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British Iron Age Diet: Stable Isotopes and Other Evidence

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This paper presents the results of new research into British Iron Age diet. Specifically, it summarises the existing evidence and compares this with new evidence obtained from stable isotope analysis. The isotope data come from both humans and animals from ten British middle Iron Age sites, from four locations in East Yorkshire, East Lothian, Hampshire, and Cornwall. These represent the only significant data-set of comparative humans (n = 138) and animals (n = 212) for this period currently available for the UK. They are discussed here alongside other evidence for diet during the middle Iron Age in Britain. In particular, the question of whether fish, or other aquatic foods, were a major dietary resource during this period is examined.

The isotopic data suggest similar dietary protein consumption patterns across the groups, both within local populations and between them, although outliers do exist which may indicate mobile individuals moving into the sites. The diet generally includes a high level of animal protein, with little indication of the use of marine resources at any isotopically distinguishable level, even when the sites are situated directly on the coast. The nitrogen isotopic values also indicate absolute variation across these locations which is indicative of environmental background differences rather than differential consumption patterns and this is discussed in the context of the difficulty of interpreting isotopic data without a complete understanding of the 'baseline' values for any particular time and place. This reinforces the need for significant numbers of contemporaneous animals to be analysed from the same locations when interpreting human data-sets.

INTRODUCTION

The archaeological and environmental evidence for British Iron Age diet shows that domesticated animals, especially sheep/goat, cattle, and pigs, were of key importance. There is little evidence for the extensive use of wild game, especially fish, which may be due to factors such as poor preservation or off-site processing, or to a situation in which they were of no real importance in the diet. Similarly, there is little evidence for the use of non-domesticated plant foods. This paper presents the results of a new study using a direct method of determining diet, namely stable isotope analysis of bone collagen. We applied this method to humans (and animals) from a number of Iron Age sites across Britain to obtain new information on the relative amounts of plant compared to animal foods in the diet, and especially to estimate the level of fish consumption at sites along rivers or on the coast. This method works well in concert with more traditional methods of dietary reconstruction, and later in this paper we compare our isotopic results with other available lines of evidence.

Dietary studies employing carbon and nitrogen stable isotope analyses of bone are currently flourishing, with site-specific papers relating to prehistoric material appearing in academic journals, and many site monographs providing the data from such analyses in specialist reports. It is currently rare, however, for a study to bring together such data for a specific time period, from a number of geographically dispersed sites within a region, and to discuss these in the light of the other evidence available for general consumption patterns at that time.

Bone collagen from both humans and animals was analysed from ten different sites at four general locations across England and southern Scotland, this allowing inter-group isotopic comparisons in terms of

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both dietary patterns and environmental background. The period from the 4th to 1st centuries BC was focused upon, using skeletal material from East Yorkshire, East Lothian, Hampshire, and Cornwall. The data-set provides a valuable reference point for the discussion of other British material from this period, particularly because of the large number of animals which have been included in this study.

THE SITES

The sites were chosen to allow sampling of a significant number of both humans and animals from the same locations. The emphasis is on the middle Iron Age, prior to the point at which Roman influences were likely to have affected dietary patterns. Sites with significant numbers of humans are not easily identified for this period, since the normal corpse disposal rite was not inhumation in cemetery groups. It is more usual to find disarticulated remains in the context of ditches and pits, which may indicate that the norm was excarnation and secondary burial of selected bones or body parts (Carr & Knüsel 1997).

Isotopic analysis was undertaken on material from the following sites: Wetwang and Garton Slack (East Yorkshire), Broxmouth, Dryburn Bridge, Port Seton, and Winton House (East Lothian), Winnall Down and Micheldever Wood (Hampshire), and Harlyn Bay, Trethellan Farm and Trevelgue Head (Cornwall). They are located on Figure 1. Summaries of the material analysed from each site are provided in Table 1. The East Lothian and Cornwall sites are directly on the coast, allowing easy access to marine resources, whilst the Hampshire sites are close to major river systems, making freshwater and estuarine resource utilisation a clear possibility. The East Yorkshire site is currently more than 20 km from the coast and does not have easy access to aquatic resources. It is located on the Yorkshire Wolds, where surface water is in short supply and tends to flow in the local streams only after heavy rainfall.

The East Yorkshire material is effectively from one large site, comprising both cemetery and settlement area. It runs along a dry valley (or 'slack') and stretches across the parish boundary between Wetwang and Garton. The burials are from a large cemetery (over 450 inhumation burials), of which more than 250 were beneath barrows within four-sided ditched enclosures (the so-called 'square barrows' of the Arras culture; Dent 1984). These include five of the well-known 'chariot' burials, Wetwang and Garton Slack being the site which has produced the largest number of these from one location (Brewster 1971; Dent 1985; Hill 2002). It is the largest Iron Age cemetery in Britain and one of the largest in western Europe. It is also the only one of its kind in Britain to have associated, contemporaneous settlement evidence (Brewster 1980; Fenton-Thomas 2003, 54).

Four sites were investigated from East Lothian in southern Scotland. Broxmouth is an hillfort within 900 m of the sea (Hill 1982, 145), with an associated cemetery area containing ten individuals and some inhumations within the hillfort itself. Dryburn Bridge is a palisaded enclosure approximately 3 km from Broxmouth. Similarities in some of the house structures between the two sites, together with radiocarbon dates, suggest that there was at least some overlap in their dates of occupation (Ashmore & Hill 1983, 91). Ten inhumation burials in pits were excavated from Dryburn Bridge, with five of these possibly representing a formal cemetery (Triscott 1982, 122). The Port Seton excavations are two enclosure complexes excavated separately, but published together, known as Fishers Road West and Fishers Road East (Haselgrove & McCullagh 2000). Fishers Road East, from which animal samples were taken, was an occupation complex inhabited by at least three separate households (Haselgrove & Lowther 2000, 175). Only two human samples were available from this site (one of which did not produce acceptable results), these being from isolated finds of bone fragments. Very close to Port Seton is Winton House, which comprised six inhumations from a small group of pit and stone cist burials (Dalland 1991).

These four sites are located along the East Lothian coast east of Edinburgh. Broxmouth and Dryburn Bridge are furthest east, Broxmouth being approximately 2.5 km south-east of Dunbar and Dryburn Bridge around 3 km south-east of that. Winton House and Port Seton are closer to Edinburgh, approximately 30 km from the other two sites. They are less than 1 km from each other. All four sites are less than 1 km from the sea.

Winnall Down and Micheldever Wood (Hampshire) are located close together near Winchester in southern England and are approximately 7.5 km apart. The former is a complex of settlement features, including enclosures, houses, and burials, which span a use period from the

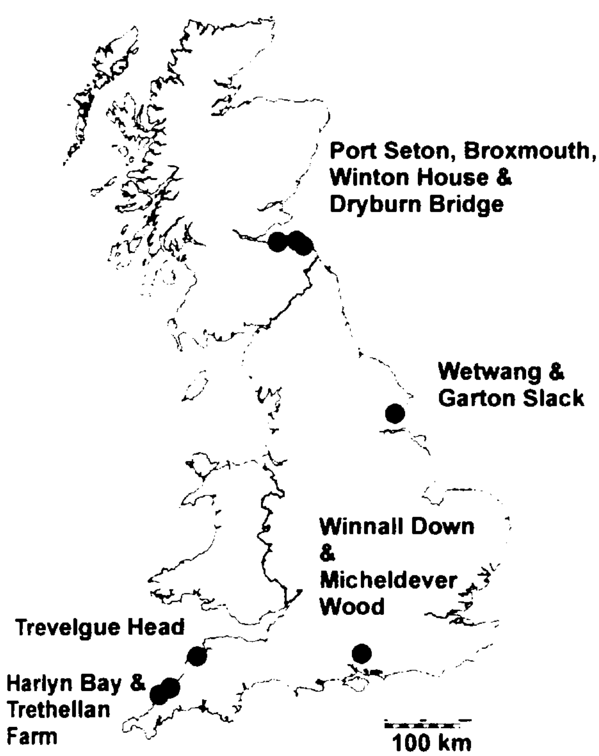

Fig. 1.
Locations of the sites discussed in the text for which isotopic data are presented

Neolithic through to the medieval period (Fasham 1985, 9 & 37). Micheldever Wood is a middle Iron Age 'banjo' enclosure, with evidence for occupation at the site, including human burials (Fasham 1987). The human skeletal remains from both sites include some complete skeletons, from graves, pits, and ditches, and also isolated bone fragments. These sites are close to a number of rivers, particularly to the River Itchen which flows into the estuarine Southampton Water approximately 25 km to the south. They would therefore have had easy access to freshwater aquatic resources and the river system would have allowed estuarine and marine foods to be obtained.

The human skeletal material from Cornwall came from Harlyn Bay and Trethellan Farm, whilst the animal bone was from Trevelgue Head. Harlyn Bay is a cemetery site without associated settlement material, discovered in 1900 (Bullen 1912; Whimster 1977). Trethellan Farm is a Bronze Age settlement site which was discovered in 1987. Following abandonment of occupation in the 13th century BC, it was used as a burial ground on an occasional basis from the 3rd century BC through to the 1st century AD (Nowakowski 1991, 13). There is no Iron Age occupation at the site and no Iron Age animal remains available from here. Trevelgue Head is a multivallate promontory fort which was excavated in 1939 by C.K. Croft Andrew, but which was never published (Forde-Johnston 1976, 167; Nowakowski & Quinnell

TABLE 1: SUMMARY OF SAMPLES ANALYSED FROM EACH LOCATION

Location	*Site*	*No. human samples*	*No. animal samples*
East Yorkshire	Wetwang & Garton Slack	62	68 (sheep/goat = 16; goat = 2; cattle = 11; pig= 11; deer = 3; dog = 6; horse = 16; fox = 1;crow = 1; vole = 1)
East Lothian	Broxmouth	12	42 (sheep/goat = 7; cattle = 5; pig = 6; deer = 7; dog = 5; horse = 5; aquatic animals = 7)
	Dryburn Bridge	5	8 (sheep/goat = 1; cattle = 4; pig = 1; dog = 1; horse = 1)
	Winton House	8	None
	Port Seton	1	8 (sheep/goat = 3; cattle = 4; pig = 1)
Cornwall	Harlyn Bay	20	4 (cattle = 2; pig = 1; unknown herbivore = 1)
	Trethellan Farm	4	None
	Trevelgue Head	None	29 (sheep/goat = 8; cattle = 7; pig = 8; deer = 4; horse = 2)
Hampshire	Winnall Down	23	43 (sheep/goat = 9; cattle = 11; pig = 4; deer = 1; dog = 3; horse = 5; birds = 8; fish = 1; vole = 1)
	Micheldever Wood	3	10 (pig = 5; fox = 1; hare = 1; toad = 1; vole = 1; stoat = 1)

forthcoming). There are no human remains from this site, but the animal bone provided an environmental background for the other two sites (Hammon 2005). All three sites are on the coast, with Harlyn Bay being approximately 20 km north of Trethellan Farm and Trevelgue Head very close to the latter. All three sites have access to river and estuary systems as well as marine resources.

All four locations include middle Iron Age material. Both radiocarbon techniques and received opinion on artefact and burial styles have changed over the period since the earliest of the published excavations and, in addition to this, the Iron Age contains some of the worst 'flat spots' on the radiocarbon calibration curve to be found in the last 8000 years, so calibrated dates tend to cover a long window of time. Based on the typology of grave goods (particularly brooches) and on a recent set of 19 radiocarbon dates obtained directly from the human bone (to be published elsewhere), Wetwang falls mainly within the period 4th–2nd centuries BC and the cemetery was probably in use for around 300 years (Jay, unpublished data; Dent 1984). It is likely that the material from the Hampshire sites and from Broxmouth is contemporaneous with Wetwang (Ashmore & Hill 1983; Fasham 1985; 1987). The Cornwall burials may cover a period of time which extends a little beyond this, Harlyn Bay perhaps covering the period from the 4th century BC and Trethellan Farm from the 2nd century BC and both extending into the early 1st century AD (Nowakowski 1991; Cunliffe 2005, 551), whilst the animal bone from Trevelgue Head is likely to be from the 4th–1st centuries BC (Nowakowski & Quinnell forthcoming). There are difficulties in being precise about the Winton House and Port Seton material, but this may also extend into a later period, whilst those from Dryburn Bridge may be slightly earlier, perhaps even early Iron Age, although three sets of radiocarbon dates on the same material are not consistent and need detailed consideration (Dalland 1991; Nowakowski 1991; Haselgrove & Lowther 2000; Cunliffe 2005, 551; Dunwell 2007). Discussion of the existing radiocarbon dates and the problems involved with these and the other dating information can be found in Jay (2005).

STABLE ISOTOPE ANALYSIS

Carbon and nitrogen stable isotope data, collected for the purpose of reconstructing broad dietary patterns from archaeological bone collagen, have been in use for some decades. The basic idea is that the chemical elements in food are taken up by the biological tissues in the consumer in a recognisable way. The amino acids from which bone collagen is constructed are thought to take their carbon and nitrogen from the protein in the consumer's food (Ambrose & Norr 1993). Since the analysis is of *stable* isotopes of these elements (eg, ^{12}C and ^{13}C, rather than radiogenic isotopes, such as ^{14}C) they will be present in the collagen in the same ratios as they were at death. This assumes that degradation, diagenesis, and contamination issues are not problems for the individual sample, but collagen is a relatively robust skeletal component which is why it is used for carbon isotopic analysis in preference to bone mineral. Where such problems do occur, quality indicators are used to discard the data from further consideration (van Klinken 1999).

Although Tauber (1981) was one of the first to apply the technique to European material, many of the earliest studies focused on Africa or the Americas, where the differences in the carbon ratios to be seen between plants with different photosynthetic pathways (C_3 and C_4 plants) are clearly in evidence. This allowed, for instance, a discussion of the point of introduction of maize (a C_4 plant) into the diet in the Americas (Vogel & van der Merwe 1977; Bender *et al.* 1981; van der Merwe *et al.* 1981). This distinction between C_3 and C_4 plants is of less relevance to prehistoric temperate Europe, where C_4 plants are not in evidence until quite late, although millet (*Panicum miliaceum*) has been present in parts of Continental Europe since the Neolithic (Renfrew 1973, 99; Zohary & Hopf 2000, 83). There has been a suggestion, based on stable isotope data, that millet may have been included as a component in the diet of Iron Age central European populations, either directly or via the consumption of animals which have consumed it (Murray & Schoeninger 1988; Le Huray & Schutkowski 2005) and Jacobs (1994, 57–8) suggested a 7th millennium BC use of millet in the Ukraine. There is no evidence, however, for plants using the C_4 photosynthetic pathway being available on a large-scale basis in pre-Roman Iron Age Britain.

Both carbon and nitrogen data can be used to identify the consumption of marine resources, since the chemical elements incorporated into those plants and animals at the base of the food chain are affected by what is available in the ocean environment and these are significantly different, in isotopic terms, to those available terrestrially. In general terms, a diet incorporating marine fish will cause human bone collagen to exhibit carbon and nitrogen isotopic ratios which are significantly enriched in the heavier of the two isotopes being analysed in each case (ie, $\delta^{13}C$ values become less negative, and $\delta^{15}N$ becomes more positive).

Nitrogen data are also routinely used in the consideration of the trophic level of the consumer. There is a 'step-wise' process involved in the way in which the nitrogen is incorporated into the food chain, such that, with each trophic level, the nitrogen isotopic ratio becomes more positive. In other words, herbivores have relatively low values and carnivores relatively high ones. Carbon values also become less negative with each trophic level, although the differences are smaller.

Whilst these statements about relative levels of isotopic ratios hold true in general terms, and they allow interpretations to be undertaken where absolute values are clearly extreme, it must also be borne in mind that environmental factors will cause subtle changes in the background signals which are more difficult to interpret (Hedges *et al.* 2004). These factors include climate (rainfall, sunlight availability, temperature, aridity), salinity, and manuring (Bogaard *et al.* 2007). It is necessary, therefore, to understand something about the ranges of absolute values which might be expected for the regions and sites being investigated, particularly since the mechanisms involved in causing changes at the base of the food chain, in the plants, are not fully understood. In this respect, since this study includes both human and animal values for a significant number of sites, it will be useful in providing a context for future research into British Iron Age material.

The best way to gain an understanding of the background values for a site is to analyse animal bone and to compare the values for these with those obtained for humans. Since prehistoric herbivores will have eaten only plant protein, the values obtained from their bone collagen provide information about the environmental differences between sites to be seen in the plants at the base of the food chain. The values for the herbivores can then be compared with the data from omnivores and carnivores, allowing more subtle interpretations to be made which can take into account these environmental factors. The data included in this study are unusual in providing a significant number of analyses of animals from each of the locations being considered. This aspect of the data-set is essential for detailed and meaningful interpretations to be undertaken.

METHODS

The data are presented as $\delta^{13}C$ and $\delta^{15}N$ values, which reflect the ratios of two isotopes (^{13}C and ^{12}C; ^{15}N, and ^{14}N) as compared to the ratios found in internationally accepted standards (VPDB and AIR for carbon and nitrogen respectively). The unit is ‰ (per mil, or parts per thousand). Collagen was extracted from human and animal bone samples using the standard procedures outlined in Richards and Hedges (1999), modified by the use of a Millipore Amicon Ultra-4 centrifugal filter (30,000 NMWL) prior to lyophilisation so that molecules over 30 kD were retained and more degraded material discarded (Brown *et al.* 1988). The collagen yields presented in Tables 2 and 3 must be considered in the light of the use of these filters.

Rib was the skeletal element sampled for the East Yorkshire humans, except for three individuals for which long bone cortex was taken. At the other sites it was not possible to be consistent in this way, both because of the fragmentary nature of much of the material and also to curatorial issues such as the avoidance of contaminating consolidants and the identification of separate individuals confused in storage. A mixture of skeletal material, including long bone cortex, ribs, and skull are, therefore, present. Animal samples were from various bone elements, depending on the material identified to species.

The collagen was combusted to CO_2 and N_2 and analysed using either a Thermo Finnigan DELTAplus XL continuous helium flow gas isotope ratio mass spectrometer coupled with a Flash EA 1112 elemental analyser or an Europa Scientific Geo 20/20 isotope ratio mass spectrometer coupled to a Roboprep elemental analyser, both at the University of Bradford. The analytical standard deviation, averaged from laboratory working standards run with the samples (methionine and bovine liver standard) and also from repeated measurements of extracted archaeological collagen, amounted to ± 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$. The isotope values presented are averaged from two replicates, analysed in separate batches, except where one replicate was discarded due to analytical problems

TABLE 2: ISOTOPIC DATA FOR HUMAN SAMPLES FROM EAST LOTHIAN, CORNWALL, & HAMPSHIRE

Sample	*Site*[1]	*Age*[2]	*Sex*[3]	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C:N	*Collagen Yield (%)*	%C	%N
BH 1	1	5	5	-20.7	11.4	3.3	8.7	45.3	16.0
BH 2	1	5	4	-20.8	11.1	3.3	4.9	46.3	16.4
BH 3	1	5	2	-20.9	10.2	3.3	8.3	46.0	16.2
BH 4	1	5	3	-20.5	11.1	3.3	9.6	43.1	15.2
BH 5	1	5	5	-20.7	10.3	3.4	1.1	41.2	14.0
BH 7	1	5	5	-20.8	10.3	3.4	6.3	43.8	15.2
BH 9	1	5	4	-21.0	10.9	3.3	8.5	45.6	16.0
BH 10	1	5	5	-20.7	10.1	3.3	4.7	44.3	15.6
BH 11	1	4	5	-20.9	10.6	3.3	3.1	52.3	18.3
BH 12	1	5	3	-20.6	10.3	3.3	3.9	43.7	15.4
BH 13	1	8	3	-20.6	10.6	3.4	2.7	43.1	15.0
BH 14	1	2	5	-20.4	10.1	3.3	1.5	39.2	13.7
DBH 2	2	5	2	-21.2	10.2	3.4	1.2	43.9	15.0
DBH 6	2	8	5	-21.3	10.6	3.5	1.0	41.7	13.7
DBH 8	2	4	5	-21.1	10.7	3.3	1.9	44.1	15.4
DBH 9	2	5	3	**-20.7**	**10.4**	3.4	**0.6**	**29.3**	**9.9**
DBH 14	2	8	5	**-21.2**	**10.5**	**3.6**	**0.8**	**42.1**	**13.9**
PSEH 2	3	2	5	-20.1	8.1	3.3	0.8	34.3	12.2
WHH 1	4	5	4	-20.9	11.9	3.3	8.8	44.9	15.8
WHH 2	4	4	2	-20.9	11.4	3.4	11.3	46.1	16.0
WHH 3	4	6	2	-20.7	11.0	3.3	10.2	44.5	15.6
WHH 4	4	7	1	-20.8	11.7	3.3	11.6	46.0	16.1
WHH 5	4	8	5	-20.8	11.6	3.4	3.5	44.0	15.1
WHH 6	4	8	5	-21.0	11.5	3.4	8.0	45.5	15.7
WHH 7	4	4	2	-20.7	11.7	3.4	10.1	45.6	15.9
WHH 1A	4	1	5	-20.7	11.3	3.4	5.6	44.8	15.6
HBH 1	5	N/K	5	-20.5	10.3	3.4	1.0	43.1	15.3
HBH 2	5	N/K	5	-20.9	10.1	3.4	1.2	44.8	15.6
HBH 3	5	3	5	-19.6	11.8	3.3	8.8	46.5	16.6
HBH 4	5	N/K	5	-20.7	11.0	3.3	2.4	45.3	16.3
HBH 5	5	N/K	5	-20.4	10.6	3.3	7.5	48.2	17.2
HBH 6	5	N/K	5	-20.9	10.9	3.4	1.6	44.5	15.5
HBH 7	5	N/K	5	-20.7	11.2	3.3	1.1	45.7	16.1
HBH 8	5	N/K	5	-21.0	10.4	3.3	1.9	45.7	16.2
HBH 9	5	N/K	5	-20.6	11.2	3.2	10.1	46.8	17.4
HBH 10	5	N/K	5	-20.5	10.6	3.3	1.8	42.8	15.3
HBH 11	5	N/K	5	-20.4	10.7	3.4	1.7	45.3	15.6
HBH 12	5	N/K	5	-21.1	11.1	3.3	3.1	47.2	17.2
HBH 13	5	N/K	5	-20.6	11.0	3.3	1.7	42.9	15.4
HBH 14	5	N/K	5	-20.7	10.8	3.4	2.5	42.9	15.0
HBH 15	5	N/K	5	-20.5	10.5	3.3	1.6	40.4	14.5
HBH 16	5	N/K	5	-20.3	10.9	3.3	7.4	44.7	15.6
HBH 17	5	N/K	5	-19.6	11.8	3.3	7.7	47.7	17.1
HBH 18	5	N/K	5	-20.6	11.0	3.3	5.9	45.6	16.4
HBH 19	5	N/K	5	-20.5	11.0	3.2	9.7	45.0	17.0
HBH 20	5	N/K	5	-20.1	10.7	3.1	10.1	47.3	17.6
TFH 1	6	5	1	-20.2	10.2	3.3	2.9	46.9	17.2
TFH 3	6	8	5	-20.8	10.1	3.5	1.0	45.9	15.3
TFH 4	6	8	5	-20.3	9.5	3.4	2.1	46.8	16.6
TFH 6	6	8	5	**-20.8**	**10.2**	**3.6**	**0.3**	**38.1**	**12.6**
WDH 1	7	8	5	-20.3	9.1	3.3	1.6	43.3	14.9
WDH 6	7	8	5	-21.0	8.7	3.5	1.0	42.9	14.2
WDH 7	7	8	5	-20.8	12.3	3.3	3.0	43.8	15.2
WDH 8	7	8	5	-20.1	8.5	3.4	2.6	43.9	15.0
WDH 10	7	8	5	-20.8	7.4	3.3	2.2	43.2	15.1
WDH 11	7	8	5	-20.3	8.8	3.4	1.9	44.1	15.3
WDH 13	7	8	5	-20.0	11.6	3.4	1.1	40.0	13.8
WDH 15	7	8	5	-20.1	11.2	3.3	1.6	40.0	14.1
WDH 16	7	8	5	-20.7	7.4	3.3	1.0	44.9	15.6

TABLE 2: ISOTOPIC DATA FOR HUMAN SAMPLES FROM EAST LOTHIAN, CORNWALL, & HAMPSHIRE

Sample	*Site*[1]	*Age*[2]	*Sex*[3]	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	*C:N*	*Collagen Yield (%)*	*%C*	*%N*
WDH 18	7	8	5	-20.3	8.2	3.3	4.0	44.8	15.9
WDH 21W	7	4	1	-20.5	8.0	3.3	2.3	44.3	15.6
WDH 23	7	8	5	-21.0	8.4	3.4	1.9	31.6	10.9
WDH 24	7	8	5	-20.2	8.5	3.2	2.7	33.7	12.1
WDH 25X	7	4	5	-20.4	8.2	3.3	3.3	44.0	15.5
WDH 26	7	8	5	-20.5	8.0	3.3	2.3	44.7	15.7
WDH 27	7	8	5	-20.4	8.5	3.2	1.9	32.1	11.5
WDH 28	7	8	5	-20.6	7.7	3.3	1.9	27.8	9.9
WDH 29	7	5	2	-20.4	10.0	3.3	2.6	45.0	16.0
WDH 37	7	1	5	-19.9	7.7	3.3	2.2	43.9	15.6
WDH 39	7	1	5	-20.0	8.8	3.3	2.3	43.7	15.3
WDH 40	7	5	2	-19.9	8.3	3.3	3.5	45.1	15.8
WDH 41	7	5	2	-20.3	8.3	3.3	2.3	43.6	15.4
WDH 42	7	6	1	-20.0	9.6	3.3	1.3	38.3	13.6
MWH 2	8	4	2	-20.3	11.0	3.3	2.6	44.4	15.6
MWH 5	8	4	1	-20.5	8.9	3.3	4.2	43.5	15.2
MWH 6	8	8	5	-20.3	9.1	3.3	1.3	34.7	12.2

[1]*Site codes*		[2]*Age codes*		[3]*Sex codes*	
Broxmouth, East Lothian	1	Child, 5 to <12	1	Male	1
Dryburn Bridge, East Lothian	2	Child, 3 to 8	2	Female	2
Port Seton, East Lothian	3	Child, unable to refine	3	Probably male	3
Winton House, East Lothian	4	Adolescent, 12 to <20	4	Probably female	4
Harlyn Bay, Cornwall	5	Young adult, 20 to <35	5	Unsexed	5
Trethellan Farm, Cornwall	6	Middle adult, 35 to 50	6		
Winnall Down, Hampshire	7	Old adult, 50+	7		
Micheldever Wood, Hampshire	8	Adult, unable to refine	8		
		No information available	N/K		

Note: All isotopic data are averaged from two replicates. Only those samples with atomic C:N ratios within the range of 2.9–3.6 indicating acceptable quality collagen (DeNiro 1985)) have been included in the table. Those data which are highlighted in bold text are within acceptable C:N range limits and have been included in the discussion, although they should be noted for either their proximity to the limits of that range, or else for their relatively low C and N percentages.

or a C:N ratio outside of the range 2.9 to 3.6 (DeNiro 1985). Where values approached the upper limit of this acceptable range, or where the percentages of carbon and nitrogen in the collagen sample are low, the data have been highlighted in the results tables for ease of reference (see van Klinken 1999). Removal of these data does not affect the averages discussed in this paper and it would have no effect on the discussion. They have been included here for completeness, since there is some level of subjectivity in the consideration of their quality indicators, although the isotopic ratios are not unusual.

RESULTS OF THE ANALYSIS

The isotopic data for East Lothian, Cornwall, and Hampshire are presented in Tables 2 (humans, n = 76) and 3 animals, n = 144). Those from East Yorkshire have been published in full elsewhere (n = 62 and 68 for humans and animals respectively; Jay & Richards 2006). Summarised data, including averages for human and domesticated herbivores at each location and the spacing between those averages ($\Delta^{13}C$ and $\Delta^{15}N$), can be found in Table 4. In general, the human $\delta^{15}N$ values are 4–5‰ higher than those for the domesticated herbivores (cattle and sheep), with an enrichment of around 1‰ in ^{13}C.

Table 4 reflects a small group of four individuals from Hampshire which have higher $\delta^{15}N$ values than the rest of their cohort. There are also five unusual humans which are not included in the summary Table 4. Two of these are from East Yorkshire and have higher $\delta^{15}N$ values than the rest of the cemetery population (12.3‰ and 11.2‰ for WWH 14 and 431, as compared to an average of 9.6±0.5‰). These are comparable to the Hampshire group of four mentioned above in this respect (WDH 15, 13, and 7,

TABLE 3: ISOTOPIC DATA FOR ANIMAL SAMPLES FROM EAST LOTHIAN, CORNWALL & HAMPSHIRE

Sample	*Species*	*Site*[1]	*δ13C (‰)*	*δ15N (‰)*	C:N	*Collagen Yield (%)*	%C	%N
BA 1	Sheep/goat	1	-21.7	8.7	3.3	5.2	43.7	15.5
BA 2	Pig	1	-21.9	6.5	3.4	6.1	45.6	15.9
BA 3	Cattle	1	-22.0	6.1	3.4	1.4	35.3	12.3
BA 4	Deer	1	-23.0	4.6	3.5	1.0	41.0	13.8
BA 5	Red deer	1	-22.1	3.3	3.3	1.5	44.0	15.5
BA 6	Red deer	1	-22.1	4.1	3.3	1.1	37.7	13.3
BA 7	Red deer	1	-22.1	4.0	3.3	3.2	44.4	15.6
BA 8	Roe deer	1	-21.4	4.8	3.3	7.8	45.8	16.1
BA 9	Roe deer	1	-21.3	2.1	3.3	1.2	42.0	14.7
BA 10	Red deer	1	-22.1	6.0	3.3	4.3	42.5	14.9
BA 11	Dog	1	-21.2	9.3	3.3	5.6	45.1	15.8
BA 12	Dog	1	-20.4	9.9	3.3	6.1	45.2	16.0
BA 13	Dog	1	-20.6	9.5	3.3	6.8	45.5	16.0
BA 14	Dog	1	-20.6	10.1	3.3	8.9	47.1	16.9
BA 15	Dog	1	-20.8	9.5	3.3	1.8	39.1	13.7
BA 16	Fish	1	-12.7	13.9	3.3	3.1	43.1	15.4
BA 17	Ling?	1	-12.3	16.2	3.2	2.3	39.6	14.6
BA 18	Shark	1	-13.1	14.3	3.4	3.8	41.4	14.2
BA 19	Fish	1	-13.2	15.5	3.3	2.9	42.3	15.0
BA 20	Cetacean	1	-14.8	12.8	3.3	3.5	44.2	15.7
BA 21	Shag or cormorant	1	-14.6	16.7	3.4	8.1	45.7	15.7
BA 22	Seal	1	-11.5	19.5	3.3	6.6	44.8	16.1
BA 23	Horse	1	-22.6	4.5	3.4	1.2	42.5	14.7
BA 24	Horse	1	-22.8	7.5	3.4	0.9	38.7	13.4
BA 25	Horse	1	-22.4	6.9	3.4	1.3	43.7	14.9
BA 26	Horse	1	-22.4	7.0	3.4	1.2	43.3	14.9
BA 27	Horse	1	-22.6	7.5	3.3	5.6	45.4	16.3
BA 28	Cattle	1	-21.6	6.5	3.2	5.1	45.5	16.4
BA 29	Sheep/goat	1	-21.8	7.5	3.3	6.1	45.5	15.7
BA 30	Pig	1	-22.0	7.8	3.1	7.0	46.2	17.3
BA 31	Cattle	1	-21.9	6.8	3.5	0.7	43.8	14.6
BA 32	Pig	1	-21.2	8.5	3.3	1.1	43.6	15.1
BA 33	Cattle	1	-22.2	4.9	3.2	6.7	45.7	16.5
BA 34	Sheep/goat	1	-21.6	6.1	3.3	5.8	44.4	15.6
BA 35	Pig	1	-22.3	7.9	3.3	5.9	44.5	15.6
BA 36	Sheep/goat	1	-21.3	6.5	3.2	6.8	44.7	16.0
BA 37	Sheep/goat	1	-21.8	6.2	3.2	1.3	43.6	15.4
BA 38	Cattle	1	-21.8	6.2	3.4	0.8	43.9	15.0
BA 39	Sheep/goat	1	-21.4	4.7	3.2	5.3	44.1	15.6
BA 40	Pig	1	-21.7	8.1	3.3	6.8	43.8	15.0
BA 41	Pig	1	-21.4	7.4	3.3	4.6	44.2	15.2
BA 39A	Sheep/goat	1	-21.3	5.0	3.2	7.4	47.1	17.0
DBA 1	Cattle	2	-21.8	4.5	3.4	0.9	44.0	15.0
DBA 2	Cattle	2	-21.8	6.8	3.4	2.2	44.0	15.2
DBA 3	Cattle	2	-21.6	5.0	3.4	2.7	44.3	15.3
DBA 4	Horse	2	-22.5	7.1	3.3	6.0	45.1	15.8
DBA 5	Dog	2	-21.5	8.6	3.5	1.6	44.4	14.9
DBA 6	Cattle	2	-21.9	6.2	3.5	1.3	44.0	14.8
DBA 8	Pig	2	-21.3	6.8	3.3	5.2	43.6	15.5
DBA 9	Sheep/goat	2	-21.8	6.3	3.3	3.3	45.0	15.7
PSEA 1	Sheep/goat	3	-21.9	7.4	3.3	3.8	42.9	15.3
PSEA 2	Cattle	3	-21.4	6.5	3.3	2.9	43.9	15.5
PSEA 3	Cattle	3	-22.1	3.7	3.4	5.7	44.6	15.4
PSEA 4	Cattle	3	**-21.8**	**6.3**	**3.6**	**0.6**	**41.4**	13.4
PSEA 7	Cattle	3	-21.4	5.6	3.3	3.1	43.4	15.3
PSEA 8	Sheep/goat	3	-21.4	7.0	3.3	1.1	35.4	12.5
PSEA 11	Sheep/goat	3	-22.0	7.7	3.5	0.3	33.8	11.4
PSEA 14 .	Pig	3	-21.6	9.2	3.3	1.2	38.8	13.9
HBA 2	Cattle	4	-21.8	5.8	3.3	1.2	41.0	14.7
HBA 3	Pig	4	-22.4	5.7	3.2	4.1	46.3	17.0
HBA 4	Unknown animal	4	-21.7	5.9	3.3	1.1	42.5	14.9
HBA 6	Cattle	4	-21.9	5.8	3.3	1.8	42.0	14.8
TREV 1	Cattle	5	-21.9	5.8	3.5	0.9	41.7	14.1
TREV 2	Cattle	5	**-22.0**	**5.8**	**3.4**	**0.2**	**24.9**	8.6
TREV 3	Red deer	5	**-22.0**	**5.4**	**3.4**	**0.4**	**20.9**	7.1
TREV 4	Red deer	5	-22.2	5.9	3.5	0.5	41.1	13.7
TREV 5	Pig	5	-21.6	7.5	3.3	0.5	42.3	14.8
TREV 6	Pig	5	-21.0	9.3	3.5	0.5	39.9	13.3
TREV 7	Sheep/goat	5	-22.1	6.4	3.4	1.3	34.8	11.8
TREV 8	Sheep/goat	5	-21.9	5.4	3.3	6.6	43.8	15.3
TREV 10	Sheep/goat	5	-21.3	5.8	3.3	4.9	43.1	15.5
TREV 11	Sheep/goat	5	-21.6	5.7	3.4	2.3	34.2	11.7
TREV 12	Cattle	5	-22.2	4.8	3.5	0.7	37.8	12.4
TREV 13	Pig	5	-21.6	6.4	3.4	6.7	43.6	15.2
TREV 14	Red deer	5	-22.0	4.8	3.4	3.4	41.5	14.3
TREV 15	Pig	5	-21.5	8.0	3.3	3.7	42.3	14.8
TREV 16	Sheep/goat	5	-21.7	6.5	3.5	0.5	41.5	13.8
TREV 17	Cattle	5	-21.7	5.1	3.4	1.0	30.6	10.5
TREV 19	Cattle	5	-21.5	5.7	3.3	1.7	37.5	13.2
TREV 20	Cattle	5	-22.5	5.1	3.3	4.8	42.7	15.2
TREV 21	Sheep/goat	5	-22.1	4.8	3.4	1.5	41.4	14.4

TABLE 3: ISOTOPIC DATA FOR ANIMAL SAMPLES FROM EAST LOTHIAN, CORNWALL & HAMPSHIRE

Sample	*Species*	*Site*[1]	δ13C (‰)	δ15N (‰)	C:N	*Collagen Yield (%)*	%C	%N
TREV 23	Horse	5	-22.5	4.9	3.5	0.5	40.7	13.0
TREV 24	Pig	5	-21.5	5.5	3.3	1.3	38.1	13.3
TREV 25	Red deer	5	-21.8	5.3	3.3	0.9	40.9	14.3
TREV 26	Pig	5	-20.8	5.5	3.3	1.8	42.1	14.7
TREV 27	Cattle	5	-22.3	6.7	3.4	1.4	41.8	14.6
TREV 28	Sheep/goat	5	-21.6	5.7	3.3	5.7	43.0	15.4
TREV 29	Pig	5	**-21.9**	**8.1**	**3.4**	**0.8**	**27.8**	**9.6**
TREV 30	Pig	5	-21.7	6.7	3.4	1.1	40.6	13.9
TREV 31	Sheep/goat	5	-22.1	5.7	3.5	1.4	40.5	13.5
TREV 32	Horse	5	-22.9	4.1	3.3	1.8	41.2	14.4
WDA 1	Pig	6	-20.7	4.3	3.4	1.0	43.6	14.5
WDA 2	Horse	6	-22.1	3.5	3.4	1.2	43.6	14.5
WDA 3	Dog	6	-20.8	6.7	3.3	2.6	44.7	15.0
WDA 4	Domestic fowl	6	-20.4	8.5	3.5	1.5	43.9	14.2
WDA 5	Cattle	6	-21.3	4.1	3.3	3.5	44.6	15.1
WDA 6	Domestic fowl	6	-20.0	7.0	3.5	1.4	43.9	14.1
WDA 7	Horse	6	-22.8	2.6	3.4	0.7	43.3	14.1
WDA 8	Cattle	6	-21.7	3.6	3.4	1.1	43.6	14.6
WDA 9	Sheep/goat	6	-21.1	3.4	3.2	3.9	44.7	15.4
WDA 10	Cattle	6	-22.0	5.0	3.3	1.6	43.9	15.0
WDA 11	Cattle	6	-22.2	4.0	3.4	1.2	43.7	14.4
WDA 12	Cattle	6	-21.7	3.6	3.4	0.8	42.3	13.8
WDA 13	Sheep/goat	6	-21.3	3.8	3.2	2.5	42.1	14.5
WDA 14	Horse	6	-22.1	5.4	3.4	1.8	45.6	16.2
WDA 15	Pig	6	-21.1	6.1	3.4	0.8	45.8	15.2
WDA 16	Dog	6	-20.0	8.4	3.3	1.2	46.1	15.9
WDA 17	Horse	6	-22.8	4.0	3.4	1.1	43.9	14.6
WDA 18	Sheep/goat	6	-21.5	4.0	3.4	0.9	43.5	14.3
WDA 19	Horse	6	-21.6	5.0	3.4	1.0	43.9	14.3
WDA 20	Cattle	6	-22.2	4.4	3.3	1.0	39.8	13.5
WDA 21	Sheep/goat	6	-21.4	4.4	3.3	0.6	43.7	14.7
WDA 22	Cattle	6	-21.4	3.9	3.4	0.9	37.5	12.7
WDA 23	Sheep/goat	6	-21.7	5.1	3.4	1.4	41.4	14.1
WDA 24	Pig	6	-22.0	6.0	3.4	0.9	42.9	14.5
WDA 25	Cattle	6	-21.9	5.5	3.3	2.1	44.7	15.9
WDA 26	Pig	6	-21.6	6.5	3.3	1.1	40.5	14.2
WDA 27	Dog	6	-20.5	10.3	3.3	1.3	44.3	15.4
WDA 28	Vole	6	**-22.9**	**6.0**	**3.6**	**0.2**	**44.0**	**14.0**
WDA 29	Greylag goose	6	-21.9	6.5	3.4	6.0	44.9	15.4
WDA 30	Sheep/goat	6	**-22.2**	**4.9**	**3.6**	**0.7**	**43.6**	**13.7**
WDA 31	Cattle	6	-21.4	3.7	3.3	1.3	40.2	14.1
WDA 32	Sheep/goat	6	-21.5	4.1	3.3	1.6	41.5	14.4
WDA 34	Grey heron	6	**-25.2**	**12.3**	**3.6**	**1.4**	**43.9**	**14.3**
WDA 35	Raven	6	-20.8	9.0	3.4	1.2	43.4	14.9
WDA 36	Cattle	6	-22.5	7.3	3.2	4.3	43.0	15.5
WDA 37	Cattle	6	-21.5	3.7	3.3	1.3	37.6	13.1
WDA 38	Sheep/goat	6	-21.2	3.0	3.3	5.0	43.3	15.4
WDA 39	Sheep/goat	6	-22.4	5.2	3.3	1.6	41.3	14.4
WDA 40	Red deer	6	-21.9	5.2	3.2	2.3	40.6	14.9
WDA 41	Mallard	6	-23.6	8.4	3.4	2.2	43.2	14.7
WDA 42	Mallard	6	-24.0	6.0	3.4	6.8	45.0	15.7
WDA 43	Mallard	6	-24.4	8.5	3.5	2.2	42.7	14.2
WDA 44	Cyprinid?	6	-24.2	11.5	3.3	6.2	44.1	15.6
MWA 1	Pig	7	-21.6	6.0	3.4	1.4	40.0	13.8
MWA 2	Common toad	7	-21.0	7.4	3.5	3.3	42.4	14.2
MWA 3	Fox	7	-20.1	7.8	3.3	1.8	42.6	15.0
MWA 4	Hare	7	-23.7	4.8	3.4	4.9	43.6	15.1
MWA 5	Pig	7	-20.5	6.1	3.3	2.3	42.9	15.1
MWA 6	Water vole	7	-23.1	3.0	3.4	0.8	41.1	14.1
MWA 7	Pig	7	-21.7	6.4	3.3	2.4	44.1	15.4
MWA 8	Pig	7	-21.1	6.0	3.4	1.4	43.2	14.9
MWA 9	Pig	7	-21.4	6.1	3.4	1.4	43.5	14.9
MWA 10	Stoat	7	-20.8	7.4	3.3	5.1	43.0	15.3

[1] *Site codes:*

Broxmouth, East Lothian	1
Dryburn Bridge, East Lothian	2
Port Seton, East Lothian	3
Harlyn Bay, Cornwall	4
Trevelgue Head, Cornwall	5
Winnall Down, Hampshire	6
Micheldever Wood, Hampshire	7

Note: All isotopic data are averaged from two replicates, except in four cases where yields were low and only one value with acceptable quality indicators was available (TREV 2, 3, and 23; WDA 28). Only those samples with atomic C:N ratios within the range of 2.9–3.6 (indicating acceptable quality collagen (DeNiro 1985)) have been included in the table. Those data which are highlighted in bold text are within acceptable C:N range limits and have been included in the discussion, although they should be noted for either their proximity to the limits of that range, or else for their relatively low C and N percentages.

Sheep are listed as a 'sheep/goat' category, in order to acknowledge the difficulty of differentiation, although the predominant proportion of these are expected to be sheep.

TABLE 4: SUMMARY DATA & AVERAGE ISOTOPIC ENRICHMENTS FOR HUMANS OVER HERBIVORES FOR THE DIFFERENT LOCATIONS

Location	$\delta^{15}N$ *Humans (‰)*	$\delta^{15}N$ *Herbivores (‰)*	$\Delta^{15}N_{(human-herbivore)}$ *(‰)*	$\delta^{13}C$ *Humans (‰)*	$\delta^{13}C$ *Herbivores (‰)*	$\Delta^{13}C_{(human-herbivore)}$ *(‰)*
Wetwang and Garton Slack Human average excluding two outliers (see text). Humans: *n* = 60; Herbivores: *n* = 25	Avge: 9.6 ± 0.5 Range: 8.6 to 10.5 (1.9‰)	Avge: 4.8 ± 1.0 Range: 3.3 to 7.1 (3.8‰)	4.8 ± 1.5	Avge: -20.5 ± 0.3 Range: -21.2 to −19.9 (1.3‰)	Avge: -21.6 ± 0.4 Range: -22.8 to −20.8 (2.0‰)	1.1 ± 0.7
Hampshire Human average excludes four individuals with higher nitrogen values (see text) (these four shown below separately). Humans: *n* = 22; Herbivores: *n* = 20 or 19 , if WDA 36 excluded	Avge: 8.5 ± 0.6 Range: 7.4 to 10.0 (2.6‰)	Avge: 4.3 ± 1.0 OR 4.2 ± 0.7 Range: 3.0 to 7.3 (4.3‰) OR 3.0 to 5.5 (2.5‰)	4.2 ± 1.6 OR 4.3 ± 1.3	Avge: -20.4 ± 0.3 Range: -21.0 to −19.9 (1.1‰)	Avge: -21.7 ± 0.4 OR -21.7 ± 0.4 Range: -22.5 to −21.1 (1.4‰) OR -22.4 to −21.1 (1.3‰)	1.3 ± 0.7
Hampshire Four individuals with higher nitrogen values excluded above (see text). Humans: *n* = 4	Avge: 11.5 ± 0.6 Range: 11.0 to 12.3 (1.3‰)	As above	7.2 + 1.6	Avge: -20.3 ± 0.4 Range: -20.8 to −20.0 (0.8‰)	As above	1.4 ± 0.8
East Lothian: Broxmouth Humans: *n* = 12; Herbivores: *n* = 24	Avge: 10.6 ± 0.4 Range: 10.1 to 11.4 (1.3‰)	Avge: 6.2 ± 1.1 Range: 3.7 to 8.7 (5.0‰)	4.4 ± 1.5	Avge: -20.7 ± 0.2 Range: -21.0 to −20.4 (0.6‰)	Avge: -21.7 ± 0.3 Range: -22.2 to −21.3 (0.9‰)	1.0 ± 0.5
East Lothian: Winton House Humans: *n* = 8; Herbivores: as above	Avge: 11.5 ± 0.3 Range: 11.0 to 11.9 (0.9‰)	As above	5.3 ± 1.4	Avge: -20.8 ± 0.1 Range: -21.0 to −20.7 (0.3‰)	As above	0.9 ± 0.4
East Lothian: Dryburn Bridge Humans: *n* = 5; Herbivores: as above	Avge: 10.6 ± 0.3 Range: 10.2 to 11.0 (0.8‰)	As above	4.4 ± 1.4	Avge: -21.1 ± 0.2 Range: -21.3 to −20.7 (0.6‰)	As above	0.6 ± 0.5
Cornwall Human average excludes two individuals likely to have had some marine input in their diet (see text). Humans: *n* = 22; Herbivores: *n* = 15	Avge: 10.6 ± 0.4 Range: 9.5 to 11.2 (1.7‰)	Avge: 5.7 ± 0.6 Range: 4.8 to 6.7 (1.9‰)	4.9 ± 1.0	Avge: -20.6 ± 0.3 Range: -21.1 to −20.1 (1.0‰)	Avge: -21.9 ± 0.3 Range: -22.5 to −21.3 (1.2‰)	1.3 ± 0.6

Note: Herbivores are the cattle and sheep and include some individuals which may be later in date (late Iron Age or Romano-British), since the environmental parameters are not expected to have changed during the later period. Very young animals have been excluded. The East Lothian herbivores are averaged from across the location (including Port Seton) and are not specific to the individual sites listed.

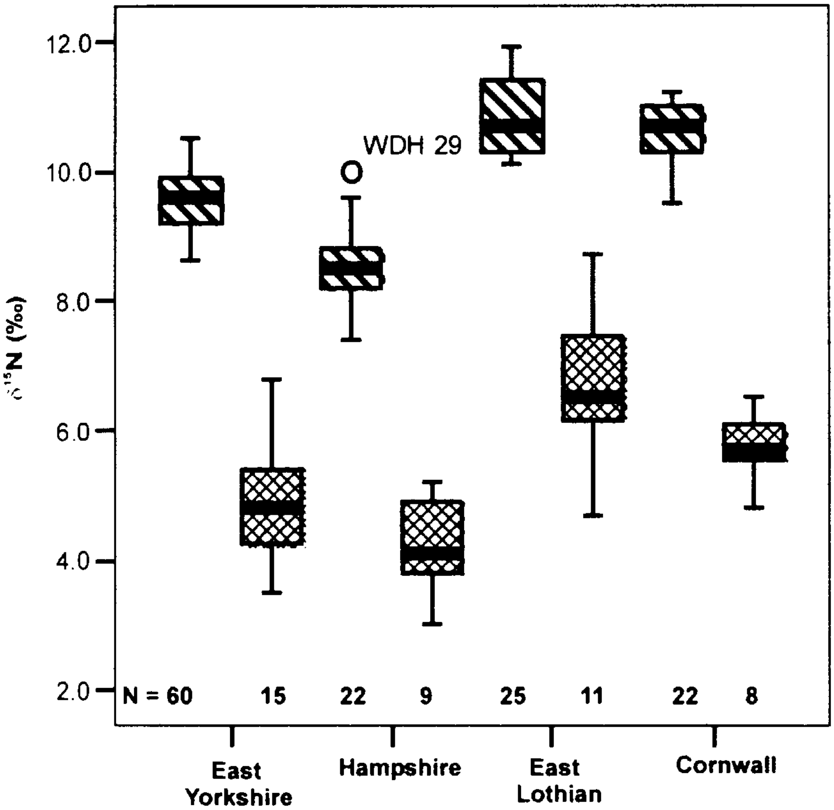

Fig. 2.
Boxplot of $\delta^{15}N$ values for humans as compared to sheep/goats at the separate locations (humans above, sheep/goats below). The more elevated human values from Hampshire (4) and East Yorkshire (2) are excluded, as are the two Cornwall individuals showing low-level marine consumption and the Port Seton sample. The boxes represent the interquartile range, containing 50% of the values, and the whiskers represent the range. The line across the box represents the median. Sample numbers are shown on the lower axis. The outlier shown is defined as a value between 1.5 and 3 box lengths (interquartile range) from the edge of the box

MWH 2; see Tables 2 & 4 for values). Another is from Port Seton and has a much lower $\delta^{15}N$ value than is seen elsewhere in East Lothian, although there are no other human values from this particular site (8.1‰ for PSEH 2, as compared to the average of 11.5±0.3‰ for Winton House, which is geographically closest). It is suggested that all of these, including those from Hampshire, may relate to mobile individuals who have built up a bone collagen signal elsewhere over a significant period of time and then moved to, or been buried at, a different location. This is discussed further below. The final two individuals of interest are from Cornwall (HBH 3 and 17) and reflect low-level marine resource consumers.

Figure 2 shows box-plots for the sheep/goat nitrogen values from the different locations, as compared to those for the humans from the same locations. This shows that the absolute averages for both humans and sheep/goats for each of the locations are different, but that the humans follow the pattern of the sheep according to their location. This is important to the discussion, since it indicates that absolute differences in the isotopic values of the humans do not necessarily reflect differences between the groups in terms of diet. In this case, the sheep data indicate that the $\delta^{15}N$ values vary at the base of the food chain according to location across Britain and this must be taken into account in the interpretation of the data.

Figure 3 is a scatter plot of the carbon and nitrogen isotopic ratios for all of the humans discussed in this paper, with the dotted lines indicating the range of carbon values from across Britain for these locations. The two unusual individuals from Cornwall mentioned above are outside this basic 'terrestrial' range of carbon values, at the less negative end of the scale (they both have exactly the same isotopic values). Since their nitrogen values are also elevated in comparison to the rest of the data from this area, they are considered to be the only ones from this data-set which provide any indication of a marine resource component to the diet (eg, fish or shellfish). This component is, however, interpreted as minor when compared with what might be visible from such data for a high-level marine consumer (eg, approximate $\delta^{13}C$ of -12‰ for Mesolithic humans from Scotland (Richards & Mellars 1998)).

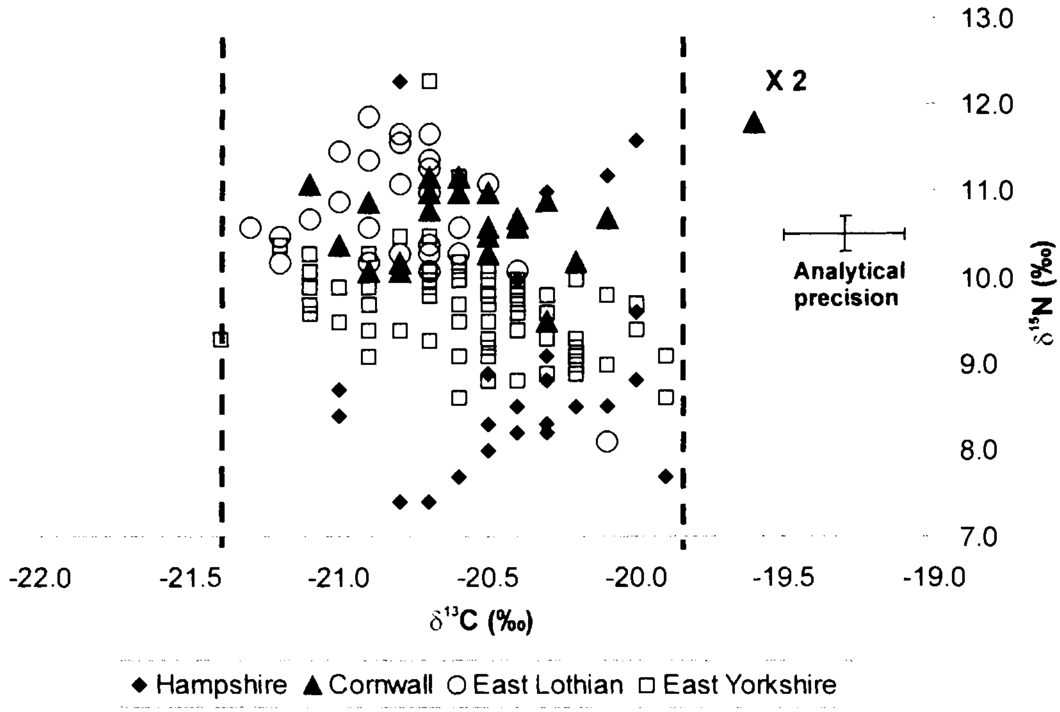

Fig. 3.
Scatter plot of the human values discussed in the text. The dotted lines indicate the range of carbon values for the majority of these from across Britain (-21.4 to -19.9‰), whilst the two low-level marine consumers from Cornwall (both with exactly the same values) are shown outside this range

DISCUSSION OF THE ISOTOPIC DATA IN ISOLATION

If the isotopic data are considered in isolation, there are four significant points for discussion. First, although there are individual outliers at each location which require separate interpretations, the main clusters of human data from the individual sites are relatively tight in isotopic terms (see Fig. 3) and they do not show any noticeable differences between possible intra-site cohorts (eg, sex, age, burial rite, etc). This suggests that, for each burial group, the dietary regime, insofar as it is possible to define it with these stable isotopes, was relatively consistent across the group.

The second major discussion point relates to the level of animal protein in the diet. For each of the locations, the spacing between the averaged isotopic ratios of the humans and the domesticated herbivores is over 4‰ for nitrogen and around 1‰ for carbon. This would seem to indicate high levels of animal protein for all of the groups investigated here. Such a conclusion must be considered in relative terms, since there is still a long way to go before the theoretical modelling tools available will allow us to discuss such conclusions in terms of absolute proportions or amounts, at least for archaeological material (Hedges & Reynard 2007). However, it can be concluded that they are at the top end of the range of animal protein consumers currently seen in the relevant literature. Figure 4 illustrates this by comparing data from animals at different trophic levels with the humans from the Hampshire sites (excluding a small number of individuals with high $\delta^{15}N$ values – see below). This does not mean that plant consumption was necessarily at low levels, since it is likely that the high protein content of meat or dairy products would 'flood' the signal to be seen from plant proteins. It may mean that significant levels of both were present in the diets of these individuals.

The high human $\delta^{15}N$ values may also reflect the consumption of animals which are either unweaned, or recently weaned, particularly suckling pigs. Since these animals are consuming milk from their mothers, they show isotopically as being at a higher trophic level than the adults. If humans consume the flesh of these young animals, then it will lead to their own nitrogen values being higher. Large quantities of bone from very young animals are not generally found at the sites, but there are problems in relying on negative evidence. In particular, if pigs or dogs were being given bone for their own consumption, then the bone from small, very young animals would be expected to disappear. In those circumstances, it is reasonable to look at the isotopic values of those animals and query whether they appear to be eating animal protein. Adult pigs from Wetwang and East Lothian appear to be very similar to those of the herbivores, but the pigs from Cornwall and Hampshire have comparatively higher $\delta^{15}N$ values. There are dog values available from Wetwang, East Lothian, and Hampshire, with the values for all of these being indicative of animal protein consumption (as would be expected). Those from the first two locations fit between the values for the herbivores and humans, but those from Hampshire are particularly high, being equivalent to the humans (see Fig. 4). These values would be consistent with the idea that animal protein was being provided to at least some groups of pigs and dogs, with particular emphasis on the Hampshire animals.

Discussion of the level of animal protein being consumed leads directly into the third main issue to be considered. Whilst the individual groups were apparently all consuming high levels of such protein, and this can be seen by comparing the animal values with those from humans at the different locations, the averaged nitrogen values for the humans at the different sites are different in absolute terms. In other

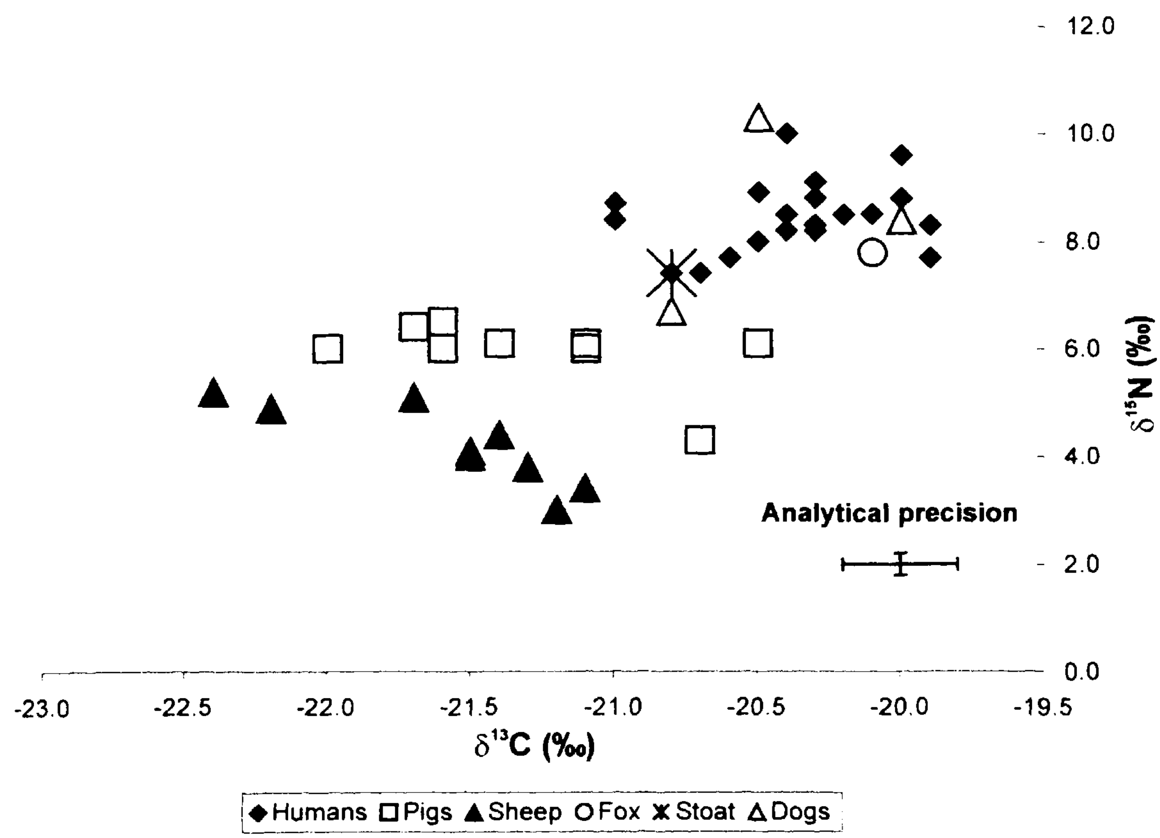

Fig. 4.
Scatter plot of humans and selected animals from the Hampshire sites illustrating the relative positions of animals at different trophic levels in the food chain. The four humans with anomalously high $\delta^{15}N$ values are omitted from the plot (see text for details)

words, the groups have very similar consumption patterns (in isotopic terms), but they also have different fixed values. This can clearly be seen in Figure 3. The herbivores from the different locations also have different absolute values and these provide the evidence for an environmental 'baseline' for the sites (see Fig. 2). Varying nitrogen isotopic values at the base of the food chain (in the plants) are fed through until they reach the humans. Environmental factors at the different sites have an effect on this 'baseline', thus varying the absolute values that are to be seen at the human trophic level.

This point is very important to consider when attempting to interpret carbon and nitrogen isotopic data. It means that interpreting individual human data-points, without the benefit of animal bone from the same sites and time periods, can be difficult and, at times, misleading.

The final matter to be considered here relates to the consumption of aquatic resources (both marine and freshwater). Although two of the locations (Cornwall and East Lothian) were chosen for sites which were directly on the coast, where marine foods would have been easily accessible, and the Hampshire sites were located in an area where riverine, estuarine, and marine foods would have been similarly fairly easily obtained, there is little evidence for the consumption of any aquatic resources in amounts large enough to have an impact on the isotopic data. The two individuals from Harlyn Bay (Cornwall) which show a low level of marine consumption are only identifiable as such because of the large size of the overall data-set.

There is little isotopic evidence for significant marine protein consumption in Britain, either for the pre-Roman Iron Age, or, indeed, for most of later prehistory. In general, the data clearly show high-level Mesolithic marine resource consumption which ceases to be visible in the Neolithic (Richards *et al.* 2003) and does not reappear again in the available data until Roman influences are present (Richards *et al.* 2006). This does not mean that very occasional fish consumption never occurred during this interval. Bone collagen is built up over a long period of time, so that the analysis of a bone sample from an adult will give results which reflect dietary protein over at least a decade. It is an averaged, lifetime diet which is being investigated. Our theoretical understanding of exactly how much fish protein would need to be in the diet before it started to become clear in the isotopic signal is not sufficient to model absolute percentages. But it is possible to talk about relative levels of consumption, with a high-level pattern visible in the Mesolithic and a low-level input for the two individuals from Cornwall discussed here.

These major discussion areas relate to the overall data-sets, but there are a number of individuals at each location who do not fit the overall pattern and who should be discussed separately. These include two individuals from East Yorkshire, one from East Lothian, and four from Hampshire, all of whom have $\delta^{15}N$ values which make them outliers within their own groups. Whilst they all look unusual when compared with their own local population, each of them would fit quite comfortably within the nitrogen value ranges to be seen at one or more of the other sites. Since their $\delta^{13}C$ values sit very comfortably within the rather restricted 'terrestrial' range of 1.5‰ depicted in Figure 3, and they are not unusual within their own groups in this respect, it is suggested that they may represent individuals for whom a collagen signal has been built up over many years at a different location, where $\delta^{15}N$ values are different to those seen at the site of burial, and that they then moved to another location, or were simply buried away from where they had lived. Analysis of strontium isotopes from the tooth enamel of the East Yorkshire individuals is currently underway, in collaboration with Montgomery, with a view to obtaining more evidence for such movement at that site.

It is often suggested that unusually high $\delta^{15}N$ values within a data-set may be indicative of aquatic (freshwater or estuarine) resource consumption. Such resources give isotopic signals which are not easy to interpret, since different species fill differing ecological niches and display a range of isotopic values. Their presence in the diet can, therefore, be used to explain high nitrogen values in humans where the circumstances are appropriate (eg, Cook *et al.* 2001; Bonsall *et al.* 2004). In this case, however, the archaeological evidence does not suggest this as a likely solution (see below for further discussion).

The Hampshire sites are the only ones which are located in such a way as to make freshwater or estuarine resources a more likely option than foods with a marine origin. Aquatic samples analysed from the early and middle Iron Age phases at Winnall Down were mallard, greylag goose, grey heron, common toad, water vole, and the one fish bone recovered from the site which was probably Cyprinid (A. Jones, pers.

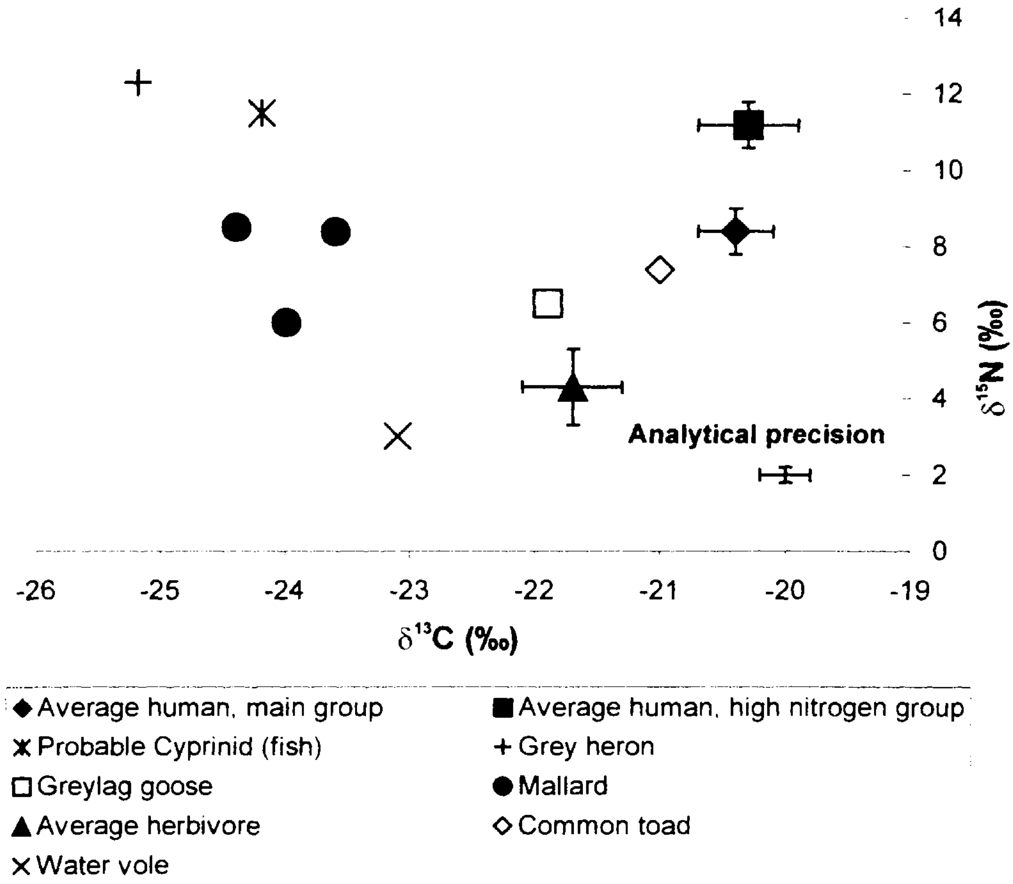

Fig. 5.
Averages for Hampshire humans, split between lower and higher nitrogen groups (n = 22 & 4 respectively), with averaged herbivores (sheep/goats and cattle) and individual aquatic animals from the sites

comm.). The isotopic data for the majority of these show significantly more negative carbon values than the herbivores and humans from the site (Fig. 5). If the humans with the higher nitrogen values at this site had been consuming significant quantities of the aquatic species actually found here, then they would also have carbon values which were more negative than the rest of the humans from the location. This is not the case. It is therefore considered that, in this case, mobility is a better explanation for these values, both in terms of the isotopic data and the archaeology.

OTHER EVIDENCE FOR DIET

The direct evidence from isotopic analysis, itself quite a general tool at this level, allows something to be said about what individuals and groups were doing, but requires support from other archaeological material when considering detailed interpretation. For instance, a high level of animal protein in the diet can be indicated by the chemical analysis, but this is not able to differentiate between meat or dairy products, whilst other evidence for butchery and dairying (eg, from animal bone or pottery residues) may tell us something more about the possibilities. In addition, a high level of animal protein in the diet does not preclude consumption of significant quantities of cereal grain, but the isotopic signal from the low-protein plants is likely to be 'flooded' by that introduced by the high-protein animal products, so that other evidence for the use of plant foods is likely to be more useful than the chemical evidence in this situation (eg, caries in teeth or the presence of cereal remains at sites).

Studies of animal bones from Iron Age sites show that cattle, sheep, pigs, goats, and horses were kept, as well as dogs. Of these, cattle and sheep are the main contributors to the assemblages, with significant levels of pig remains putting them in third place. Goats have been identified at some sites, but goat and sheep skeletal material is not easily differentiated and there is a tendency in publications to combine the two into a 'sheep' category, which is acknowledged to contain an unknown number of goats (Hambleton 1994, 14). Hambleton's study of British material across the Iron Age shows a general tendency for cattle and sheep to occur in roughly equal proportions (*ibid.*, 43–4). This is the very general picture, there being plenty of individual sites where cattle outnumber sheep, or *vice versa*, and a few outliers which show larger proportions of pig. Her regional analysis shows that the pattern is similar across Britain, so that the same general situation applies in the Northern region (*ibid.*, 45) as in Wessex and the Upper Thames areas, for instance.

What this tells us is that cattle, sheep/goats, and pigs were all likely to have been used to provide contributions to the diet in significant amounts. Butchery marks on some horse and dog bones might also indicate that they were consumed, but their much smaller presence in the archaeological record suggests that such consumption was limited and not a staple element. The absence of younger horses from the assemblages, together with the fact that horse bones are much less frequently cut or fragmented than cattle bones, suggest that horses were not kept primarily for meat (Maltby 1996, 23). However, horse bone from both of the Hampshire sites discussed in this paper showed evidence for butchery, and at Winnall Down horse carcasses were treated in similar ways to those of cattle in this respect (Maltby 1985, 106; Coy 1987, 47). Dog bones have also been found with butchery and skinning marks, which could indicate that they were occasionally eaten (eg, at both the Hampshire sites (Maltby 1985, 107; Coy 1987, 47)), but such utilisation is likely to be rare since complete bones and partial or complete skeletons are found much more often than for other domestic species (Maltby 1996, 23–4).

It is perhaps of some interest that bones of non-domesticated animals, including fish, are not found in any quantity on Iron Age sites (Hambleton 1999, 14). One of the possibilities for a major animal protein resource which could have been obtained in reasonably large packages is deer. It is interesting to note that where deer remains occur in the archaeological record, there is a high incidence of antler and a low incidence of other skeletal elements (Grant 1981, 210; Hambleton 1999, 22). This might suggest that hunting was occurring, but that the butchery and consumption was undertaken away from settlement sites. Alternatively, it is possible that antler was collected after being shed by the animals (Grant 1981, 210).

It is very difficult to use the information available from the bones to tell us much about whether the ruminants were used mainly for dairying or meat, and what proportions of the overall food resource were made up of the ruminants, the pigs and other contributors such as non-domesticated animals which might have been butchered away from the settlements. Dairying as interpreted from animal bone assemblages has largely relied upon ageing and sexing the material and assuming that a dairy herd will involve killing off male juveniles, leaving adult females available for milk production. There has, however, been some discussion about what a dairy herd would look like in the animal bone record and how easy it might be to recognise in situations where off-site trading, exchange, or slaughter were involved (eg, Entwistle & Grant 1989; Legge 1989; McCormick 1992).

The numbers of bones in the assemblages do not necessarily indicate the relative meat values of the animals. If there are two sheep and one cow, it is true to say that there are twice as many sheep as cows, but the meat value of the larger animal is more than that of the two sheep put together. Harcourt estimated that Iron Age cattle would have produced approximately 10 times the meat of a Soay sheep, with the pig producing 1.5 times (Harcourt 1979, 150 & 155). Another point to bear in mind is the lifespan and breeding capacity of the animal. Pigs produce many more young during a year than sheep, for instance.

Consideration of these points also assumes similar preservation and recovery rates for the bones of the various animals. This is unlikely to be the case. Preservation will be affected by factors such as bone density and porosity, and there have been suggestions that pig, in particular immature pig, is less likely to survive for physical reasons (eg, Ioannidou 2003; Robinson *et al.* 2003). The ways in which food preparation and discard affect recovery must also be considered. If suckling pig, for instance, were a significant part of the diet (as might be suggested at

Wetwang; see Jay & Richards 2006), then cooking these young animals on a spit and discarding the remains on a site where dogs and pigs are living may well not result in any of the bone surviving. An experimental study on the consumption of bones by pigs suggested that pig bone would almost all disappear if fed to them, whilst cattle bone would generally survive in a gnawed state (Greenfield 1988). Pigs will certainly consume almost all of the bone from smaller animals if it is given to them. Survival of small animal bones, such as those from birds or fish, is rarely to be compared with large mammals, and recovery of these is not to be expected where time-consuming techniques such as sieving and flotation have not been employed. In fact, these techniques are rarely employed on Iron Age sites, except where these are specifically undertaken as research excavations, so an average animal bone assemblage is unlikely to produce material which is comparable between faunal categories.

The numbers of bones found from very young animals (recently weaned, or unweaned), has not been generally indicative of a situation in which their large-scale consumption is in evidence from the zooarchaeological record. But when processing, discard, and preservation issues are taken into account, it has to be questioned whether they would be, particularly if pigs and dogs were consuming animal bone at the settlement sites. In support of suckling pigs being spit-roasted is the example of a young pig forequarter included in the Wetwang village 'chariot' burial, where the bones from the snout and the ends of the legs were burned in a manner consistent with this form of cooking (Mackey, pers. comm.). This burial also included a number of very young animals in the enclosure ditch, which may have been the remains of a funerary rite involving the consumption of an entire litter. The burial practice at Wetwang generally does involve the inclusion of pig remains in a small number of graves and these tend to be young animals. Piglet remains from early Iron Age Staple Howe (Yorkshire) were suggested to have been indicative of suckling pig consumption in the animal bone report (King 1963, 136) and the remains of one very young piglet were found at Port Seton (Hambleton & Stallibrass 2000, 151).

Analysis of pottery residues may help in the discussion about the consumption of animal protein and its possible sources. A limited amount of work has been done on Iron Age ceramics, including material from Maiden Castle, Danebury, and Yarnton (all in the south of England, in Dorset, Hampshire, and Oxfordshire respectively), and from Stanwick and Easingwold (both further to the north, in North Yorkshire). The southern English sites and Stanwick all appear to show ruminant adipose and dairy fats, with a limited level of plant lipids visible (Copley *et al.* 2005a). None of them indicates that pig adipose fat was present in isolation in the pottery, although it may have been present in mixtures with ruminant adipose fat. It is important to be aware here, however, that there is a possibility that pig and ruminant mixtures may be confused with the fats from non-adipose ruminant sources, such as from bone marrow, liver, or brain processing (Mukherjee 2004). This apparent lack of pure pig fats contrasts with the picture for the later Neolithic as found in Grooved Ware vessels, where porcine fats appear to be present on a much larger scale than is seen for the earlier Neolithic, the Bronze Age, or the Iron Age (Dudd *et al.* 1999; Mukherjee 2004, 273, fig. 7.1; Copley *et al.* 2005a; 2005b; 2005c).

The analysis from Easingwold indicates the presence of ruminant adipose fat sources (probably meat processing) and some plant usage, but does not show the presence of cattle dairy protein (Stacey 1999; Craig *et al.* 2000). This site, however, is later in date (1st century AD) than those for which the isotopic evidence is presented here and Roman influences may have started to change dietary patterns. Work on material from Iron Age Cladh Hallan, in the Outer Hebrides, does show the presence of protein from cows' milk (Craig *et al.* 2000), but this, again, is not strictly comparable, since the Western and Northern Isles of Britain present special cases in terms of their environments, marginality and dating. The Iron Age here is generally later than is seen further south, and this site is again later in date than the period under discussion.

Whilst this evidence is useful, there continue to be problems in coming to definitive conclusions. Clearly, both meat and dairy products were included in the diet. The absence of pure pig fats in pottery does not mean that significant numbers of pigs were not eaten, since there are many ways of cooking it which would not involve the use of a pot. Again, spit-roasting is the obvious contender. Evidence from bone, however, for roasting on or in a fire is in short supply. It was seen at Durrington Walls in the late Neolithic, but apparently has rarely been found elsewhere (Albarella & Serjeantson 2002, 42).

The Iron Age is a period when very few perennial (living for a number of years) food plants appear to have been utilised, with annual seed-bearing plants (mainly cereal grasses and legumes) forming a higher than usual proportion of the plants available for human consumption (Jones 1996, 29). There was probably a very high dependence on plants produced in cultivated fields (*ibid*, 31). In contrast, plant foods such as fruit and nuts seemed to have played a much larger part in both earlier and later periods in supplying nutritional requirements (*ibid*, 29). This may have a parallel in Iron Age meat consumption, where very few wild animals, such as birds, fish, or deer, appear to have been included in the diet, on the basis of the remains found at sites. Significant use of cereal grains at the sites discussed in this paper is clearly indicated by the archaeological evidence.

For the Hampshire sites, detailed environmental sampling was undertaken and the conclusions reached for Winnall Down were that, during the middle Iron Age, the occupants were an arable farming community dependent on cereal production (particularly barley) (Monk 1985, 116). Again, the environmental evidence at Port Seton indicated cereal crop usage, with emmer wheat and barley being predominant (Haselgrove & Lowther 2000, 176). At Wetwang and Garton Slack, a large pit with a significant amount of charred barley was discovered (Brewster 1980, 363).

In addition to the environmental evidence for cereal grains, together with the presence of querns and site features interpreted as storage facilities, such as pits and 'granaries', high-level grain consumption is likely to be reflected in the caries seen in the teeth of Iron Age individuals. Caries rates appear to increase over time during prehistory, with the introduction of cereal agriculture bringing a higher level of dietary starch and Iron Age carious teeth being more numerous than those seen in the Neolithic and the Bronze Age (Brothwell 1959; Hardwick 1960; Brothwell & Blake 1966; Hillson 1996, 283). Studying caries in Iron Age populations is difficult, since a significant number of individuals from one site retaining relatively complete dentitions is rarely found. However, Wetwang and the other East Yorkshire cemeteries provide a rare opportunity for this and significant levels of caries are found here (J. Dawes, unpublished data; Stead 1991; Freebairn 2005).

The question of whether Iron Age people were generally consuming significant amounts of fish has been open for some time. There is very little evidence, either artefactual or zooarchaeological, to suggest such consumption (Dobney & Ervynck in press), but there is a tendency for the assumption to be made that, since the resource was readily available and the technology was available to exploit it, it *must* have been exploited. The evidence from stable isotopes strongly suggests that this was not the case, at least not to any significant extent, and this tends to be supported by the lack of fishing equipment or fish bones from middle Iron Age sites, although small numbers of these do exist. At Harlyn Bay, for instance, the grave goods included two perforated slate needles which Whimster proposed were suggestive of the manufacture or repair of fishing nets (1977, 80), although they may easily have had another purpose. The early Iron Age site at Staple Howe in Yorkshire has a number of artefacts described as netting needles and gorges, the possible uses for the former being listed to include fish net construction and the latter being described as useful for catching fish or birds (King 1963, 126). It should be borne in mind, however, that the uses for these artefacts are tentatively ascribed, so that a better understanding of the level of fish in the diet might actually lead to a redefinition of the artefact classes themselves.

The only fish bones recovered from any of the sites discussed in this paper were from Winnall Down and Broxmouth. At the former, only one probable Cyprinid bone was recovered, despite this site being extensively sampled for environmental evidence. A limited collection of marine fish bone was recovered from Broxmouth, although this was all from the Later phase of the site and does not relate to the period being discussed. One middle Iron Age site with a very limited collection of fish bone which was specifically targeted as part of a sampling and sieving programme is Haddenham in Cambridgeshire, which has good access to the River Ouse and its drainage system (Serjeantson *et al.* 1994). Only a small amount of fish bone was recovered in comparisonto the rest of the faunal assemblage (25 bones) and Serjeantson *et al.* concluded that although this might suggest that fishing was insignificant, it might also mean that fish processing was undertaken off-site.

CONCLUSIONS

A comparison of the data from the different locations presented here shows that the humans were generally consuming isotopically very similar diets. This is true both between and within the groups, with no significant differences being evident either geographically or between intra-group cohorts based on, for instance, sex or status. It is only at the level of the individual that such differences may be found, with two low-level marine consumers present in Cornwall and a limited number of individuals from Hampshire and East Yorkshire who may have been buried away from the area in which they spent a significant part of their lives.

The isotopic analysis indicates that this diet was high in animal protein and did not include a significant level of aquatic resources, even at sites where it might have been expected given source proximity. This supports the overall picture from the archaeological evidence which suggests that cattle, sheep and, to a somewhat lesser extent, pigs were the major animal protein contributors to British middle Iron Age diet and that cereal grains (particularly emmer and spelt wheat and barley) were consumed, certainly in quantities large enough to produce significant levels of dental caries. Non-domesticated resources are not significantly in evidence, neither animals nor plants, and that would include fish.

The data presented have been used to suggest a generalised picture for Britain in these terms, although the possibility of regional and chronological diversity continues to be open in a number of respects. Whilst the locations used for this study give a good geographic spread, there are inevitably gaps in the coverage. It might also be argued that the analysis of inhumation cemeteries means that 'unusual' populations have been investigated, since isolated, disarticulated remains are perhaps more normally associated with this period in time. The levels of contributions from different sources of animal protein, both in terms of meat and dairy products and with respect to the species exploited, might also vary from one group to another without the isotopic patterns reflecting this. It is hoped, however, that the data presented here will provide a framework for future analysis of a wider range of material.

The nitrogen data for the animals and their relationship with those of the humans shows a pattern which indicates that the 'baseline' environmental values (from the plants) at the different locations are different. This is a very important factor to be borne in mind when interpreting isotopic data. It is too simplistic to say that a population with a lower nitrogen value than another is consuming less animal protein, since the difference in the nitrogen background values has not been taken into account in such a comparison. This study reinforces the need to consider animal bone data from the same sites and time periods as the human data if detailed interpretations are to be undertaken.

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