108766487.

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