

One for the master and one for the dame: stable isotope investigations of Iron Age animal husbandry in the Danebury Environs

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Abstract Stevens et al. (Oxford J Archaeol 29: 407–428, 2010) speculated that the extensive faunal intra-population isotopic variability at Danebury hillfort was due to the animals being husbanded within various ecological isozones (i.e. microenvironments with distinct natural or anthropogenic isotopic baselines) within the Danebury Environs, and subsequently brought to the hillfort. We test this hypothesis through isotopic analysis of 357 animals from five sites in the Danebury Environs (Suddern Farm, Nettlebank Copse, Houghton Down, New Buildings, Bury Hill). Our results demonstrate that the hypothesis is incorrect as the Environs animals also exhibited extensive intra-site isotopic variability. The observed patterns require considerable human management of herds and flocks, either through animal droving over long distances, or movement restriction through personal attendance or penning/corraling within a landscape containing a mosaic of isozones. Large-scale importation of animals to the Danebury sites from distant regions that have different isotopic baseline values is possible. However, the practical requirements of this model (i.e. long distance trade

networks maintained in terms of frequency, proportion and source of animals over 500 years) make this improbable. Rather, we propose a model that includes distinct ecological isozones within the Danebury Environs landscape, with some animals from each of the sites consuming foodstuff from different isozones for most of their lives. This likely involves control of the landscape on a communal probably kinship basis, with individuals having access to certain parts of the landscape at certain times. The landscape could be seen as being made up of numerous interlocking activity-territories, defined in both space and time, remembered and inherited. Irrespective of which model proves to be the most accurate, these results paint a picture of complex land management during the Iron Age.

Keywords Carbon · Nitrogen · Bone collagen · Animal management · Isozones · Landscape

Introduction

Danebury, one of the largest and most impressive Iron Age hillforts in Southern Britain, is located in Stockbridge, Hampshire (Fig. 1) and was occupied during the latter half of the first millennium BC. Like other hillforts, Danebury is thought to have been both a place of residence and a centre where a range of communal and ritual activities took place, including food storage, processing and exchange (Cunliffe 1984a, 1984b, 1995). Evidence supporting the idea of Danebury being a focus in a redistribution network comes from palaeobotanical, zooarchaeological and stable isotope data. Palaeobotanical remains indicate that grain was being brought to the site for processing and was then stored in pits and granaries prior to redistribution (Jones 1984, 1995; Jones and Nye 1991). Stable isotope analysis of cereal grains indicate that crops from several locations may have

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been mixed within the hillfort (Lightfoot and Stevens 2012). Stable isotope analysis of animal bone collagen provides further support for the idea of resources being brought to Danebury for redistribution. Extensive heterogeneity is visible in the animal isotope values at Danebury, which indicates the animals consumed a variety of isotopically distinct diets (Stevens et al. 2010). We speculate that the substantial variation in Danebury animal isotope values is due to the animals being husbanded at a number of locations within the Danebury Environs that have different microenvironments with distinct natural or anthropogenic isotopic baselines (hereafter “isozones”). The animals would then be brought to the hillfort. Thus we would expect animals from archaeological sites within the Danebury Environs to have more limited intra-population isotopic variability than at Danebury and considerable inter-population variability. To test this theory we conducted carbon and nitrogen isotope analysis on animal bones from five of the Danebury Environs archaeological sites, Suddern Farm, Nettlebank Copse, Bury Hill, New Buildings and Houghton Down, with the expectation that they would all exhibit a more limited range in faunal isotope values than seen at Danebury hillfort.

Sites

Danebury (summarized from Cunliffe 1984b, 1993, 1995; Grant 1984, 1991)

Danebury hillfort, Hampshire, is located at relatively low altitude (145 m OD), however, as the surroundings rarely exceed 100 m, Danebury is the dominant feature in the landscape (Fig. 1). The hillfort was occupied during the latter half of the 1st millennium BC. It is found on chalkland, which dips gradually to the south until it becomes overlain by clays and sands in the Hampshire Basin, and dips more steeply to the north to a scarp slope 24 km away, overlooking the valley of the River Enborne, a tributary of the Thames. Soils covering the chalk within the region are thin (200–300 mm thick), but in places patches of clay-with-flints cap the hilltops. The surrounding river valleys contain colluvial and alluvial deposits. Upland pastures were appropriate for grazing sheep, the gentle slopes and light soils lend themselves to cultivation and the wide flood plain of the River Test contained water meadows particularly suitable for grazing cattle. Details of animal mortality profiles and the husbandry focus at Danebury Hillfort are given in Table 1.

Suddern Farm (summarized from Cunliffe and Poole 2000b)

Suddern Farm, Middle Wallop, is a settlement site occupied more or less continuously from the Early Iron Age to the

first century AD. It is situated on a low spur of chalk, *c.* 85 m OD, above the valley of the Wallop Brook, which lies 1 km to the east (Fig. 1). To the west, the land rises steeply to Suddern Hill with the higher ridge of downland, reaching 170 m OD, just beyond. The site is in a prime location, with good arable land, and easy access to well-watered pastures for cattle and open high down where sheep could graze. There is also a small Iron Age cemetery at the site, which has been the subject of palaeodietary isotopic investigations (Stevens et al. 2013). Cattle, sheep, goat, pig, horse, dog, wild mammals and birds were present within the zooarchaeological assemblage. Sheep and cattle predominated, and there were few changes in the assemblage through time. Samples for isotopic analysis were taken from each of the main domesticates (namely, sheep, cattle, pig, horse and dog) throughout the period of occupation, although only one dog bone was sampled. The results of zooarchaeological analysis are presented in Table 1, which details mortality profiles and husbandry emphasis for this and each of the Danebury Environs sites.

Nettlebank Copse (summarized from Cunliffe and Poole 2000d)

Nettlebank Copse, Wherwell, occupies a shallow spur facing eastwards along a dry valley which leads to the River Test some 3 km away (Fig. 1). The chalk bedrock has a discontinuous mantle of clay-with-flints and it is likely, but not proven, that erosion from the valley sides has created a rich colluvial deposit in the dry valleys. There may have been nearby springs but the nearest permanent water supply would probably have been the River Test. Fertile clay-rich soil is available in the immediate region. Nettlebank Copse is a two-phase site, with an Early Iron Age settlement and a Late Iron Age banjo enclosure. The Early Iron Age phase was a small, likely single-family farming unit consisting of an oval shaped enclosure with two circular houses. It was occupied for a short time in the fourth century BC, perhaps 20 to 30 years. The site was likely occupied year-round. The first ditch of the Late Iron Age banjo enclosure was probably dug shortly after the settlement was abandoned, *c.* 300 BC. The second ditch dates to the mid-first century BC until the mid-first century AD. The lack of young animals suggests that lambing and calving did not take place at the site, and indeed that the site may not have been used at all in spring or summer.

The Early Iron Age animal bone assemblage contains cattle, sheep, horse, pig and dog, with one possible goat. Small mammal and amphibian bones were also noted, but no large or medium wild mammals or fish were recovered. The Late Iron Age animal bone assemblage was very similar, containing sheep, cattle, pig, horse and dog, plus fox, hare and red deer. In both periods sheep were the most

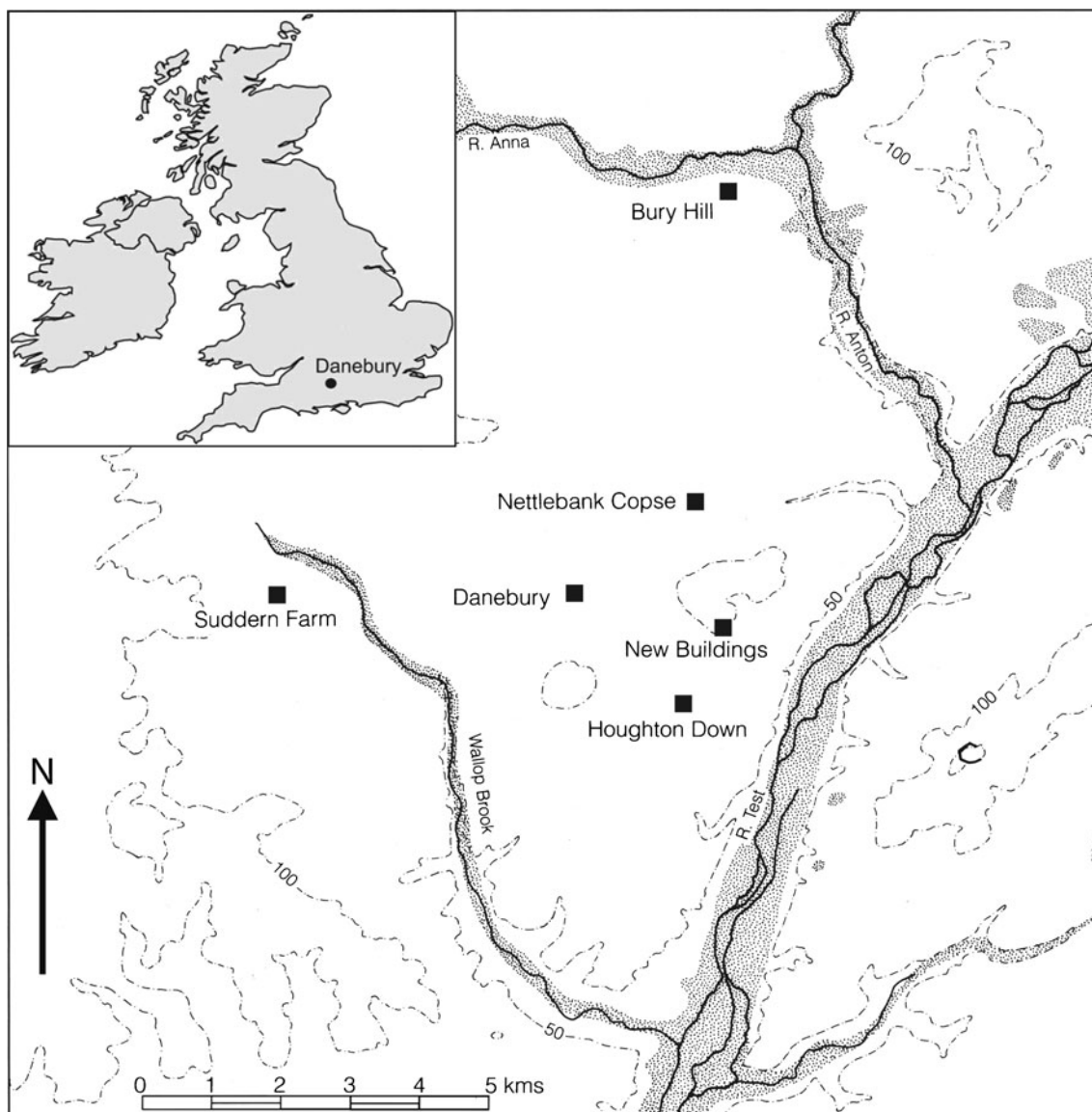


Fig. 1 Location of Danebury hillfort and Environs sites sampled for this study. Modified from Cunliffe and Poole 2000a

numerous species, followed by cattle then pig. Samples were taken for isotopic analysis from the five main domesticated species. Details of the husbandry focus are given in Table 1.

Bury Hill (summarized from Cunliffe and Poole 2000a)

Bury Hill, Upper Clatford, is a two-phase hillfort site dated to the Early Iron Age (not sampled) and the Middle Iron Age in the late second- or early first century BC. It occupies the relatively level summit of a low hill that rises to a maximum of 100 m OD (Fig. 1). The location allows the site to command the confluence of the valleys of the rivers Anna and Anton. The river valleys are floored with alluvium and flanked by narrow gravel terraces. The rivers would have provided a permanent water supply and a continuous band

of meadow 200 m wide. This would be suited to cattle rearing, possibly providing hay in the late summer and pasture for much of the early part of the year. The comparatively gentle slopes nearby meant that most of the area was available for arable which, in times of fallow, would have provided good gleaning for sheep and pigs. The hillfort is therefore well situated to exploit both the upland chalk soils and the pasture and hay meadows of the river flood plains.

The zooarchaeological assemblage contained horse, sheep, cattle, pig, dog, fox and two wild bird species, but the assemblage was not well-preserved compared to the other Danebury Environs sites due to the more acidic, clayey soil. The zooarchaeological assemblage contained an unusually high proportion of horse, ten times that at other sites. Samples for isotopic analysis were only taken from horse bones from the

Table 1 Results of zooarchaeological analyses at sites summarized from Cunliffe and Poole (2000a, b, c, d, e) and Grant 1984, 1991

Site	Species	Mortality profile/husbandry emphasis	Raised at site?
Danebury	Horse	Pack animals/traction, riding. Some consumed but not raised for meat	No
	Sheep/goat	Secondary products: milk, wool and manure more important than meat	Probably
	Cattle	Secondary products: milk and traction more important than meat	Very young individuals present
	Pig	Meat and manure	suggests breeding at site
	Dog	Guard or sheep dogs, occasionally consumed but not raised for meat	
Suddern Farm	Horse	Mature at death—not primarily kept for meat	No evidence for breeding
	Sheep/goat	Killed relatively young—meat important	Very young individuals present
	Cattle	More focus on milk than other Danebury sites	Yes
	Pig	The majority died in the second year of life—focus upon meat and other carcass products	A few young individuals present
	Dog	Skinning and meat consumption practiced, but probably primarily for guarding and herding	Yes
Nettlebank Copse (early Iron Age)	Horse	All but one were over three years of age at death—transport and traction, probably eaten but not primary function	May not have been bred at site
	Sheep/goat	Neither meat nor wool yield paramount, both subordinate to the need to maintain the flock	Perinatal individuals present
	Cattle	Meat production subordinate to other factors, e.g. herd maintenance and traction.	Relatively few young animals
	Pig	Mostly killed young—meat production	
	Dog	Herding, hunting and guard dogs, no strong evidence they were eaten	Yes
Nettlebank Copse (late Iron Age)	Horse	No information	
	Sheep/goat	No information	Unlikely
	Cattle	No information	
	Pig	Consistent with meat production	
	Dog	No evidence they were eaten	May have bred at site
Bury Hill	Horse	Unusually high proportion of horse bones, age profile suggests not primarily kept for meat—hunted or managed semi-feral population?	Probably not bred at site—semi-feral?
	Sheep/goat	Relatively high juvenile mortality suggests meat production	Likely lambing took place at or near the site
	Cattle	Relatively old age structure suggests meat or traction important	Limited data suggests yes
	Pig	Present but limited sample size	Juveniles present
	Dog	Present, but small sample size	
New Buildings	Horse	Mainly mature—probably kept for traction or riding and possibly eaten	No evidence for breeding
	Sheep/goat	Seemed to die young—meat and manure. Some older individuals for wool and/or breeding stock.	Young animals present
	Cattle	Small sample, but no evidence for intensive management	
	Pig	Few pig bones found	
	Dog	Possibly guarding and hunting	Yes
Houghton Down (early period)	Horse	Transport and possibly traction—although probably eaten, meat was not the primary aim	May not have been bred at site
	Sheep/goat	Priority to flock maintenance rather than meat or wool production	Lambing at or near the site
	Cattle	Meat production important but herd maintenance and milk production also important	Juveniles present
	Pig	Largely meat and other carcass products	Foetal pigs present
	Dog	Hunting and herding	Yes

later phase of the hillfort due to poor preservation. Details of the husbandry focus are given in Table 1.

New Buildings (summarized from Cunliffe and Poole 2000c)

New Buildings is a mid-first millennium settlement site, dating from c. 470 to 360BC, with a Late Bronze Age occupation

which was not sampled and therefore will not be discussed further. It is situated at 100 m OD on the south-facing flank of the chalk ridge that runs eastwards midway between Danebury and the River Test (Fig. 1). Today, the soil is 0.15 m thick and it is unlikely that it was ever significantly thicker. The soil has a comparatively high clay content that adds to its coherence and stability. Immediately to the west of the site there is

evidence of extensive arable exploitation on the downland itself. In addition, the site was 1 km away from the water meadows of the Test valley, providing water and food for cattle. The zooarchaeological assemblage was small but indicates the presence of cattle, sheep, horse, pig and dog. Samples for isotopic analysis were taken from all of these species, although only one dog bone was sampled. Details of the husbandry focus are given in Table 1.

Houghton Down (summarized from Cunliffe and Poole 2000e)

Houghton Down is a settlement site situated on Chatgrave Hill on Houghton Down, Stockbridge. It has two phases of occupation, Early (*c.* 800 to 270BC) and Late (*c.* 100BC to AD400). As samples were only taken from the former, this discussion will be limited to the Early period. The settlement is situated on the crest of a slight rise in a ridge of undulating downland and stretches from the crest of the hill at 100 m OD down a gentle north-facing slope to 95 m OD (Fig. 1). It is bounded to the east by the valley of the river Test and to the west by a narrow dry valley. From the settlement, the ground slopes gently to the edge of the floodplain *c.* 1 km to the east. The soil of the ridge in this area is thin and does not have a capping of clay-with-flints. The location of the site near to a permanent water supply would have facilitated cattle husbandry and the floodplain would have provided a wide range of useful resources. The faunal assemblage indicates the presence of sheep, cattle, pig, horse, dog and cat, possibly otter, domestic fowl and other birds at the site, with sheep the most numerous species, followed by cattle and then pig. Samples for isotopic analysis were taken from each of the five main domesticates, although only one dog bone was sampled. Details of the husbandry focus are given in Table 1.

Farming practices in the Danebury environs

The farming system represented at the Danebury Environs sites, and at Danebury itself, was the familiar Iron Age system seen at many southern English sites, based on spelt wheat and hulled six-row barley, with cattle, sheep and pig as the major domesticated animals. In common with many other “Wessex” sites, the proportion of sheep was high (Hambleton 2008), which together with evidence from age distributions and material culture suggests that wool production was important. Bury Hill, with its high proportion of horse and horse-related artefacts, is an exception, and may be a site with a special emphasis on training and management of horses (Hamilton 2000). Animals are vital in mixed farming system as providers of manure (Bogaard 2012). The downland slope soils were vulnerable and had probably degraded considerably by the Iron Age. The increase in

sheep during the Iron Age was likely the result of the need to manure large tracts of land to maintain crop yields. The sheep are likely to have been kept for a large part of the year on land which they were manuring which has obvious implications for soil $\delta^{15}\text{N}$ values which are raised by manuring (see below).

Within this overall uniformity, Campbell (2000) and Hamilton (2000) found evidence of variation in the way the different sites were used, in terms of emphasis on different suites of activities at different times of year. In the Early and Middle Iron Age the picture is of a landscape with occupied sites of various types and sizes, supported by the “normal” Iron Age farming system. Somewhere around 270 BC there was a change in the ceramic style, representing an eastward reorientation of exchange networks away from the Salisbury Plain/Avon domain towards the South Downs zone. Around the same time, Danebury underwent a major refurbishment and intensification of use. Danebury sat virtually alone in the landscape as there is little or no evidence that the Danebury Environs sites were occupied at this time (apart from the previously unoccupied Bury Hill, with its unusual animal bone assemblage, which seems to fall late in the sequence) (Table 2). The evidence implies that Danebury was now the focus of occupation, as well as of exchange systems. It is therefore possible, indeed probable that husbandry practices and economic networks varied significantly over the relevant period. Yet there is no discernible difference in the archaeozoological or archaeobotanical evidence to suggest that the landscape was being used differently—somehow, in spite of the shift in archaeologically visible settlement patterns, the ways in which the different environmental zones were being used appears to have remained the same. In the Late Iron Age, around 100 BC, there was another shift in ceramic tradition, Danebury and Bury Hill were abandoned, and most of the Danebury Environs sites were reoccupied. There is evidence for developing contacts with mainland Europe via the south coast. This time there were changes in the farming system: the proportion of cattle in the animal bone assemblages rose, new crops (oats and peas) appeared, and Campbell (2000) and Hamilton (2000) suggest that the annual regime switched from autumn sowing of cereals to both spring and autumn sowing. These would represent major behavioural changes for people, with considerable reorganisation of activity schedules, and possibly of landscape use.

Background to isotopes

Stable isotope analysis of archaeological fauna is a quantitative method for reconstructing their dietary intake. This method has advantages over traditional archaeozoological methods in that it enables comparisons to be made both

Both the carbon and nitrogen isotope results for the different species follow the general pattern observed in archaeological specimens the British Isles (Fig. 2). The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for all of the fauna are listed in the online supplementary dataset and summary statistics (mean, standard deviation, minimum, maximum and range) for each species at each site are given in Table 3 and outliers can be seen in the boxplots shown in Figs. 3 and 4. The $\delta^{13}\text{C}$ values are within the typical range observed for animals living in ecosystems dominated by C_3 plants. The $\delta^{13}\text{C}$ of the cattle, sheep and pigs are similar, whereas the horse $\delta^{13}\text{C}$ are typically lower relative to the ruminants due to them being hind-gut fermenters. The $\delta^{15}\text{N}$ of the cattle, sheep and horse are similar, whereas the pig $\delta^{15}\text{N}$ are generally higher due to an omnivorous diet. Therefore isotopic variation in pigs is a reflection of both isotopic variation in the plants they consumed and quantity of animal protein they consumed.

As different periods of the Iron Age are represented at the different sites (Table 2) it is necessary to check for temporal trends within sites before undertaking an inter-site comparison. Within each multi-period site (Suddern Farm, Danebury, Nettlebank Copse) no differences were observed in the $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ values for each species between the EIA,

MIA, MIA/LIA, LIA, 1st C AD. However, when all sites were considered together some differences in sheep $\delta^{15}\text{N}$ were observed between time periods. Mean sheep $\delta^{15}\text{N}$ during the EIA ($\delta^{15}\text{N}=4.5\pm 0.8\%$, $n=78$) was significantly higher than that of sheep in the MIA/LIA ($n=21$, $\delta^{15}\text{N}=4.0\pm 0.8\%$) (one-way ANOVA with post-hoc Bonferroni correction, $P=0.023$). Furthermore, mean sheep $\delta^{15}\text{N}$ during the early Iron Age was significantly higher than that of sheep in the LIA ($\delta^{15}\text{N}=4.0\pm 0.6\%$, $n=38$) (one-way ANOVA with post-hoc Bonferroni correction, $P=0.002$). These temporal differences are not driven by one particular site. Given that only a weak temporal trend is observed in the $\delta^{15}\text{N}$ of only one species, climatic and/or environmental parameters are unlikely to be the driving factor and thus fauna from all time periods at each site are subsequently considered collectively.

In order to assess whether the isotopic variation observed at Danebury could be due to the gathering of animals from the Environs sites, we compare the isotopic signatures of fauna between sites. Our expectation was that each site would have its own distinct isotopic range (i.e. its own “isozone”). Although some statistically significant differences were observed between the mean isotope signatures of particular species at select sites, no consistent pattern was observed between any sites. First,

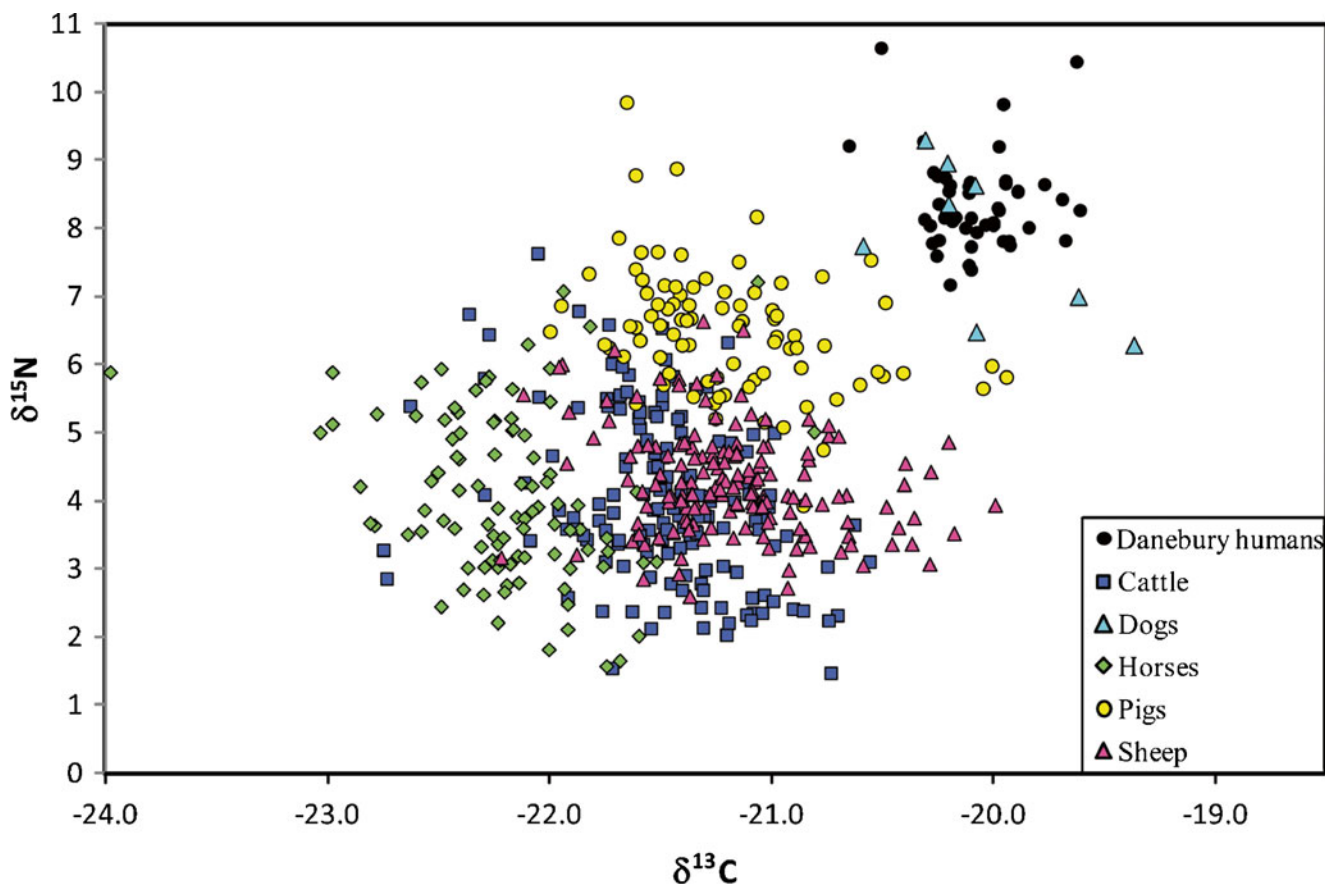


Fig. 2 Faunal and human carbon and nitrogen isotopes from Danebury Hillfort and Environs sites

Table 3 Summary statistics for fauna from each site

Site	<i>n</i>	$\delta^{13}\text{C}$ Mean	$\delta^{13}\text{C}$ Std dev	$\delta^{13}\text{C}$ Min	$\delta^{13}\text{C}$ Max	$\delta^{13}\text{C}$ Range	$\delta^{15}\text{N}$ Mean	$\delta^{15}\text{N}$ Std dev	$\delta^{15}\text{N}$ Min	$\delta^{15}\text{N}$ Max	$\delta^{15}\text{N}$ Range
Cattle											
Danebury	39	-21.6	0.3	-22.4	-20.7	1.7	4.3	1.2	2	6.7	4.7
Suddern Farm	39	-21.4	0.3	-22.1	-20.7	1.4	3.7	1.4	1.5	6.8	5.3
Houghton Down	18	-21.5	0.5	-22.8	-21	1.8	3.9	0.9	2.3	5.8	3.5
Nettlebank Copse	35	-21.3	3.6	-22.1	-20.6	1.5	3.9	1.1	2.1	6.5	4.4
New Buildings	17	-21.7	0.5	-22.7	-21	1.7	4.1	1.2	2.9	7.6	4.7
Bury Hill	0										
Sheep											
Danebury	57	-21.2	0.4	-22.2	-20.3	1.9	4.2	0.8	2.6	6	3.4
Suddern Farm	32	-21.2	0.4	-21.9	-20.4	1.5	4.1	0.7	2.9	6.5	3.6
Houghton Down	18	-21	0.2	-21.4	-20.7	0.7	4.5	0.5	3.5	5.7	2.2
Nettlebank Copse	34	-21.1	0.5	-22.1	-20	2.1	4.1	0.8	2.7	6.2	3.5
New Buildings	19	-21.3	0.3	-22	-20.8	1.2	4.8	0.8	3.7	6.6	2.9
Bury Hill	0										
Horse											
Danebury	17	-22.3	0.3	-23	-21.6	1.4	4	1.3	1.6	5.8	4.2
Suddern Farm	26	-22.1	0.3	-23	-21.6	1.4	3.9	1.4	1.7	7.1	5.4
Houghton Down	7	-22.1	0.3	-22.6	-21.7	0.9	3.5	0.9	2.5	5.3	2.8
Nettlebank Copse	18	-22	0.4	-22.5	-20.8	1.7	3.8	1	2.1	5.6	3.5
New Buildings	13	-22.5	0.6	-24	-21.1	2.9	4.8	1.1	3	7.2	4.2
Bury Hill	16	-22.3	0.3	-23	-21.9	1.1	4.6	1.1	2.6	6.3	3.7
Pig											
Danebury	30	-21.3	0.4	-21.8	-20.4	1.4	6.5	1	3.9	9.9	6
Suddern Farm	8	-21.2	0.3	-21.6	-20.7	0.9	6	0.7	5.1	6.9	1.8
Houghton Down	8	-21.2	0.3	-21.5	-20.5	1	6.8	0.7	5.2	7.7	2.5
Nettlebank Copse	35	-21.2	0.5	-22	-19.9	2.1	6.6	0.9	5.2	8.9	3.7
New Buildings	5	-22.2	0.4	-21.6	-20.8	0.8	6.4	1.1	4.8	7.7	2.9
Bury Hill	0										

no differences were seen in pig carbon or nitrogen isotope values between sites. In carbon, four statistically significant differences were seen in horse, cattle and sheep. New Buildings mean horse $\delta^{13}\text{C}$ ($n=13$, $-22.5\pm 0.6\%$) is different to both Nettlebank Copse ($n=18$, $-22.0\pm 0.4\%$) and Suddern Farm ($n=26$, $-22.1\pm 0.3\%$) (Kolmogorov Smirnov Z tests, $p=0.022$ and $p=0.013$, respectively). New Buildings mean sheep $\delta^{13}\text{C}$ ($n=19$, $-21.3\pm 0.3\%$) is marginally different to Houghton Down ($n=18$, $-21.0\pm 0.2\%$) (Kolmogorov Smirnov Z test, $p=0.047$). Finally, Danebury mean cattle $\delta^{13}\text{C}$ ($n=39$, $-21.6\pm 0.3\%$) is different to Nettlebank Copse ($n=35$, $-21.3\pm 0.4\%$) (Mann Whitney test, $p=0.001$). In nitrogen, two statistically significant differences were seen in sheep and cattle. New Buildings mean sheep $\delta^{15}\text{N}$ ($n=19$, $4.8\pm 0.8\%$) is different to Nettlebank Copse ($n=34$, $4.1\pm 0.8\%$) (Kolmogorov Smirnov Z test, $p=0.012$) and New Buildings mean cattle $\delta^{15}\text{N}$ ($n=17$, $4.7\pm 1.2\%$) is marginally different to Suddern Farm ($n=39$, $\delta^{15}\text{N}=3.7\pm 1.4\%$) (Kolmogorov Smirnov Z test, $p=0.041$). The lack of

consistent offsets between sites suggests that the fauna at each site are not feeding within distinct isozones.

Our second expectation was that each Environs site would have a much smaller range of isotopic variation than that seen at Danebury hillfort. As seen in Table 3, the range of variation observed for both carbon and nitrogen in all species at Danebury is similar to the ranges of variation seen at the Environs sites. The one exception to this is the pig range in $\delta^{15}\text{N}$ values, which is substantially larger at Danebury (6‰) than at the other sites (1.8 to 3.7‰). However, when the two outliers at Danebury, as identified in Fig. 4 (DBH93 and DBH127), are removed the range of variation is reduced to 2.2‰, similar to the other sites. Although the ranges are sometimes slightly less at Houghton Down than the other sites, this appears to be due to the smaller sample size at this site compared to the others.

The amount of intra-species isotopic variation observed at Danebury hillfort and each of the Environs sites is very large, particularly in nitrogen. Up to 5.4, 5.3 and 3.6‰

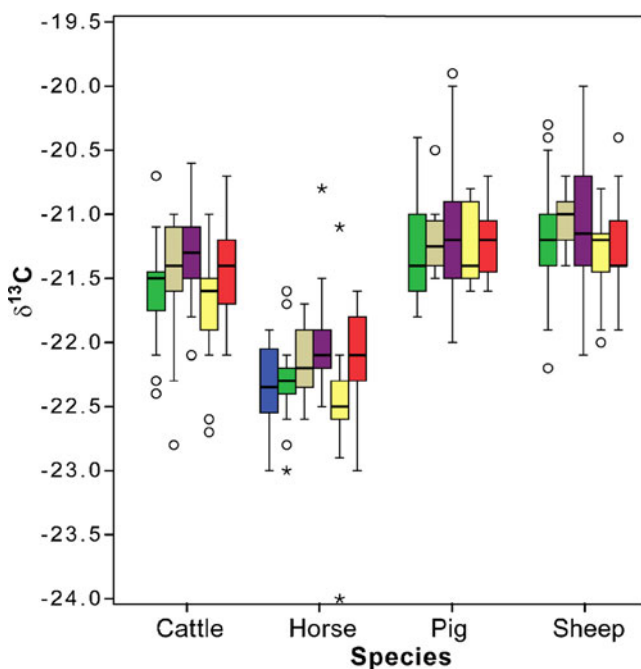


Fig. 3 Box plot of faunal carbon isotopes for each species by site; Bury Hill (blue), Danebury (green), Houghton Down (beige), Nettlebank Copse (purple), New Buildings (yellow), Suddern Farm (red)

variation in $\delta^{15}\text{N}$ is seen in cattle, horse and sheep, respectively (Table 3, Fig. 5a–d). When all sites are considered collectively the $\delta^{15}\text{N}$ ranges increase (Figs. 2 and 5). The variation seen in cattle and horse are 6.1‰ and 5.6‰

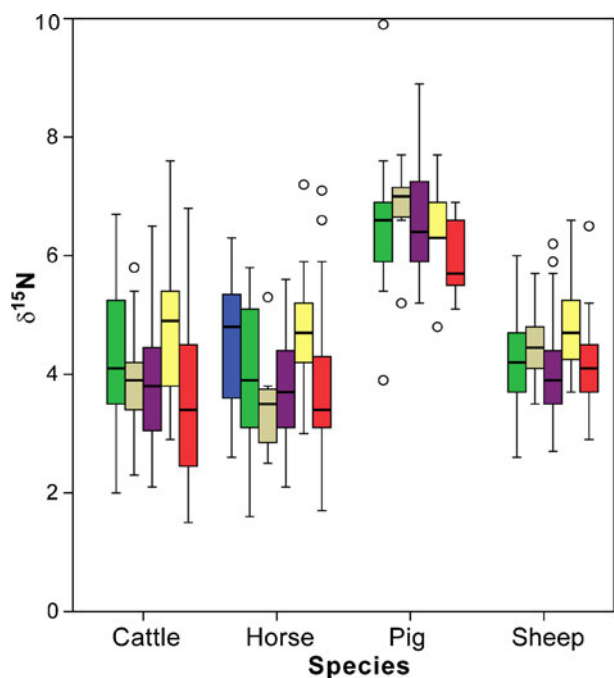


Fig. 4 Box plot of faunal nitrogen isotopes for each species by site; Bury Hill (blue), Danebury (green), Houghton Down (beige), Nettlebank Copse (purple), New Buildings (yellow), Suddern Farm (red)

respectively ($\delta^{15}\text{N}$ typically range from 1.5 to 6.5‰). The $\delta^{15}\text{N}$ variation in sheep is notably smaller at 4.0‰ ($\delta^{15}\text{N}$ typically range from 3 to 6.5‰). The intra-population variability for each species observed at archaeological sites around the world is typically 2‰. Furthermore, an increase of 3 to 5‰ in $\delta^{15}\text{N}$ is routinely observed between trophic levels (Bocherens and Drucker 2003). Here, we see an extremely large intra-population variation equivalent to at least one trophic level in sheep and more than one trophic level in cattle and horses.

Discussion

We speculated that the large amount of intra-population isotopic variability observed at Danebury was due to the animals being husbanded at a number of different ecological isozones within the Danebury Environs and subsequently brought to the hillfort (Model: Fig. 6). Archaeological sites within the Danebury Environs should therefore have more limited intra-population isotopic variability than at Danebury, and greater inter-than intra-population variability. However, the isotope results do not support this straightforward model. Instead, a more nuanced model is required to explain the observed animal isotope signatures.

In order to produce the large range in isotopic variation seen within Danebury and the Environs sites every species must have had individuals that consumed isotopically different diets. Furthermore, the cattle and horses must have had access to a wider range of isotopically distinct diets than the sheep. The most likely scenario in which this could occur is for subgroups of each species at each site to have spent a significant proportion of their lives feeding from distinct ecological isozones. These isozones could be due to natural isotopic variation between landscapes or within the landscape, for example between watermeadows and upland pasture, or anthropogenic, for example due to collected fodder or intensive manuring of certain crops or areas.

We envisage several economic models in which animals that lived the majority of their lives in different isozones could be found together in the zooarchaeological assemblages at Danebury hillfort and the Environs sites.

A second model (Fig. 6) has each Environs site situated within its own ecological isozone, as in model 1, but this is not detectable in the animal isotopic values because of very large-scale redistribution of animals via Danebury. A very high number of the adult animals from the Environs sites (some of them close to the time of culling) would have had to have been gathered at Danebury. They would then be mixed and randomly redistributed to each of the sites such that each site has the full range of isozones represented. This could also include movement directly between the Environs sites. This model is not parsimonious as it requires an

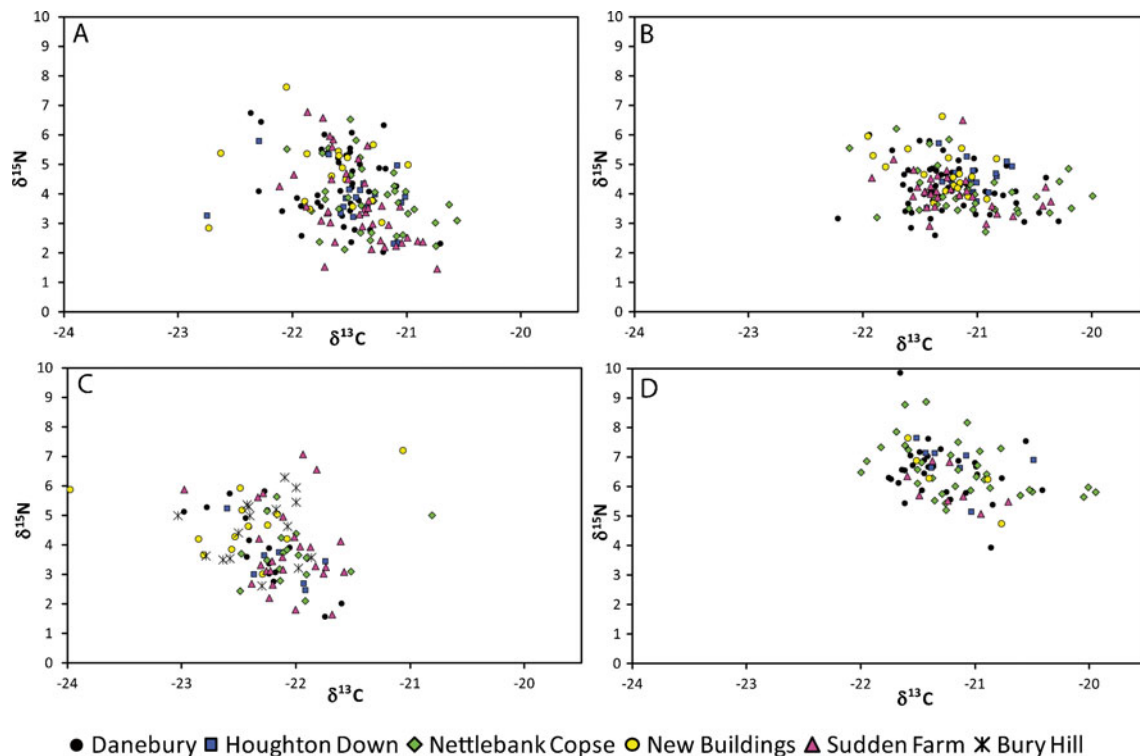


Fig. 5 Faunal $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for fauna from Danebury hillfort and the Environs sites (**a** cattle, **b** sheep, **c** horses, **d** pigs)

extremely high rate of animal movement through exchange, and the amount of animal movement between sites with distinct isozones to be equal and constant throughout the Iron Age. If each site did have its own unique isozone but also imported some animals from different isozones, we would expect each site to be biased toward the isotopic baseline of its own isozone.

In a third model (Fig. 7), the distinct isozones are not in the Danebury region. Animals are brought into Danebury from at least one area outside of the region and redistributed to the Environs sites. In addition to this, there could also be movement of some animals within the Environs sites, and between the Environs sites and Danebury. Weaknesses of this model relate to the duration of the exchange network. The mechanism by which animals were moved and exchanged over long distances would have had to have been maintained over a 500-year period with little or no variation in the proportion and source of imports. First in support of this model, there is evidence that a range of ecological isozones existed across Iron Age Britain. Low nitrogen isotope values like some of those observed in the Danebury Environs have not been widely found at Iron Age sites outside Hampshire whereas higher nitrogen isotope signatures are seen in other regions of the British Isles (Jay and Richards 2007). Second, various pieces of evidence exist suggesting long-distance animal movement took place during British prehistory. Drove ways are thought to have become established at this time. Strontium isotope analysis of

a single horse from the nearby Iron Age site of Rooksdown in Hampshire, showed that it was not raised locally and may have been imported from as far away as Wales, Scotland or the continent (Bendrey et al. 2009). Similar analyses of cattle from the Late Neolithic site of Durrington Walls, Wiltshire, demonstrated that a high proportion of cattle were not born locally, and must have travelled substantial distances to the site from a range of areas within the British Isles. However, strontium isotopes of a single horse from Bury Hill indicate that this animal at least was born on chalkland, the dominant geology of the local region (Bendrey et al. 2009). Further strontium isotope analysis of Iron Age fauna from the Danebury Environs would provide evidence in support of or against this model.

In our final model (Fig. 8), distinct ecological isozones exist within a relatively small area of the Hampshire landscape, and at least some individual animals of each species had their movement restricted to specific isozones within the landscape. Boundaries of isozones may relate to landscape properties such as gradient, distance from river, underlying geology, soil type, and so forth. Artificial isozones may also exist due to human influence, such as intense manuring of a specific area. In this scenario, people at each of the Environs sites had access to food stuffs from multiple isozones on which the animals were reared, resulting in the wide variation in faunal isotope values. Furthermore, some individuals from each species must have had their movement restricted. Some animals must have been reared on a particular isozone

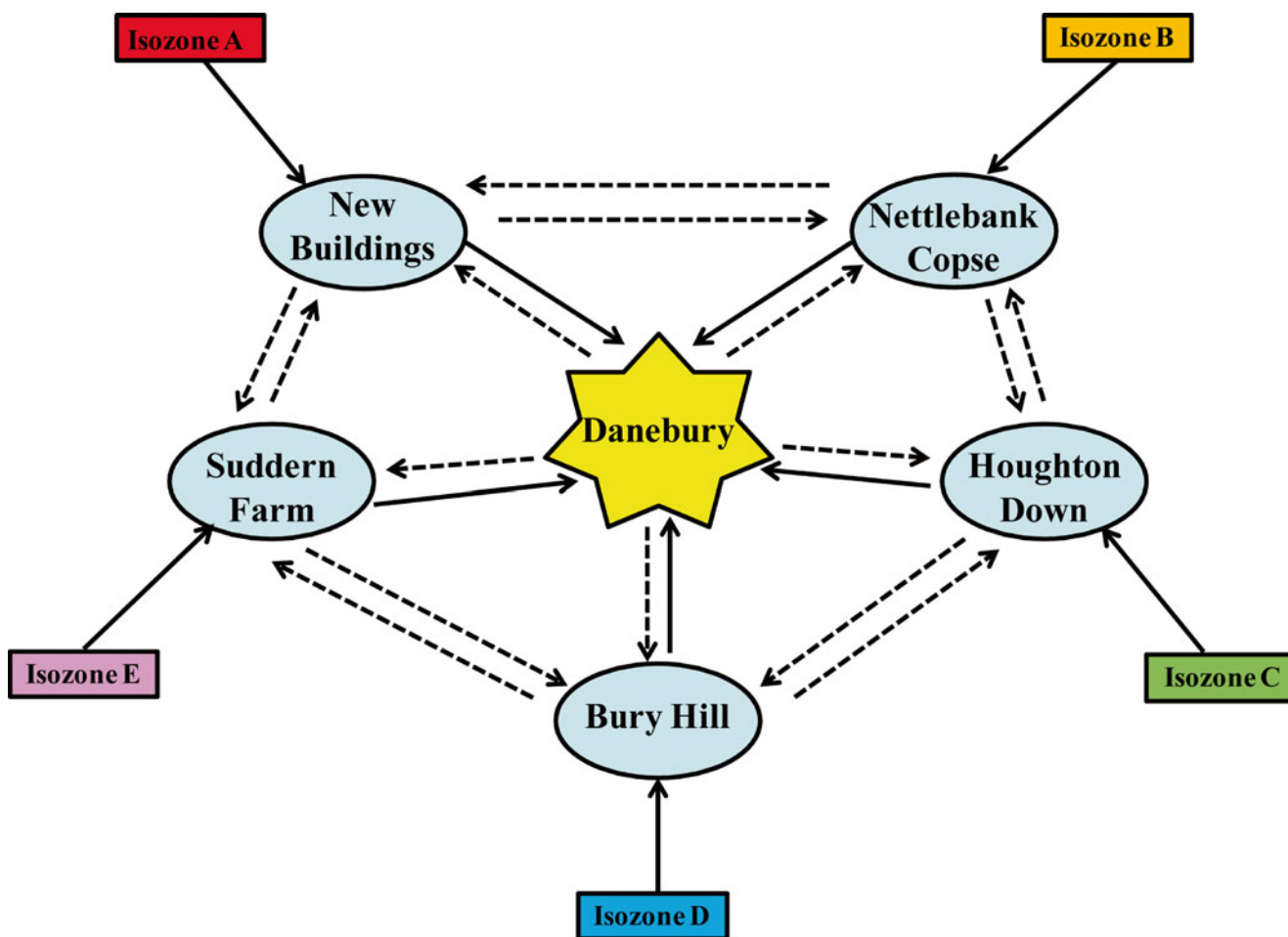


Fig. 6 Economic models 1 (solid lines) and 2 (solid and dashed lines) (see text for description)

for the majority of their lives, while others from the same site must have spent a similar amount of time feeding from a different isozone. Additionally, some animals may have consumed foodstuffs from two or more isozones (either through animal movement or foddering practices) producing an averaged isotopic signal. This does not necessarily have to happen simultaneously, or even within the same year. However, it must happen over a relatively small number of years, because high isotopic variation is seen within single excavation units. This model could also incorporate the movement of animals within the Environs sites, between the Environs sites and Danebury, and from areas outside of the Danebury region. However, the strength of this model is that it does not require a consistent pattern of large-scale exchange or long-distance movement over a 500-year period.

Within this final model, there are two scenarios by which multiple isozones could exist within the region of each of the sites. The first is that anthropogenic isozones could be created within the Danebury Environs landscape by intensive manuring and selective foddering. Long-term intensive manuring has been shown to increase plant $\delta^{15}\text{N}$ values by up to 9‰ (Fraser et al. 2011). In this scenario, the low

herbivore $\delta^{15}\text{N}$ signatures would relate to animals consuming vegetation from unmanured contexts and those with high $\delta^{15}\text{N}$ values would relate to animals consuming vegetation from intensively manured contexts. Those herbivores with intermediate $\delta^{15}\text{N}$ values would reflect the consumption of plants that have been subjected to low level manuring (e.g. due to animals being grazed on fields in rotation so that their dung could enrich the soil) or alternatively the consumption of plants from both intensively manured and non-manured contexts. This is possible; however, if such extensive variation in manuring practice was typical in the Iron Age we would expect to see a similar large amount of variation in other locations in the British Isles. This is not to say that manuring does not account for *some* of the herbivore isotopic variation. Indeed the increase in periodontal disease in sheep through time points to continued degradation of soil, thus manuring must have been important for maintaining soil fertility and crop yields. However, manuring alone cannot fully account for the isotopic variation observed.

The second scenario is that the isozones are primarily natural; however the presence of multiple natural ecological isozones within specific areas of the Hampshire landscape is

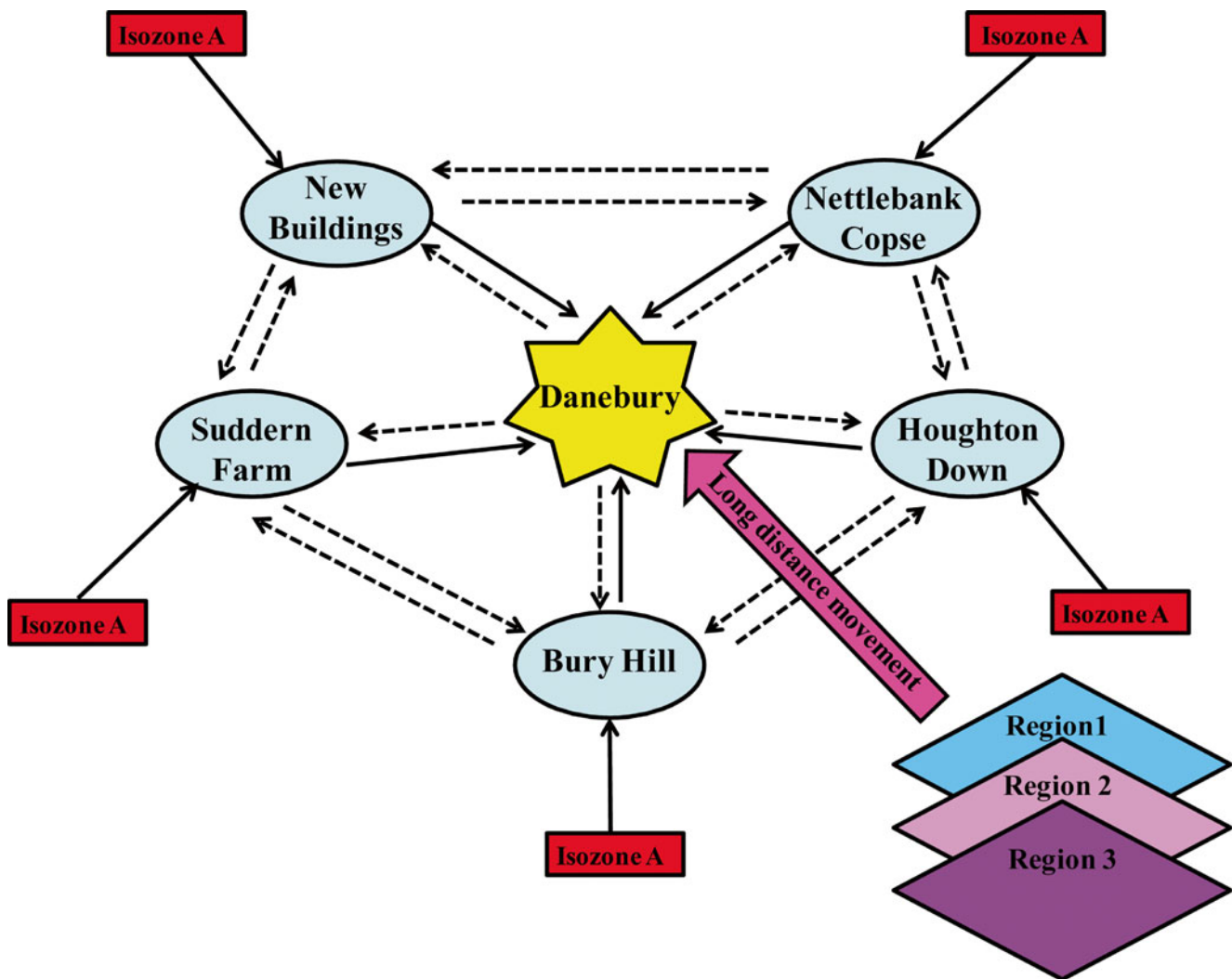


Fig. 7 Economic model 3 (see text for description)

purely hypothetical. Nevertheless, the areas around Danebury and each of the Environs sites includes a variety of landscape properties that could result in multiple distinct ecological isozones within small areas. On the gentle slopes, the chalk bedrock (highly alkaline) is covered by relatively shallow soils. On the hilltops, the chalk is covered with clays containing flint (generally neutral or slightly acidic). The surrounding river valleys contain colluvial and alluvial deposits that in areas are thought to have been waterlogged for part of the year. To the south and east of the Environs in the Hampshire Basin, more sandy soils (generally acidic) overlie the upper and lower green sand bedrock. Such diversity in landscape types is seen within close proximity in other regions of the British Isles; however, only in regions where chalk is the underlying bedrock have such low nitrogen isotopic values been observed. Thus, it seems the combination of landscape properties in the Hampshire region may increase the isotopic range observed within the isotopic baseline of an area.

Whether the isozones within the Danebury Environs Landscape are natural or anthropogenic, for the observed pattern of isotope signatures to be produced, the movement of some of the horse, sheep and cattle has to have been restricted by humans. This is consistent with evidence from Iron Age Britain, which indicates that the husbandry regime may have included the management of animals through herding or corralling, indeed controlling of flocks or herds is often necessary for protecting arable crops. As noted above, the cattle and horse $\delta^{15}\text{N}$ typically range from 1.5 to 6.5‰ whereas the sheep $\delta^{15}\text{N}$ typically range from 3 to 6.5‰. Thus, no sheep had lifetime access to foodstuffs from isozones with low $\delta^{15}\text{N}$ values whereas some cattle and horse individuals spent the majority of their lives consuming foodstuffs from such isozones. By contrast, some individuals from all of these species had lifetime access to foodstuffs from isozones with high $\delta^{15}\text{N}$ values. If the isozones are anthropogenic, some cattle and horses would have to have only fed on non-manured contexts for the majority of their

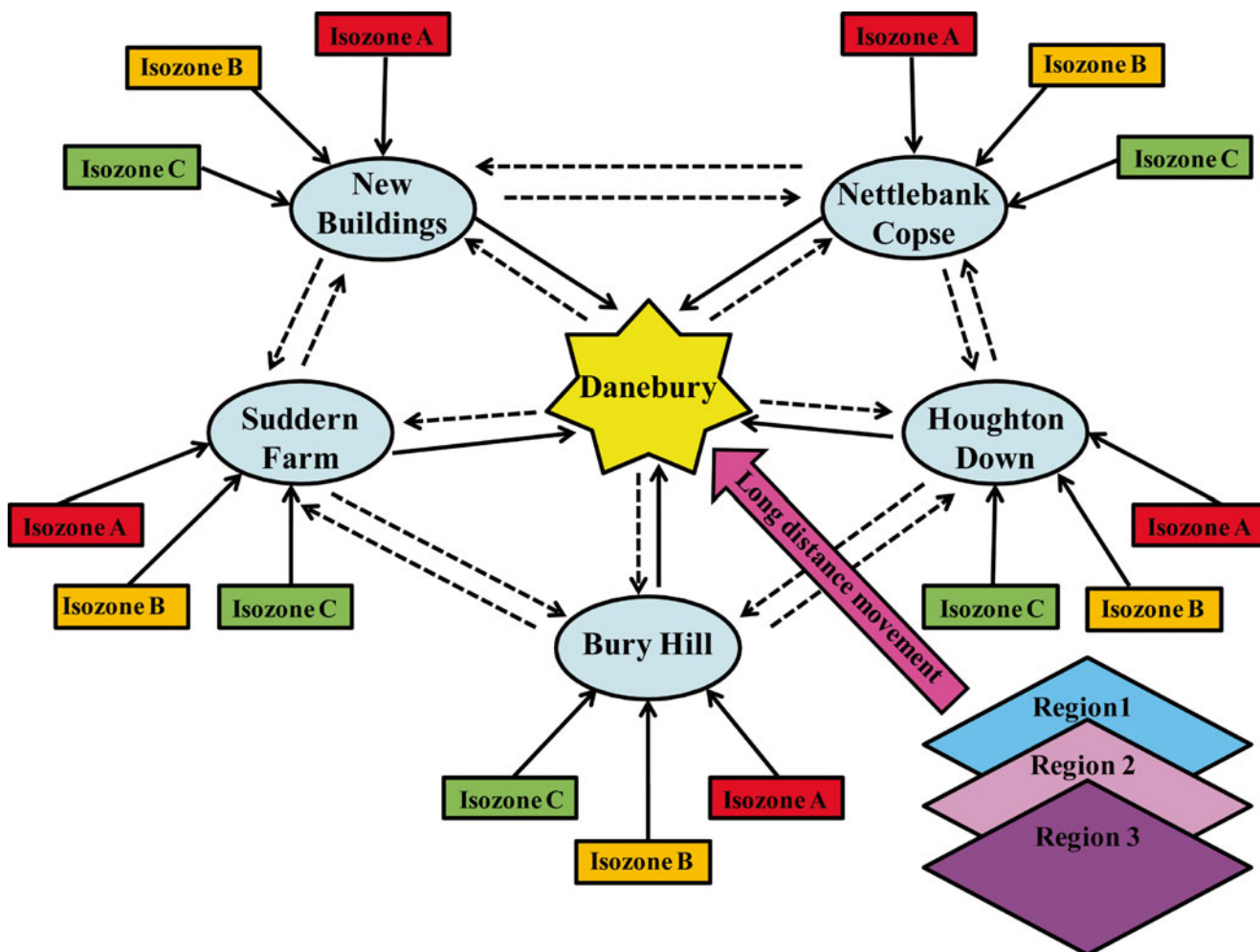


Fig. 8 Economic model 4 (see text for description)

lives whereas other cattle and horses would have to have only fed on intensively manured contexts for the majority of their lives. Sheep, on the other hand, would have to have spent a significant proportion of their lives feeding on vegetation from manured contexts, with no individuals feeding solely on non-manured vegetation. If the isozones are primarily natural, the sheep would not have had access to one of the isozones. This scenario is consistent with the ecological requirements of the species under consideration. Cattle thrive in lush vegetation conditions and will consume as much as 16 gal of water per day (Green 1992), whereas sheep flourish on the relatively poor pasture of hillslopes and are susceptible to foot rot and liver fluke in damp conditions (Albarella 2007). Thus cattle are better able to subsist in the wetland conditions of river valleys that are less suitable for sheep. If cattle were kept in all areas of landscape, but sheep did not have access to the river valley pastures, this could explain the differences in the ranges of variation in cattle and sheep $\delta^{15}\text{N}$ values.

This final model is consistent with the landscape system described in the Early Irish laws (Kelly 1997). The way in

which people and their animals used the landscape is likely to have been articulated via systems of kinship and clientage. Land would be “owned” or held in common by social groups, probably kin-based, rather than individuals. Individuals and their animals would have rights of access to, or use of, certain parts of the landscape at certain times, which might be more or less co-ordinated with the activities of other individuals or families. Individual trajectories of landscape use could be quite variable over time, but might also be consistent from year to year, and animals could be controlled both by personal attendance and more or less temporary enclosure. While both people and their herds/flocks might gather in large groups at certain times of year, at other times they would be dispersed. The landscape could be seen as being made up of numerous interlocking activity-territories, defined in both space and time, and remembered and inherited. This could explain the apparent continuity of landscape use through the settlement changes of the third century BC, such that the Danebury Environs sites could be reoccupied at the same locations two centuries later. Periodic gatherings might occur based on farming activities—e.g.

birth of lambs and calves, harvesting and crop-processing—or on a relative lack of agricultural activity giving people time to gather and renew social relationships, e.g. at a midwinter feast. This would allow for exchange at small and large scales, and such gatherings may well have been important components of the hillfort system of the Early and Middle Iron Age.

All the above models assume static agricultural/economic scenarios; however, they may have been dynamic, potentially hinted at by the minor isotopic trends observed in some species. In order to test the proposed models in a more dynamic system would require isotopic data taken from discrete time slices (e.g. ceramic phases). Currently, there is too little isotopic data to test different scenarios in this manner. A more in-depth isotopic investigation may allow links between settlement pattern dynamics and animal husbandry practices over the 500 year occupation to be explored.

Conclusions

We speculated that the large amount of intra-population isotopic variability observed by Stevens et al. (2010) in the faunal isotope signature at Danebury hillfort was due to the animals being husbanded at a number of sites within the Danebury Environs that had distinct ecological isozones, and that the animals were subsequently brought to the hillfort. Our isotopic results from the Danebury Environs sites demonstrate that this is not the case as they also exhibited extensive intra-site isotopic variability. The observed patterns of animal isotopic variation require considerable human management of herds or flocks, either through animal droving over long distances, or movement restriction, possibly through penning or corraling. One possible model that could explain the isotopic variation observed at Danebury and its Environs sites is that large numbers of animals were imported from distant regions that have different isotopic baseline values to Danebury and the Environs sites. The practical requirements of this model (i.e. long distance trade networks maintained in terms of proportion and source of animals over 500 years) make this model improbable. Rather, we propose a model that includes distinct ecological isozones within the Danebury Environs landscape, with some animals from each of the sites consuming foodstuff from different isozones for most of their lives. This interpretation of the isotope results is consistent with previous suggestions that earthwork features of Iron Age sites may have had a pastoral stock management role and have acted as stock enclosures (Fowler 1983; Davis 1987). The control of animal landscape use may be a reflection of the greater need for stock protection due to

increasing social tension during the Iron Age or the greater need to fertilize soils (Cunliffe 1986). Further zooarchaeological and isotopic research may help determine which of the possible models is more likely. Irrespective of which model proves to be the most accurate, these results paint a picture of complex land management during the Iron Age.

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