Centre for Archaeology Report 33/2002

The Medieval and Post-Medieval Bone Remains from Heigham Street, Norwich

J Weinstock

Summary

This report presents the results of the examination of almost 2400 identified specimens from the hand-recovered Medieval and Post Medieval (13th-18th centuries) bone assemblage from Heigham Street, Norwich. Cattle, small ovicaprids, and pigs comprise most of the assemblage. Due in all probability to the recovery method, bird and fish bones are present in relatively small numbers. In the earlier periods, the age structure of cattle shows that they were used mainly as traction as meat sources, the former decreasing in importance in the later periods. Both wool and mutton were important products gained from sheep.
A relatively large number of cattle horn cores was recovered; this suggests that one or more industrial activities (e.g. tanning, horn working) took place at the site. All cattle are from the "short-horn" type.
Osteometrical data is scant, but it seems to show an increase in the size of cattle and sheep during the late 16th / early 17th century. This, together with the frequency of some non-metrical traits, may indicate that at this time new stock may have been imported to the city.

Keywords

Animal bone
Bird remains
Fish bone
Medieval
Post-Medieval

Author's address

University of Southampton, Department of Archaeology, Southampton, Hants, SO17 1BJ, Tel. (023) 8059 4778,
E-mail: j.weinstock@soton.ac.uk

The medieval and post-medieval bone remains from Heigham Street, Norwich

Introduction

Excavations in the suburb of Heigham, Norwich (Figures 1 & 2), were carried out by Peter Donaldson and Malcolm Atkin in 1975 and 1976 respectively for the Norwich Survey. The excavations uncovered evidence for almost 600 years of occupation, beginning *c.* 1225. These six centuries were divided by the excavators into 9 periods, some of which were further subdivided (see Atkin, in press). The site was divided into four areas or 'sub-sites' (A, B, C, D) each representing a different area of use, which may be equated with medieval tenement boundaries (Atkin, in press). These four sites were then grouped into A/B and C/D. B seems to be an adjunct of A and, up to period 6, D seems to have been principally used as a yard for the Buildings in C. According to the excavators, areas C and D had an urban character, whereas the buildings in Area A seems more to represent a farmstead.

During the excavations, more than 4000 animal bones were recovered by hand. This method usually results in the under-representation of smaller mammal species, birds and fish (Clason & Prummel 1977; Payne 1972, 1992) and this must be kept in mind while interpreting the relative abundance of species and skeletal representation (see below).

The bone assemblages of the earlier periods (1-3) are very small (Table 2). Therefore, for most purposes, specimens from these three periods were combined into a single 'period' (1-3). This enabled the inclusion of some specimens that were described by the excavators as coming from periods 1-3.

The dating of the different periods is as follows (after Atkin in press):

Period	Dates
1	1225-1275
2	1275-1325
3	1325-1375
4	1375-1450
5	1450-1500
6	1500-1575/80
7	1575-1625
8	1625-1700
9	1700-1800

Methods

Quantification

An attempt was made to identify all recovered fragments to skeletal element and taxon, with the exception of ribs and vertebrae caudal to the second cervical (axis) which were assigned to one of three size-classes: large (cattle/horse), medium (ovicaprids/pig/dog), and small (leporids/cat/fox). When two or more fragments were distinguished as being derived from the same bone they were recorded as one specimen. The number of identified specimens (NISP) served as the basic unit in counts. Additionally, the weight of each fragment was recorded, not in order to calculate 'meat weights' but as a second method to evaluate the relative representation of the different species and skeletal elements; this quantification method is less affected than NISP by the effects of bone fragmentation (Uerpmann 1973). 'Minimum number of individuals' (MNI) was generally not calculated. Among other problems, this method seriously overestimates the less frequent taxa when dealing with relatively small assemblages, which is the case in Heigham Street (especially for the earlier periods).

Identification

From the 3974 bone fragments recovered, 60% were identified to skeletal element and taxon. However, it must be remembered that many of the unidentified specimens are fragments of the axial skeleton of the major domestic species; thus, the category 'unidentified large' undoubtedly includes mostly ribs and vertebrae of cattle.

The identification of ovicaprid bones to either sheep or goat was carried out using the criteria delineated by Boessneck *et al.* (1964) and Payne (1985). A specific identification was achieved in about 30% of the cases; among these only one specimen of *Capra* is present (an almost complete metacarpal from period 6), whereas more than 180 bones were assigned to *Ovis*. Therefore, the ovicaprid bones are collectively referred to in this report as 'sheep'. Concerning the galliforms, the criteria of McDonald (1992) were used to separate chicken (*Gallus gallus*)/pheasant (*Phasianus colchicus*) and guinea fowl (*Numida meleagris*). An attempt was made to separate chicken and pheasant through their tarsometatarsi: spurred tarsometatarsi lacking the posterior continuous keel are regarded as being characteristic for chicken (e.g. Albarella & Davis 1996). From these three galliform species, only *Gallus* was definitely identified in Heigham Street and, given the ubiquity of this species in medieval and post-medieval assemblages, all bones of galliforms are regarded as belonging to chicken. All bones of geese belonged to one of the larger species (*Anser*); they belong very probably to the domestic goose but, given the morphological similarities between the domestic and the wild forms, an unambiguous identification could not be made. The category ‘Aves indeterminate’ includes small bone fragments without articular ends.

Ageing and sexing

Tooth wear of the more economically important mammal species (cattle, ovicaprids, and pig) was recorded using the eruption and wear stages of Grant (1982). Mandibles of cattle, ovicaprids, and pigs were also assigned to the age stages of O’Connor (1988). In addition, mandibles lacking the teeth needed in order to assign them to one of Grant’s or O’Connor stages but that could potentially contribute to ageing information (mostly those having anterior deciduous premolars but lacking dp_4, or having a worn P_3 but no P_4) were assigned to broad age categories (e.g. juvenile, adult). The fusion stage of all mammal limb bone epiphyses and vertebrae apophyses was recorded (ages of epiphysial closure after Habermehl, 1975). Bird bones with porous articular ends were recorded as ‘juvenile’. For the sexing of specimens, the form of the canine or its alveolus was used for pigs. For the ungulates, the thickness of the ventro-medial wall of the acetabulum in the pelvis – thicker in males – was used as sexing criterion. Metrical data can also be used in sexually dimorphic species. However, there is a considerable overlap in the size of males and females in species such as cattle and sheep and only specimens near to the ends of the size distribution can be sexed unambiguously. In the domestic fowl sex was determined in the tarsometatarsus by the presence (male) or absence (female) of a spur.

Measurements

The definition of measurements follows generally that of von den Driesch (1976), but additional metrical data was recorded (e.g. distal depth of humerus, proximal depth of radius; for definition of these parameters see Weinstock, 1997, 2000). Osteometrical data is presented in the Appendix.

Results

This part begins with a discussion of the preservation of the faunal remains; this is followed by a general discussion on the abundance/presence of the different species. A more detailed treatment of each of the main species (e.g. skeletal representation, ageing, and butchery patterns) is presented in later sections.

Preservation, burning, gnawing and butchery marks

The bones were generally in a good condition and thus gnawing and butchery marks were readily visible; only a handful of specimens shows evidence of weathering.

The proportion of burnt bones is low in all periods (Table 1) and in all of the main domestic species (Table 2). However, this proportion is not homogenous in all contexts; for example pits 123, 343, and 376 show much higher frequencies of specimens modified by fire (Table 3). Since pit 376 contained only 14 fragments, the relative abundance of burnt bones could be an artefact of chance alone. In contrast, the higher amounts of burnt bones in context 123 – a cesspit that also contained scraps of leather, nails, buckle fragments, pins, part of a wooden bowl, pottery, and a horseshoe – is consistent with the idea that it contained mostly household rubbish (Atkin, in press).

Dog gnawing occurs in Heigham St. in low frequencies in all periods (Table 1). Similarly low frequencies have been recorded in urban sites, e.g. at medieval and post-medieval Castle Mall, Norwich (Albarella *et al*., 1997). In contrast, higher frequencies (>20%) are usually found in more rural environments (Albarella *et al*. 1997; Albarella & Davis, 1994; Davis, 1992). There are no significant differences in the frequencies of gnawing in different contexts (Table 3). However, a clear difference exists between the proportion of gnawing in cattle on the one hand and in sheep and pigs on the other (Table 2), with a higher frequency in the latter. Accordingly, it can be concluded that dogs had greater access to the bones of the smaller species. This, in turn, suggests that the remains of sheep and pig represent mainly household refuse. In contrast, the relatively lower proportion of gnawed cattle bones may indicate that at least a considerable portion of the remains of this species represent primary butchery refuse and/or refuse of one or more specialised trades (e.g. butcher, horn working). This is also supported by the skeletal representation of cattle (see below). In rural locations, where most of the remains can be taken to represent domestic refuse, gnawing in cattle bones could be expected to be as frequent as in sheep and pig. Such is the case, for example, in the Saxon and medieval site of West Cotton, Northamptonshire (Albarella & Davis, 1994).

The frequency of butchery marks shows only small variations between the different periods; it ranges from 13% in Period 9 to 25% in Period 8. The actual percentage of butchered bones is certainly higher, since very many vertebrae and ribs – which were not identified to species but certainly belong in their great majority to cattle, sheep, and pig – show chop marks (Table 4). Some variability was also found between different contexts, including those assigned to the same general category (e.g. ‘pit’). Whether the differences are real (due e.g. to differing depositional histories and different function of the structures) or have a large stochastic component due to the relatively small size of the samples cannot be decided. What is clear, though, is that sheep and pig show less sign of butchery than cattle (Table 2). This pattern – repeatedly observed at different sites (e.g. Albarella & Davis 1994; Albarella *et al*. 1997) – has its origin in the greater need to chop the larger cattle bones during the portioning of the carcass.

Presence and relative abundance of the different species

The overwhelming majority of the animal remains from Heigham St. – as in almost all Medieval and post-medieval assemblages – belong to cattle, sheep, and pig. Other domestic mammals (dog, cat, and horse) are present in small numbers. Wild mammals include mole, rabbit, fallow deer, and fox. With the exception of rabbit, all are represented by only a handful of specimens at the most (Table 5). Birds are present in most periods but always in small quantities (<1% - 6% of identified bones); together, chicken and goose comprise more than 80% of the identified bird remains. Some fish bones were also retrieved from the excavations. Since the assemblage was handpicked, only the larger species are represented.

It must be kept in mind that the relative abundance of the different species can, to a large extent, be influenced by the recovery methods utilized. In hand-retrieved assemblages such as that from Heigham St. the bones of smaller species (e.g. birds, rabbit, and fish) have much lower chances of being recovered than those of larger species. Thus the abundance of small mammals, birds and fish is consistently underestimated. This is also the case for the smaller skeletal elements of medium and large-sized mammals such as loose teeth, astragalus, phalanges, carpals, tarsals, and sesamoids. Therefore this recovery method tends to produce an overestimation of the larger body-sized species. The relative abundance of the taxa can also be partly determined by the quantification method used; for example, the number of identified fragments (NISP) tends to overestimate the abundance of cattle, possibly by 10%-20% (estimation by Albarella *et al*. 1997 for Castle Mall, Norwich). In contrast, using the minimum number of individuals (MNI) will result in an overestimation of the less frequent species, especially in smaller assemblages.

With the exception of period 1, cattle are by far the most abundant species in Heigham Street, followed by sheep and pig. This is equally true whether the quantification is based on NISP or on bone weight (Figures 3-5). Thus, according to the data from Heigham St. – as well as from other areas in the city (Albarella *et al*. 1997; Jones 1994) – the bulk of the meat eaten in Norwich consisted of beef. Nevertheless, as mentioned above, recovery certainly plays a part in this pattern, and it can be seen as certain that sheep and pig were somewhat more abundant than suggested by the faunal remains. Moreover, the proportion of cattle may be overestimated if most of the horn cores represent, as it seems, refuse from a craft (see below).

Sheep was more abundant than pig in almost all periods, the exception being period 1 (1225-1275) where pig was more numerous than both cattle and sheep (period 2, with a total of seven bones: six unidentified and one pig bone, was not considered). Since the assemblage of period 1 consists of only 41 identified fragments, not too much should be made of the relative abundance of the three species. Nevertheless, a trend towards higher frequencies of pigs has been recorded for different parts of the country – including other areas in Norwich itself – during the early and mid-medieval periods. An increase in the abundance of sheep at the expense of pig occurred by the late Middle Ages (Grant 1988; Albarella & Davis 1996; Albarella 1997; Albarella *et al.* 1997; Jones 1994). During post-medieval times, the abundance of pig is low for the great majority of British sites (Albarella & Davis 1996). Heigham St. fits this general pattern.

Equids were present in most periods, though always in very small amounts. Three loose maxillary teeth – all from different periods and thus different individuals – show characteristic 'caballine' enamel pattern (see e.g. Armitage & Chapman 1979; Uerpmann & Uerpmann 1994). This and the size of the post-cranial bones suggest that most of the equid remains belong to horses rather than to donkeys or mules. Only a very small humerus from period 5 may represent either a donkey or a very small horse.

The large majority of the dog remains come from period 4. The reason for this concentration is the recovery of 16 fragments from context 179 that probably belonged to a single individual. The remains of cats do not show such a concentration. Most were recovered from periods 6 and 7, but since these contexts contain the larger faunal assemblages in the site, this is to be expected.

The relative abundance of wild mammals in the suburb of Heigham St. is low, namely 1.3% of all identified mammal bones. This is almost identical to their frequency in Castle Mall, also in Norwich (1.2%; calculations based on Table 2 in Albarella *et al*., 1997). These low frequencies are characteristic of urban and village assemblages in medieval and post-medieval times, whereas in castles wild mammals tend to be more abundant (Albarella and Davis, 1996). The species present at Heigham St. are mole, rabbit, fox, and fallow deer. The mole, a burrowing animal, may be intrusive, as may be at least some of the rabbits. Some rabbits may also represent animals taken by predators or those which died in their burrows; this is especially likely for the juveniles (for a discussion on the problem of interpretation of the presence of rabbit bones in archaeological sites see e.g. Connell *et al*., 1997). However, a radius with chop marks on its distal end demonstrates that at least some rabbits represent refuse from human consumption.

From the 59 identified bird specimens more than 95% belong to chicken, goose, and duck (in this order of abundance). Assuming that all of the goose and duck bones belong to domestic animals, wild birds are only represented by raven and pigeon (one fragment each).

Cattle

Body part and spatial distributions

All parts of the skeleton of cattle are present in the assemblage from Heigham St., though in very different frequencies. Cranial elements – skull and mandible – make over 70% of the total, whereas all limb bones are relatively rare (Figure 6). The assemblage is undoubtedly affected by recovery bias; this is strongly suggested by the low number of small-sized elements such as loose teeth, carpals, and tarsals, and by the total absence of sesamoids. The apparent abundance of cranial fragments is due, in part, to the high tendency of the skull to fragment. In order to compensate for this factor, loose teeth (which are not numerous anyway), skull fragments with no horn-cores, and horn-cores with no skull attached can be taken out of the calculation. The resulting body-part distribution is presented in Figure 7; head fragments still comprise almost half of the cattle bones. It must be stressed that the 'horn-cores with skull' are usually large, well preserved fragments, over 60% of which were measured. Thus, the high frequency of horn cores is real and not an artefact of fragmentation. In addition to these remains, the large majority of the almost 400 rib fragments and c. 200 vertebrae from large unidentified ungulates belong certainly to cattle. Thus, the body part representation of cattle is characterised by a relative abundance of cranial elements and by the common presence of axial elements. The relative rarity of parts of the skeleton that due to their size and density are often encountered in relatively large quantities in archaeological assemblages, such as the distal humerus, distal tibia, and metapodials, must have thus a pre-depositional (i.e. cultural) rather than post-depositional explanation (see below).

While horn cores are the most common element in Heigham St., their abundance varies spatially (Figure 8). They are very plentiful in area A (>30%), and fairly numerous in areas C/D and B, whereas in areas C and D – which from period 6 were considered separately – they are few (C) or lacking altogether (D; NISP=15, not shown in Figure 8).

Only minor differences were found between the body part representation of different periods (Table 6 and Figure 9).

Ageing and sexing

Three lines of evidence can be summoned in order to assess the age at which cattle were slaughtered: the epiphysial fusion of post-cranial bones, the eruption and wear of mandibular teeth, and the surface texture of the horn cores. Only for periods 6, 7, and perhaps for period 8, is the available evidence just large enough to warrant an exploration of this issue.

Mandibular tooth eruption and wear indicate a difference in the kill-off patterns of period 6 on the one hand and periods 7 and 8 on the other (Table 7 and Figure 10). In the former some animals were killed young but most were culled after they reached the adult stage (represented by mandibles with an erupting or slightly worn M_3). In the latter periods the proportion of juveniles – represented by mandibles with slightly worn deciduous teeth and unerupted M_1 – is much higher. Since the number of specimens is small, the results should not be seen as exact figures of the proportion of individuals killed in each of the age stages. Nevertheless, they do probably reflect a real trend towards an increased culling of young animals. This shift in the culling age seems to be the culmination of a trend which apparently began already in the late medieval period, as emerged from the analysis of cattle mandibles from Castle Mall in Norwich (Albarella *et al.*, 1997). This pattern is not unique to Norwich but rather national in scale (Grant, 1988). The killing of a high number of calves in post-medieval sites has been documented from a number of sites, such as Exeter (Maltby, 1979), Launceston Castle (Albarella & Davis, 1996), and Lincoln (Dobney *et al.*, 1996). It seems to be at least partially correlated with the gradual change in the role of cattle from source of traction power to meat and milk provider (Albarella *et al.* 1997; Connell *et al.* 1997). By the 17th century, horses had almost completely replaced oxen as draught animals (Overton & Campbell, 1992). Since in Norfolk the emphasis lay upon meat production rather than dairying (Overton & Campbell, 1992), there was no need to keep a large number of fully grown cattle.

Epiphysial fusion evidence from periods 6 and 7, although not abundant, shows that only a small minority of animals attained maturity, and more than two thirds failed to reach their second birthday (Tables 8 and 9). In contrast to the dental evidence, however, the post-cranial material fails to show a high juvenile mortality. Discrepancies between the dental and post-cranial mortality patterns have been observed in Norwich and elsewhere, not only in cattle but in other domestic species as well (e.g. Cartledge, 1987; Connell *et al.*, 1997). This discrepancy is probably due to a larger rate of destruction of the more fragile juvenile limb bones compared to juvenile teeth and mandibles.

The system developed by Armitage (1982) notwithstanding, the 'ageing' of horn cores is a more problematic issue than the ageing of either dental or post-cranial remains. This is due to the fact that, for some stages at least, it involves a somewhat subjective evaluation of their surface texture. Nevertheless, specimens from very young (calves) and older adults are easy to identify. The horn core assemblage from Heigham St. consists mainly of young adults (Armitage's stages 3 and 4) with rather less juveniles and some older adults (Table 10 and Figure 11). The relative paucity of the juveniles may be mainly due to their being more prone to both pre- and post-depositional destruction than those of older cattle. Alternatively, if the horn cores do represent refuse from a horn-worker workshop (see below), then it should not be expected that they reflect the age profile of the slaughtered cattle. In that case, the horn-cores of adults would probably be preferentially selected for their large and well-matured horn-sheaths. A case of selection of adult horn-cores, probably related to horn working, was reported by O'Connor (1991) from 16th century Lincoln.

The sexing of cattle remains presented considerable difficulties due to the paucity and fragmented state of the post cranial elements commonly used in such analyses (i.e. metapodials and pelvis). None of the metapodials was complete, and therefore their proportions – which are often used to separate males, castrates, and females – could not be established. Likewise unfruitful was the sexing of horn cores after the criteria set by Armitage (1982). The cores were remarkably homogeneous in their shape and size.

Size and type

Only very limited osteometrical data is available for teeth and post-cranial bones. Nevertheless, that which is available, such as the measurements of the 1st phalanges (Figure 12), suggests that larger cattle were present at the site at least from period 7 (1575-1625). This result is in agreement with the increase in the size of cattle reported by Albarella *et al.* (1997) for Castle Mall, Norwich, beginning in period 6 (late 16th century). This must be seen within the context of a broader trend of size increase in cattle which took place, though not completely synchronous, in different parts of the country, such as Cornwall (Albarella & Davis, 1996) and Lincoln (Dobney *et al.*, 1996).

In contrast to the scant metrical data obtained from other skeletal elements, a large number of measurements were taken from horn cores (Figures 13 & 14). From more than 50 complete cores, none has a posterior-dorsal length of 220mm or greater and thus, in the classification of post-medieval horn-cores of Armitage (1982), all belonged to 'shorthorn' cattle.

Alternatively, if the classification of Armitage & Clutton-Brock (1976) is used, three of the cores could be classified as 'medium-horned'.

In periods 7 and 8, the cores tend to have a greater basal circumference and larger major and minor basal diameters (Figure 13) but the basic shape of the cores is similar to that of earlier periods (Figure 14). It is interesting to note that cattle with longer horns coexisted in England with the shorthorn cattle from the late 16th century (Albarella *et al.* 1997; Armitage, 1990). Evidence for longer horned cattle was found, among other sites, at Castle Mall, and Coslany Street, both in Norwich. It is interesting to speculate whether the absence of cattle with longer horns in Heigham St. might be due to the butchers and/or tanners and horn workers having a different source of cattle as those in the Castle Mall site.

Non-metric traits and pathologies

Two non-metrical traits are repeatedly observed in mandibles of domestic ruminants in archaeological sites: the absence of the second premolar (P_2) (Andrews & Noddle, 1975) and the lack of the third pillar (hypoconulid) in the third molar (M_3). Since these traits are congenital, the frequency of their occurrence could, in principle, be used to identify populations or regional types (Albarella *et al.*, 1997). In a survey of almost 7500 modern cattle in America, the P_2 was found to be absent in about 1% of the specimens (Garlick, 1954, cited in Andrews & Noddle, 1975). If this proportion is assumed to be typical of all modern cattle populations, then the frequency of this trait seems to have been higher in the past. It was recorded, for example, in 12% of the 4th century mandibles in Lincoln (Dobney *et al.*, 1996), in 19% of the Roman mandibles from York (O'Connor, 1988), and, more relevant, in *c.* 50% of mandibles from the medieval and post-medieval levels at Castle Mall, Norwich (Albarella *et al.*, 1997). This trait was also observed at Heigham St. in a total of six out of twelve mandibles (i.e. 50%). Since most of the mandibles belong to period 6, the chronological variability in the absence of P_2 cannot be investigated (for period 6, five out of nine specimens, 55%, lack P_2).

Whereas Heigham St. and Castle Mall have very similar frequencies concerning the absence of P_2, they differ in the absence of the hypoconulid in M_3. The latter was observed in three out of 22 (13.6%) specimens from Heigham St., compared with only four out of 137 (3%) in Castle Mall. Using 'Fisher's Exact Test', the probability (p) that cattle from both sites represent the same population is 0.069. Though not statistically significant, the probability of 0.069 is close enough to the 0.05 value, to make it unwise to reject completely the hypothesis of a different origin for the cattle of Heigham Street.

In three instances, small oval depressions (Type I as defined by Baker & Brothwell, 1980:109-111) were observed in second phalanges of the forelimb, two from period 7 and one from period 8. These depressions are probably not pathological but their origin is unknown (Baker & Brothwell, 1980).

Pathological lesions, in the form of occipital perforations, were observed in five specimens from Heigham St.: one from period 4, two from period 6, and two from period 7. This type of pathology was also found in cattle skulls from a number of sites in England, such as Lincoln (Dobney *et al.* 1996), Coslany Street, Norwich (e.g. Albarella, 1997), and Exeter (Maltby, 1979) but also elsewhere in Europe, for example in Konstanz, Germany (Prilloff, 2000: 52). The cause of these lesions is still unknown; suggestions have included parasitic infestation, infections, developmental anomalies, and the recurrent strain caused by cattle being yoked by the horns. On the basis of the available evidence, Brothwell *et al.* (1996) thought only the latter two as likely explanations. The recent find of a skull of bison (*Bison bonasus*) from Armenia dated to 2000 B.C. with similar perforations seems to rule out the effects of the yoke as a cause for this type of condition (Manaseryan *et al.*, 1999).

Butchery

Cattle bones in Heigham St. were heavily butchered (see also section on 'preservation'). Most skeletal elements present chop or cut marks, made either during the disarticulation of the carcass or the preparation of food prior to cooking (Table 11). Instances of the former include the chopping off the upper part of the mandibular ramus, chop marks on the proximal femur, distal radius, and cut marks in the hyoid (made during the extraction of the tongue). Vertebrae of large ungulates, of which most belong with certainty to cattle, were often split, indicating that carcasses were being halved down the backbone. Split vertebrae are especially common in periods 5-9, but a split lumbar vertebra was also found in deposits from period 3. Cut marks on metapodials and phalanges are regarded as being indicative of skinning. In Heigham St. some specimens of these elements have chop marks, but no cut marks.

A significant part of the cattle bone assemblage consisted of horn cores with an attached fragment of frontal bone (in occasions occipital and temporal bones as well). These specimens show evidence of having been chopped off the rest of the skull with a cleaver or axe, in a way similar to that observed in other medieval and post-medieval sites in northern Europe such as Chichester, Konstanz, and Leiden, (Armitage, 1990; Prilloff, 2000; van Wijngaarden-Bakker, 1994). An important proportion of the cores shows chop or, much less often, cut marks located usually just above or just below the base (N=32 and N=9 respectively). The marks were made during the separation of the keratinous sheath from the bony core. Thus, the high frequency of horn cores and chop marks on them attest the intensive use of horn at Heigham St. The relevance of the abundance of cores for the investigations of probable activities taking place at the site is discussed in a later section.

Sheep

Given their close morphological similarity, the osteological distinction between the sheep and goat is not always possible. In the assemblage from Heigham St. 182 specimens (= 32% of all ovicaprid bones) were identified as sheep and only one as goat. This is not surprising; with the occasional exception of horn cores, bones of goats are rare in British archaeological sites and their paucity is even more accentuated during post-medieval times. In the large assemblage from Castle Mall, Norwich, goats represented less than 1% in the late medieval and post-medieval period, compared to 7% in the late Saxon and early medieval times (Albarella *et al*. 1997). Therefore it does not seem inappropriate to include also specimens that could not be assigned unambiguously to either sheep or goat in the analysis of body part representation, age, sex, and size, in the assumption that all, or at least the overwhelming majority, belong to sheep.

Body part and spatial distribution

The representation of the different body parts of sheep at Heigham St. is a result of a number of different processes. The bias against the smaller elements such as carpals, tarsals, phalanges, and loose teeth, is even more marked than in cattle, and is probably a product of the recovery method used. Skull and mandibles are very common or common in all excavation areas. Metapodials are also relatively abundant, except in area C/D; since this area had the largest number of specimens, the paucity of metapodials is interesting. Meat-bearing bones of the upper limbs are relatively common, especially in areas C/D and C. However, whereas elements of both the upper fore- and upper hind limbs are found in similar proportions in A and B, the former are much more abundant than the latter in areas C/D and C (Figure 15). It must be stressed that in spite of the evidence that horn cores of sheep were used (see below) not a single fragment was found at the site; this contrasts strongly with the skeletal representation of cattle.

It is clear that in all areas at least some of the remains of sheep represent food refuse. Nevertheless, the high frequency of skull and metapodials in areas A and, especially, B could mean that some primary butchery took place at the site. Alternatively (but not mutually exclusively) the high proportion of metapodials could argue for the tanning of hides – assuming these were brought to the tanner or tawyer with the feet still attached.

A clear difference in the body part representation can also be seen between period 6 on the one hand and periods 7 and 8 on the other, with the former showing a much higher relative abundance of metapodials and less meat-bearing elements (Figure 16). The source of this difference is the relatively large numbers of metapodials found in a number of pits in area B, all from period 6. Thus, for example, pit 123 – described as a cess pit by the excavator - contained three metacarpals and eleven metatarsals, while from pit 137 seven metacarpals and five metatarsals were recovered. The small size of the assemblages render it difficult to decide whether this difference has any 'functional' explanation – e.g. changes in the activities being carried out in areas A and B taking place between period 6 and 7 – or whether it is due to stochastic processes.

Age and sex

The analysis of the kill-off patterns of sheep was only feasible for periods with larger quantities of material, i.e. periods 6, 7, and 8. The dental and post-cranial evidence shows that very few animals were killed during the first two years of life, with mortality increasing markedly thereafter. Very old animals – those with very worn third molars or permanent premolars – were very rare (Tables 15-18 and Figure 17). The epiphysial fusion seems to indicate some difference between periods in the proportion of the animals that reached an age of 3.5-4 years (i.e. before the fusion of the late-fusing epiphyses). However, these differences are not apparent in the dental evidence in the form of M_3 wear (Figure 18).

Thus, most animals lived at least two years, but only a small proportion lived beyond four years of age. This mortality pattern is consistent with the dual exploitation of sheep for wool and meat. According to Muffet, (1655, cited in Albarella & Davis, 1996) animals not older than four years of age produced the best mutton. Since most of the material belongs to the later periods (6, 7 and 8), this pattern must be regarded as characteristic of the 16th and 17th centuries in Heigham Street. It is in agreement with the mortality pattern in the post-medieval period in Castle Mall, Norwich (Albarella *et al.*, 1997), Lincoln (Dobney *et al.*, 1996), West Cotton (Albarella & Davis, 1994), and Colchester (Luff, 1993).

Given the small degree of sexual dimorphism in domestic sheep (Albarella & Davis, 1996), the determination of the sex proportions in Heigham St. was carried out through the analysis of the morphology of the ventro-medial wall of the acetabulum in the pelvis, which tends to be thicker in males than in females. From twelve specimens that were sexed ten were assigned to females and only two were identified as males. Both male specimens come from period 7; the female specimens from period 1, 1-3, 5, 7 (one specimen each), 6 (n= 3), and 8 (n=2). Given the small number of specimens within each period, a discussion of possible interpretations of the sex ratio seems unwarranted.

Size

The number of measured sheep specimens in Heigham St. was low. Therefore, in order to explore possible variations in the size of sheep through time, the log-ratio method was used since it allows the inclusion of different skeletal elements, thus enlarging the sample size considerably (for explanation of method see Bull & Payne, 1988). A group of female Shetland sheep (Davis, 1996) served as the standard required by this method. The results for period 5-9 are presented in Figure 19 (no metrical data is available from periods 1-4). A small, but clear increase in the size of sheep took place between periods 6 and 7. The available metrical data, however, is insufficient to clarify whether the increase was accompanied by changes in the length/width proportions of the bones.

In their analysis of the large bone assemblage from Castle Mall, Norwich, Albarella and colleagues (1997) noticed an increase in the size of sheep in Period 6. However, since this period is dated to the late 16th to 18th centuries, they could not be more precise on when this size change took place. The assemblage from Heigham St. can contribute valuable information on this issue. The larger size of sheep in period 7 compared to period 6 demonstrates that the size increase in the Norwich area must have taken place somewhere between the last part of the 16th century and the beginning of the 17th century. The presence of more robust sheep in Norwich should be seen within the frame of a broader, nation-wide trend for larger sheep – reflecting perhaps the introduction or development of improved breeds - during post-medieval times. Seemingly, however, there were regional differences in the timing of the appearance of these heavier animals. Dobney *et al.* (1996) have reported an increase in the size of sheep in Lincoln as early as the first half of the 16th century, whereas O'Connor (1995) has suggested that significant changes in York did not take place until the late 18th century.

Non-metrical traits and pathology

Given the size of the assemblage, it is difficult to make a reliable estimation about the proportion of polled versus horned sheep. Two skull fragments of polled sheep were recovered, one from period 5 and the other from period 8. In contrast, fragments of skulls with evidence of the cores having being chopped off were recorded in thirteen cases: one case in period 4, five in period 6, three each in 7 and 8, and one in period 9.

The second non-metrical trait recorded was the presence/absence of the second permanent premolar in mandibles. As in cattle, this tooth is sometimes congenitally absent in sheep. The P_2 was absent in 6 (19%) mandibles from Heigham St., whereas it was present in 26 cases (81%). When the occurrence of this trait is investigated for each period separately, an interesting fact emerges. In period 6, only two out of sixteen mandibles (i.e. 12.5%) lack a P_2, whereas in period 7 three out of eight mandibles (38%) show this trait. This would seem to support the idea that the increment in size in period 7 was caused by the introduction of stock and not by the improvement of the local one. However, probably due to the small number of cases, the difference in the frequency of P_2 between periods 6 and 7 is not statistically significant (Fisher's exact test p=0.289 ∀=0.05).

Butchery

Approximately 18% of the ovicaprid bones show butchery marks (Table 19). The chopping off of the horn cores from the skull was one of the most characteristic patterns seen in the assemblage, and this attests to the intensive use of sheep horn as a raw material, despite the fact that no horn cores from this species were found at the site. A similarly characteristic butchery mark is the sagital splitting of the skull – both from horned as well as from polled sheep – along the frontal suture presumably in order to remove the brain. In ten specimens both splitting and chopping off the horn cores were recorded. The great majority of such specimens come from the post-medieval deposits – not surprisingly, since these contain most of the material at Heigham St. – but one split skull was also found in period 4 (1375-1450). The splitting of sheep skulls was also common in the medieval and post-medieval levels of Exeter (Maltby, 1979). The atlas and axis were usually split longitudinally – as were most vertebrae of medium-sized mammals, which include certainly many sheep. This demonstrates sheep carcasses were split into right and left halves in a similar fashion as in cattle.

Pig

Body part distribution

The smaller skeletal elements of the pig are very rare; this was also the case in cattle and sheep and it can be ascribed to hand-recovery used at the site (Table 20). Compared to cattle and sheep, however, meat-bearing bones are present in higher frequencies. The relative abundance of some of the elements varies between the different excavation areas (Figure 20). Skull and mandible fragments are abundant in most areas, but especially in C/D. The central metapodials (III and IV) are very common in areas B and C, but much less so in A and C/D. Interestingly, area C shows a markedly different pattern than other excavation areas. In the former, bones of the cranial skeleton are represented by a single mandible; in contrast, metapodials and meat-bearing bones (scapula, humerus, radius, and femur) are abundant. Most of the pig bones from this area come from a single feature (pit 506) from period 1, which given the high frequency of meat-bearing bones it contained – not just from pig but from sheep as well – must have served as a recipient of domestic refuse.

Ageing and sexing

The analysis of the state of epiphysial fusion of the post-cranial elements shows that pigs were killed young. Somewhat more than a third did not survive their first year and, according to this type of evidence, very few, if any, reached an age of two years (Table 21). The dental evidence confirms this pattern: a peak in the mortality occurred during the juvenile stage, and most of the remaining individuals were killed just before the eruption of the M3, i.e. younger than *c.* 16-20 months (Table 22, Figure 21). Very few animals lived beyond two years of age. Unfortunately, the material is not rich enough to attempt an investigation of possible changes in the slaughter pattern from the medieval to the post-medieval periods, but such a change has been described for Castle Mall in Norwich (Albarella *et al.*, 1997), Exeter (Maltby, 1979), and Lincoln (Dobney *et al.*, 1996).

Morphological and size differences between the sexes allow the sexing of loose canines and mandibles with the canine or its alveolus. In Heigham St. six mandibles and five loose mandibular canines are from females, whereas males are only represented by two loose canines, a mandibular and a maxillar one. If each period is analysed in isolation, the ♀ : ♂ ratio in periods 6 and 7 – which comprise most of the material - is 4:1 in both. Given the small numbers involved, not much weight should be attached to this ratio. Still, an overrepresentation of females is unusual in archaeological sites, especially in urban (i.e.

‘consumer’) ones. If not a product of chance, the sex ratio in Heigham St. could indicate that some pigs were being bred at the site, as was also suggested for Castle Mall, where a high proportion of females – though not as high as in Heigham St. – was also recorded (Albarella *et al*. 1997).

Size

The fact that most pigs were killed young means that osteometrical data from Heigham St. is very limited. An increase in the size of pigs in post-medieval times has been suggested for Castle Mall (Albarella *et al*., 1997) and Lincoln (Dobney *et al*., 1996). However, even using the ‘log-ratio’ method and grouping the measurable specimens into two groups only – medieval and post-medieval - not enough evidence is available in Heigham St. to explore this question (Figure 22). Likewise, the assemblage cannot contribute to the investigation of the inter-regional size variation in contemporary pigs.

Butchery

About 17% of the pig bones show cut or chop marks, made both during the butchery process and during the preparation of food for consumption. The frequency of butchery marks varies according to skeletal element (Table 23): humerus and pelvis show particularly high frequencies, whereas no marks were found in either metapodials or phalanges. A first cervical vertebrae (atlas) was chopped sagitally, suggesting that the carcasses of pig were split into right and left halves along the vertebral column, in a similar way as in sheep and cattle. This is also indicated by the large proportion of the unidentified vertebrae of medium-sized mammals that were also split longitudinally, of which some belong without doubt to pigs.

Other mammal species

Equids

Equid bones were recovered from most periods (NISP= 17). The remains consist mainly of feet and cranial elements but include also a scapula, a humerus, and a radius (Table 24). As mentioned above, the morphology of the enamel folds of all teeth and the size of the bones suggest that most of the remains belong to horses. Only a very small humerus from period 5 may be either that of a donkey or a very small horse. A height at the withers of only 118cm was calculated for this specimen using the factor of Kiesewalter (1888) corrected by Boessneck & Ciliga (1966). The only other bone from which this parameter could be obtained was a metatarsus, also from period 5 (143cm).

All bones come from mature animals and, judging from the heavy or very heavy wear in some of the teeth, some individuals reached an advanced age, possibly 15-20 years (Habermehl, 1975). It is interesting to note that four of the fragments show butchery marks. An atlas was chopped in its anterior cranial articulation; this probably happened during the separation of head and neck. The glenoid of the scapula and the shaft fragment of radius show also chop marks. Finally, an anterior first phalanx has chop marks in its distal end. Thus, the location of these butchery marks indicate the utilization of both meat and skin of at least some of the horses that, due to their advanced age, could not work efficiently anymore. The question remains: was horse meat eaten by people or was it fed to the dogs? The feeding of dogs with horse meat was recommended by Markham in his book *Country contentments: or, the husbandsman recreations* (1633, quoted in Albarella & Davis, 1996). A metatarsal with gnawing marks from period 5 shows that horse bones were accessible to dogs, but so were bones from other species, and thus, in itself, cannot serve as evidence that horse flesh was used to feed dogs.

A specimen from period 5 consists of the third and intermediate tarsals fused together (ankylosis). This condition (commonly involving also the metatarsus) is known as spavin and is not uncommon in horse bones from archaeological assemblages, but it is occasionally seen in cattle and camels as well (von den Driesch, 1975). Its aetiology may be different from case to case, but among the causes for this condition are old age, heavy work, faulty shoeing, or working in hard surfaces (Baker & Brothwell, 1980; von den Driesch, 1975). In any case, an animal with such a pathological condition would be perfectly well able to perform traction work (von den Driesch, 1975).

Dog

The remains of dogs were not very common, but the frequencies of gnawed bones, especially sheep and pig, as well as coprolites, points to their ubiquitous presence at the site and to their role in the alteration of the assemblage. The remains were found in different periods, but most come from a partial skeleton found in context 179, period 4 (Table 25). The partial skeleton includes 17 fragments: two ribs and six lumbar vertebrae (normally not identified to species), a right and a left pelvis, right and left femur, metatarsals II-IV (right), and left radius and ulna, all presumably belonging to the same mature individual. In addition to the bones, a dog coprolite was found in this context. The metatarsals were complete and other fragments were probably also complete at the time of deposition but were damaged during the excavation (as shown by fresh breaks). The left femur is almost complete and has cut marks in the dorsal face of the distal shaft. The location of the cuts is consistent with defleshing rather than skinning. While not common, cut and chop marks associated with the dismembering or defleshing of dog carcasses have been reported from a number of medieval and post-medieval sites such as Castle Mall (Albarella *et al.* 1997), Lincoln (Dobney *et al.*, 1996), and West Cotton (Albarella & Davis, 1994). Whether the meat was used to feed other dogs, or whether it was destined for human consumption (e.g. in periods of famine) remains an open question.

Most of the bones represent medium-sized dogs, however, a mandible and a maxillary bone from a single individual (context 253, period 7) belong to a small dog, about the size of a small terrier. A tibia from period 6 preserved in its entirety represents an individual *c*. 47cm tall (calculated after Harcourt, 1974).

The absence of the P_2 – a congenital, non-metrical trait – was observed in a mandible from period 7 (context 313).

Cat

Bones of cats were recovered, always in small numbers (total N= 10), from both medieval and post-medieval layers. Except for a mandible, all the remains are those of long bones. Bones from the feet (metapodials, phalanges) are missing; this is not surprising, given their small size and the hand-recovery used at the site. Half of the fragments have open epiphyses and must have come, therefore, from young animals. A high proportion of immature cats has been considered as evidence of the use of their fur (Maltby, 1979: 86; Serjeantson, 1989). The high frequency of juvenile bones in Heigham St. could be interpreted in the same manner. In some sites, a high proportion of cut marks, mostly on skulls, mandibles, and metapodials, attests the use of cat fur – e.g. Castle Mall, Norwich (Albarella et al., 1997) and West Cotton in Northamptonshire (Albarella & Davis, 1994). No cut marks were observed on any of the specimens from Heigham St., but since almost all of these are bones of the upper legs – which are usually not damaged during skinning – this is no argument against the exploitation of cat pelts.

It can be mentioned that two cat bones (both from period 7) were gnawed by dogs.

Rabbit

Rabbits were introduced in Britain in the 12th century, where they were managed and kept in warrens by the nobility. Thanks to their burrowing habits, rabbits began to escape from captivity soon thereafter, probably during the 13th century, and by the 16th century they were abundant and widespread in lowland England (Lever, 1994: 75). The price of rabbit decreased accordingly with its increased abundance. In the 13th century rabbits were still a luxury; the price of one averaged 3½*d.* plus a further 1*d.* for the skin, i.e. rather more than a craftsman's daily wage, whereas in the 15th century it was worth 2¼*d.*, or less than half the daily wages (Rackham, 1986: 48). Thus, it is not surprising that the overwhelming majority of the 21 rabbit bones found in Heigham St. come from periods 7, 8, and 9. Nevertheless, two fragments from earlier periods are present: a tibia from period 4 and a humerus from period 6 (Table 26).

Only one of the fragments, a distal radius from period 8, shows butchery marks.

Fallow deer

Only six specimens of fallow deer were found, all but one from deposits dated to period 8. They include a distal fragment of a metatarsal and two phalanges (a 1st and a 2nd) – all from a single, mature individual from context 304 – and a distal humerus and distal tibia, both with fused epiphyses, from context 85. The tibia was damaged by fire, part being calcined and part charred. The remaining fragment, from period 5, is a piece of frontal bone with the lower part of the antler still attached. Chop marks were visible both in the frontal and in the antler beam, just above the brow tine.

Fox

Fox is represented at the site by three fragments found in context 85 (period 8): the left humerus, radius, and ulna from the same individual. No cut or chop marks were observed in any of the bones, though this species was probably hunted occasionally for its fur (Albarella *et al.*, 1997).

Birds

Domestic fowl

Domestic fowl, though not numerous, are the most common bird species. No significant differences were detected in its relative abundance between the different periods (Table 5 & 27). The paucity of remains of chicken, and of birds in general, is due, at least in part, to their small size compared to that of the most common mammals, being often overlooked in hand-recovered assemblages. This may be especially true for the even smaller bones of juveniles. Albarella et al. (1997) reported an increase in the proportion of both juveniles and females from the medieval to the post-medieval periods in Castle Mall, Norwich. These increases were thought to be indicative of a shift in the exploitation of domestic fowl from eggs to meat. The assemblage from Heigham St. is too small to investigate these issues in a reliable manner (Table 28). Sex determinations from the tarsometatarsus could be made in only three cases: two males (periods 4 and 6) and one female (Period 8). None of the fragements showed cut or chop marks, but two femora were gnawed.

Goose

In medieval times, geese were a source of a number of valued products: meat, eggs, fat, and feathers. Still, geese occur normally in lower frequencies than domestic fowl in British sites (Grant, 1988). In Heigham St., geese were marginally less common that domestic fowl; they are present in most periods, in frequencies ranging from 0.6% to 2.6%. All fragments belong to adults and their size suggests that they all probably belong to the domestic form. Carnivore gnawing was recorded from two fragments, a humerus (period 5) and a tibiotarsus (period 9).

Ducks

Ducks are represented by eight fragments from which half were found in period 5. The size of seven of them is consistent with their being from domestic animals. The size of a mandible from period 3 suggests that it is derived from a wild duck, but the fragment could not be identified to species. The Fenland around Norwich would have certainly provided ample opportunity for wildfowling.

Other birds

A radius of an adult pigeon (*Columba* cf. *livia*) was recovered from deposits dated to period 6. This specimen does not show cut or chop marks. Nevertheless, it is not unlikely that it represents food refuse, since pigeons were commonly eaten in medieval and post-medieval times (Albarella & Davis, 1994, 1996; Grant, 1988).

Raven (*Corvus corax*) is represented in the assemblage by a proximal humerus from period 7. This species was formerly widespread, but its range was much reduced in the 19th century. Today, it is absent from eastern regions of England, including Norfolk, but occurs in western England, Wales, Ireland, and Scotland (Snow & Perrins, 1998). It feeds opportunistically, obtaining part of its food by scavenging. Thus, it is not uncommon to find it near rubbish-tips, slaughterhouses, and, where not persecuted, even around dwellings. According to Snow & Perrins (1998) it often hides food; it prefers to cache fat or fatty meat, but also has been observe to hide whole eggs, bread, dates, dung, and, particlularly relevant here, also bones.

Fishes

Fish are one of the animal groups where abundance and diversity in archaeological assemblages are most affected by the recovery method. A number of studies of sieved assemblages from medieval Norwich showed that herring were, by far, the most numerous species consumed in the city (see e.g. Jones & Scott, 1985; Locker, 1987, 1994, 1997). This is not surprising since Norwich was, in fact, a centre for curing herring brought from Yarmouth after the river became too shallow for seagoing craft (Williams, 1988 quoted in Locker, 1997). Herring was relatively cheap, selling by the end of the 14th century at nine pieces for 1*d*. (Hammond, 1993: 47). In spite of this, not a single bone of this species was recovered in the hand-collected assemblage from Heigham Street. That this is due to the recovery method is demonstrated by the comparison between the sieved and the hand-collected assemblages from Castle Mall (Locker, 1997). While herring are the most frequent fish in the former, cod and other large gadids are the most common taxa in the latter.

A total of 43 fragments of fish were collected during the excavations at Heigham Sreet. Not surprisingly, cod and other (unidentified) large gadids form c. 80% of the fish assemblage. The presence of some head bones of cod/gadids indicate that these fishes were sold fresh and whole (after gutting). However, there is evidence from Castle Mall – in the form of cut and chop marks on the cleithra of some specimens – that stockfish, brought probably from Iceland, was also sold in the city (Locker, 1997). Other marine fish found at Heigham St. include ling and flatfish. Given that the Norfolk coastline is the extreme south of the range of ling, it is likely that most of the remains of this species are derived from dried and salted fish brought to Norwich from more northern and western areas, e.g. off the coast of Ireland (Locker, 1997). A supracleithrum from a very large ling found in period 6 is larger than that of a recent specimen in the reference collection of the Faunal Remains Unit (Southampton) which had a total body length of 1.20m. Freshwater fish are represented by four fragments of roach, probably from the same individual (period 9).

Discussion

The faunal remains from the suburb of Heigham, dating in their greater part to the late medieval and post-medieval periods, confirm, in broad terms, observations made elsewhere in Norwich. The assemblage is strongly dominated by the three most common domestic species: cattle, sheep, and pig in order of abundance. Other domestic mammals – horses, cats, and dogs – are present in small amounts. There is evidence, in the form of cut marks, that the meat of dogs was utilised; whether for dog or human consumption is, however, unknown. Wild mammals include fallow deer, fox, and rabbit.

Birds, mostly domestic fowl and goose, are present in small amounts, as are fish remains. Both birds and fish are certainly underrepresented due to the recovery method employed during the excavations.

Cattle were used mainly as traction and meat sources, the former decreasing in importance in later periods, probably as a result of their replacement by horses as working beasts. Sheep were normally killed when older than two and younger than four or five years of age. This indicates that both wool and mutton were important products. Pigs, as sources of meat only, were killed young, typically at about 1.5 years, but many were slaughtered within their first year of life.

Probably the main contributions of the bone assemblage of Heigham St. are in what concerns

i) the understanding of the ‘agricultural revolution’ in the Norwich area and
ii) the character of the activities taking place at the site.

Heigham Street and the agricultural revolution

There seems to be a disagreement among historians on whether the 'agricultural revolution' in England took place during the 18th century, more or less synchronous with the industrial revolution, or whether it represents a rather gradual phenomenon starting already during the 15th and 16th centuries (see e.g. Kerridge, 1967, 1988). The archaeozoological evidence can help to clarify this issue by investigating the evolution in the size of cattle and sheep as a measure of livestock improvement (Davis, 1997). In this context, an existing problem is the relative scarcity of well stratified post-medieval assemblages (Davis, 1997; O'Connor 1995). Herein resides the importance of the faunal assemblage from the suburb of Heigham.

From the available data it would seem that an increase in the size of cattle and sheep took place at different times in different areas. Larger (heavier) cattle and sheep appear in Devon, Cornwall, and Northumberland as early as the 15th-16th centuries (Davis, 1997). In York, on the other hand, there seems to be no evidence for a size increase in these species until the late 18th century (O'Connor, 1995). Due to lack of metrical data from the critical period, the situation in Norwich could not be clarified by Albarella *et al.* (1997).

While the metrical data for the 16th and 17th centuries available from Heigham Street is scant, it suggests that an increase in size of cattle and sheep took place between periods 6 and 7, i.e. during the late 16th and early 17th centuries. Moreover, changes in the frequency of some congenital, non-metrical traits in sheep suggests that the increase in size was brought about, at least in part, by the introduction of new stock. There is historical evidence in England for both crossbreeding and even import of foreign livestock in the 16th and 17th (Davis, 1997). Some breeding stock may even have been imported to England from as far away as Holland (Davis, 1997; Thirsk, 1985: 558). During the 16th and 17th centuries the city of Norwich had close contact with the Low Countries (see e.g. Ayers, 1994: 96-98) and it is not impossible that, if new stock was brought to the city, it originated there.

Thus, the metrical analysis of the faunal remains from Heigham St. is consistent with the assertion that the 'agricultural revolution' in Norfolk was well underway by the close of the 16th and the beginnings of the 17th centuries. Nevertheless, this must be confirmed in the future when more substantial material from the relevant periods becomes available.

Tanning or horn-working?

While it is clear that many of the bone remains from Heigham St. represent food refuse, the high frequency of cattle horn cores indicates that a significant part of the assemblage must have a different origin.

Long before and during medieval and post-medieval times, horn was a valuable resource in the manufacture of different products such as knife-hafting and combs (MacGregor, 1985, 1989) and was unlikely to be discarded as refuse (Serjeantson, 1989). There is evidence that the hides brought by the tanners from the butchers commonly had still feet and horns attached (Prummel, 1978; Serjeantson, 1989). The tanner would cut out the horns before beginning with the tanning process and would sell them to the horn workers, either as complete horns or only the keratinous sheath; in the latter case, horn cores would be discarded with other refuse from the tannery. In other occasions, however, the butcher himself would remove the horns from the hide. In this case he would sell them directly to the horn worker, again, either as 'complete horn core' i.e. with the horn sheath still attached to the bony cores or with this core already removed. If the butcher separated the sheath from the cores himself, then the cores were disposed of together with other slaughter-yard refuse (Armitage 1990).

Thus, a high frequency of horn cores in archaeological assemblages may be derived from one or a combination) of three activities: butchery, tanning, and/or horn-working (Armitage, 1990). The situation is made more complex by the relatively short-lived practice, beginning in the 17th century, of using the osseous by-product of tanning or horn-working (horn cores, metapodials) as building material (Armitage, 1989). Therefore, the interpretation of an assemblage that is rich in horn cores must be made in conjunction with contextual evidence (features) and other type of finds.

In medieval and post-medieval Norwich, as in many other cities, the premises of tanners and horn-workers were normally situated near the river (Ayers, 1994). The riverside location of Heigham Street, lends support to the idea that one or both of these crafts were carried out there. A more direct piece of evidence for leather-working is the broken leather-worker's knife found in a pit in area A (Goodall, 1993). This area, may be remembered, was the one with the higher concentration of horn-cores.

Two trades, strictly separated from each other, involved the tanning of hides. The tanners dealt with skins of oxen, cows and calves, whereas the tawyers processed those of sheep, horses, and deer (Salzman, 1923: 245; Cherry, 1991). In this context, it is perhaps significant that while there is evidence, in the form of butchery marks, that sheep horn was used, horn cores of this species were not found at the site. This may suggest that tanners, rather than tawyers were active at Heigham Street. It is also possible, of course, that some horn-working was carried out in the area. If this was the case, however, it is not unreasonable to expect some sheep horn cores to be present as well. In short, while it is very probable that most of the cattle horn cores and metapodials in Heigham St., especially in excavation area A, represent refuse from one or more tanneries, the existence of horn-worker premises in the tenements cannot be ruled out.

Acknowledgements

I would like to thank Dale Serjeantson (Southampton), Polydora Baker and Sebastian Payne (Portsmouth), and Kerstin Pasda (Erlangen, Germany), for reading and commenting on an earlier version of this paper. Thanks are also due to Claire Ingrem (Southampton) for help in the identification of the fish remains.

References

Atkin, M in press 'Excavations in the suburb of Heigham', *in* Atkin, M & Evans D H Excavations in Norwich 1971-1978 Part III. East Anglian Archaeology 100.

Albarella, U 1997 *The Medieval animal bones excavated in 1996 from Coslany Street, Norwich, Norfolk*. London: AML report 86/97.

Albarella, U, Beech, M, & Mulville, J 1997 *The Saxon, Medieval and Post-Medieval mammal and bird bones excavated 1989-91 from Castle Mall, Norwich, Norfolk.* London: AML report 72/97.

Albarella, U & Davis, S J M 1994 *The Saxon and Medieval animal bones excavated 1985-1989 from West Cotton, Northamptonshire*. London: AML report 17/94.

Albarella, U & Davis, S J M 1996 'Mammals and birds from Launceston Castle, Cornwall: decline in the status and the rise of agriculture'. *Circaea* **12**, 1-156.

Andrews, A H & Noddle, B A 1975 'Absence of premolar teeth from ruminant mandibles found at archaeological sites'. *Journal of Archaeological Science* **2**, 137-144.

Armitage, P 1982 'A system for ageing and sexing the horn cores of cattle from British post-medieval sites (17th to early 18th century) with special reference to unimproved British longhorn cattle', *in* Wilson, B, Grigson, C, & Payne, S (eds) *Ageing and sexing animal bones from archaeological sites*, 37-54. Oxford: BAR British Series 109.

Armitage, P 1989 'The use of animal bones as building material in post-medieval Britain', *in* Serjeantson, D & Waldron, T (eds) *Diet and crafts in town: the evidence of animal remains from the Roman to the Post-Medieval periods*, pp. 147-160. Oxford: BAR British Series 199.

Armitage, P 1990 'Post-medieval cattle horn cores from the Greyfriars site, Chichester, West Sussex, England'. *Circaea* **7**, 81-90.

Armitage, P & Chapman, H 1979 Roman mules. *The London Archaeologist* 3: 339-346.

Ayers, B 1994 *Norwich*. London: Batsford.

Baker, J & Brothwell, D 1980 *Animal diseases in archaeology*. London: Academic Press.

Boesneck, J & Ciliga, T 1966 'Zu den Tierknochenfunden aus der Siedlung der römischen Kaiserzeit auf dem 'Erbbrink' bei Seinstedt, Kreis Wolfenbüttel'. *Neue Ausgrabungen und Forschungen in Niedersachsen* **3**, 145-179.

Boessneck, J, Müller, H H, & Teichert, M 1964 'Osteologische Unterscheidungsmerkmale zwischen Schaf (*Ovis aries* L.) und Ziege (*Capra hircus* L.)'. *Kühn-Archiv* **78**, 5-129.

Brothwell, D, Dobney, K & Ervynck, A 1996 'On the causes of perforations in archaeological domestic cattle skulls'. *International Journal of Osteoarchaeology* **6**, 471-487.

Bull, G & Payne, S 1982 'Tooth eruption and epiphysial fusion in pigs and wild boar', *in* Wilson, B, Grigson, C, & Payne, S (eds) *Ageing and sexing animal bones from archaeological sites*, 55-71. Oxford: BAR British Series 109.

Cartledge, J 1985 'The animal bones', *in* Atkin, M, Carter, A & Evans, D H Excavations in Norwich 1971-1978. Part II. *East Anglian Archaeology* **26**, 220-222.

Cartledge, J 1987 Mammal bones. In: Ayers, B Excavations at St. Martin-at-Palace Plain, Norwich, 1881. *East Anglian Archaeology* **37**, 111-113.

Cherry, J 1991 'Leather', *in* Blair, J & Ramsay, N (eds) *English medieval industries*, pp. 295-318. London: The Hambledon Press

Clason, A T & Prummel, W 1977 'Collecting, sieving, and archaeozoological research'. *Journal of Archaeological Science* **4**:171-175.

Connell, B, Davis, S J M, & Locker, A 1997 *Animal bones from Camber Castle, East Sussex, 1963-1983*. AML report 107/97.

Davis, S J M 1992 *Saxon and Medieval animal bones from Burystead and Langham Road, Northants; 1984-1987 excavations*. AML report 71/92.

Davis, S J M 1996 'Measurements of a group of adult female Shetland sheep skeletons from a single flock: a baseline for zooarchaeologists'. *Journal of Archaeological Science* **23**, 593-612.

Davis, S J M 1997 'The agricultural revolution in England: some zoo-archaeological evidence'. *Anthropozoologica* **25-26**, 413-428.

Dobney, K, Jaques, S D, & Irving, B G 1995 *Of butchers and breeds: report on vertebrate remains from various sites in the city of Lincoln*. Lincoln Archaeological Studies 5.

von den Driesch, A 1975 'Die Bewertung pathologisch-anatomischer Veränderungen an vor- und frühgeschichtlichen Tierknochen'. *in* Clason, A (ed) *Archaeozoological studies*, pp. 413-425. Amsterdam: Elsevier.

von den Driesch, A 1976 *A guide to the measurement of animal bones from archaeological sites*. Peabody Museum Bulletin 1. Cambridge, Mass.: Harvard University.

Garlick, N L 1954 The teeth of the ox in clinical diagnosis. III. Developmental abnormalities and general pathology. *American Journal of Veterinary Research* **15**, 500-508.

Goodall, I H 1993 'Leather-working'. *in* Margeson, S Norwich Households: the medieval and post-medieval finds from Norwich Survey Excavations 1971-1978'. *East Anglian Archaeology* **58**, 189-190.

Grant, A 1982 'The use of tooth wear as a guide to the age of domestic ungulates', *in* Wilson, B, Grigson, C, & Payne, S (eds) *Ageing and sexing animal bones from archaeological sites*, 91-108. Oxford: BAR British Series 109.

Grant, A 1988 'Animal resources', *in* Astill, G & Grant, A (eds) *The countryside of medieval England*, pp. 149-261. Oxford: Blackwell.

Habermehl, K-H 1975 *Die Altersbestimmung bei Haus- und Labortieren.* 2nd edition. Berlin: Paul Parey.

Hammond, P W 1993 *Food and feast in medieval England.* Phoenix Mill, Gloucestershire: Sutton.

Harcourt, R 1974 'The dog in prehistoric and early historic Britain'. *Journal of Archaeological Science* **1**, 151-175.

Jones, A K G & Scott, S A 1985 'The fish bones', *in* Atkin, M, Carter, A & Evans, D H Excavations in Norwich 1971-1978. Part II. *East Anglian Archaeology* **26,** 223-228.

Jones, G 1994 'Mammal and bird bone', *in* Ayers, B S Excavations at Fishergate, Norwich, 1985. *East Anglian Archaeology* **68**, 37-42

Kerridge, E 1967 *The agricultural revolution*. London: Allen and Unwin.

Kerridge, E 1988 *Trade and banking in early modern England*. Manchester: University Press.

Kiesewalter, L 1888 *Skettmessungen an Pferden als Beitrag zu theoretischen Grundlage der Beurteilungslehre des Pferdes*. Dissertation, Leipzig.

Lever, C 1994 *Naturalized animals: the ecology of successfully introduced species*. London: Poyser.

Luff, R 1993 *Animal bones from excavations in Colchester, 1971-1985*. Colchester: Colchester Archaeological Report 12.

Locker, A 1987 'The fish remains', *in* Ayers, B Excavations at St. Martin-at-Palace Plain, Norwich, 1881. *East Anglian Archaeology* **37**, 114-117.

Locker, A 1994 'Fish Bones', *in* Ayers, B Excavations at Fishergate, Norwich, 1985. *East Anglian Archaeology* **68**, 42-44.

Locker, A 1997 *The Saxon, Medieval, and Post-Medieval fish bones from excavations at castle Mall, Norwich, Norfolk*. AML Report 85.

MacDonald, K C 1992 'The domestic chicken (Gallus gallus) in sub-Saharan Africa: a background to its introduction and its osteological differentiation from indigenous fowls (Numidinae and *Francolinus* sp.)'. *Journal of Archaeological Science* **19**, 303-318.

MacGregor, A 1985 *Bone, antler, ivory, and horn. The technology of skeletal materials since the Roman period*. London: Croom Helm.

MacGregor, A 1989 'Bone, antler and horn industries in the urban context', *in* Serjeantson, D & Waldron, T (eds) *Diet and crafts in towns*, pp. 107-129. Oxford: BAR British Series199.

Maltby, M 1979 *The animal bones from Exeter 1971-1975*. Exeter Archaeological Reports 2. Sheffield.

Manaseryan, M H, Dobney, K & Ervynck, A 1999 ‘On the causes of perforations in archaeological domestic cattle skulls: new evidence’. *International Journal of Osteoarchaeology* **9**, 74-75.

O’Connor, T 1988 *Bones from the General Accident site, Tanner Row*. The Archaeology of York 15(2). London: Council for British Archaeology.

O’Connor, T 1991 ‘The animal bone’, *in* Stocker, D St. Mary’s Guildhall, Lincoln. *The Archaeology of Lincoln* **12**, 88-96.

O’Connor, T 1995 ‘Size increase in post-medieval English sheep: the osteological evidence’. *Archaeofauna* **4**, 81-91.

Overton, M & Campbell, B 1992 ‘Norfolk livestock farming 1250-1740: a comparative study of manorial accounts and probate inventories’. *Journal of Historical Geography* **18**, 377-396.

Payne, S 1972 ‘Partial recovery and sample bias: the results from some sieving experiments’, *in* Higgs, E.S. (ed.) *Papers in economic prehistory*, pp. 49-64. Cambridge: Cambridge University Press.

Payne, S 1985 ‘Morphological distinctions between the mandibular teeth of young sheep, *Ovis*, and goats, *Capra*’. *Journal of Archaeological Science* **12,** 139-147.

Payne, S 1992 *Some notes on sampling and sieving for animal bones*. Ancient Monuments Laboratory Reports 55/92. London: English Heritage.

Payne, S & Bull, G 1988 ‘Components of variation in measurements of pig bones and teeth, and the use of measurements to distinguish wild from domestic pig remains’. *Archaeozoologia* **2,** 27-65.

Prilloff, R-J 2000 *Tierknochen aus dem mittelalterlichen Konstanz*. Stuttgart: Theiss.

Prummel, W 1978 ‘Animal bones from the tannery pits of ‘s-Hertogenbosch’. *Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek* **28**, 399-422.

Rackham, O 1986 *The history of the countryside*. London: Dent & Sons.

Salzman, L F 1913 *English industries of the middle ages*. London: Constable.

Serjeantson, D 1989 ‘Animal remains and the tanning trade’, *in* Serjeantson, D & Waldron, T (eds) *Diet and crafts in town: the evidence of animal remains from the Roman to the Post-Medieval periods*, pp. 129-146. Oxford: BAR British Series 199.

Snow, D W & Perrins, C M 1998 *The birds of the Western Palearctic*. Oxford: Oxford University Press.

Thirsk, J 1985 Agricultural innovations and their difussion, in Thirsk J (ed) *The agrarian history of England and Wales V 1640-1750. II Agrarian change*. Cambridge: Cambridge University Press., 533-589.

Uerpmann, H-P 1973 ‘Animal bone finds and economic archaeology: a critical study of “osteoarchaeological method”’. *World Archaeology* **4**, 307-332.

Uerpmann, H-P & Uerpmann, M 1994 ‘Maultiere in der römischen Armee zur Zeit der Eroberungsfeldzuge in Germanien’, *in* Kokabi, M & Wahl, J (eds) *Beiträge zur Archäozoologie und Prähistorischen Anthropologie*, pp. 353-357. Stuttgart: Konrad Theiss.

Weinstock, J 1997 ‘The relationship between body size and environment: the case of Late Pleistocene reindeer (Rangifer tarandus)’. *Archaeofauna* **6**, 123-35.

Weinstock, J 2000 *Late Pleistocene reindeer populations in Middle and Western Europe. An osteometrical study of Rangifer tarandus*. Tübingen: Mo Vince Verlag.

van Wijngaarden-Bakker L. (1994) Mittelalterliche Rinderhornzapfen aus Leiden. In: Kokabi M & Wahl J. (eds) Beiträge zur Archäozoologie und Prähistorischen Anthropologie. Stuttgart: Konrad Theiss Verlag.

Williams, N J 1988 *The maritime trade of the East Anglian ports 1550-1590*. Oxford: Clarendon Press.

Table 1: Relative abundance of burnt, gnawed, and butchered bones in different periods. Percentages are calculated from Number of fragments (identified+unidentified) in each period (for the calculation of gnawing and butchery frequencies, loose teeth were excluded).

modifications	Period 1-3	4	5	6	7	8	9
burnt	1%	0%	2%	5%	2%	3%	1%
gnawed	6%	8%	6%	5%	5%	6%	7%
butchery	16%	19%	22%	20%	23%	25%	13%

Table 2: Relative abundance of burnt, gnawed, and butchered bones in main domestic species. Percentages are calculated from NISP in each period (for the calculation of gnawing and butchery loose teeth were excluded).

Species	modification		
	burnt	gnawed	butchery
cattle	1.1%	5.0%	25.8%
sheep, sheep/goat	3.8%	13.2%	16.9%
pig	1.68%	15.5%	17.2%

Table 3: Relative abundance of burnt, gnawed, and butchered bones in different contexts.

modification	pit 114	pit 117	pit 123	pit 137	pit 343	pit 362	pit 376	other contexts (total)
burnt	4.2%	0%	11.8%	4.21%	17.8%	1.9%	35.7%	1.9%
gnawed	4.2%	3.7%	5.4%	7.8%	7.1%	4.9%	0%	5.5%
butchery	8.4%	27.5%	23.2%	18.7%	23.2%	19.6%	28.5%	21.8%
NISP in context	71	109	185	166	56	102	14	2542

Table 4: Relative abundance of bones with butchery marks in vertebrae and ribs. The overwhelming majority of 'Unidentified large' belongs undoubtedly to cattle; 'medium size' are mostly sheep and pig.

	% with butchery marks	
	unidentified large	unidentified medium
cervical vertebrae	72%	72.2%
thoracic vertebrae	51%	50.0%
lumbar vertebrae	57%	69%
ribs	23%	7%

*Table 5: Abundance of the different taxa by period. * includes 6 vertebrae and 2 ribs, from a single individual (vertebrae and ribs were generally not identified to species); 2 pelvis fragments, a femur, and 3 metatarsals may also belong to the same animal. + includes the sum of sheep/goat, sheep, and goat.*

SPECIES	Period							
	1+2+3	4	5	6	7	8	9	Total
DOMESTIC MAMMALS								
cattle (*Bos*)	63	61	116	526	374	161	84	1385
sheep/goat^{+} (*Ovis*/*Capra*)	24	21	35	201	153	96	45	575
sheep (*Ovis*)	*4*	*8*	*12*	*76*	*38*	*29*	*15*	
goat (*Capra*)	-	-	-	*1*	-	-	-	
pig (*Sus*)	29	5	15	73	49	37	18	226
horse (*Equus caballus*)	2	1	5	4	2	3	-	17
dog* (*Canis familiaris*)	-	19	1	2	4	1	2	29
cat (*Felis catus*)	2	-	-	3	5	-	-	10
WILD MAMMALS								
mole (*Talpa europea*)	-	-	-	-	-	1	-	1
rabbit (*Oryctolagus cuniculus*)	-	1	-	1	8	10	1	21
fox (*Vulpes vulpes*)	-	-	-	-	-	3	-	3
fallow deer (*Dama dama*)	-	-	1	-	-	5	-	6
BIRDS								
chicken (*Gallus gallus*)	-	2	5	7	6	8	-	28
goose (*Anser*)	-	3	3	6	6	2	1	21
duck (*Anas*)	1	-	4	1	-	2	-	8
pigeon (*Columba* cf. *livia*)	-	-	-	1	-	-	-	1
raven (*Corvus corax*)	-	-	-	-	1	-	-	1
birds indet.	-	1	2	3	6	2	-	14
FISH								
cod (*Gadus morhua*)			1	3	8	2		14
ling (*Molva molva*)			1	1				2
large Gadid (Gadidae)	1		6	8	1	2	2	20
flatfish indet.		1		1			1	3
roach (*Rutilus rutilus*)							4	4
Total identified	122	115	195	841	623	335	158	2389
unidentified	126	39	188	482	408	248	94	1585

Table 6: Skeletal element distribution of cattle by period.

					Period					
skeletal element	1	3	1-3	4	5	6	7	8	9	Total
horn core	2	3	2	7	8	31	28	6	1	88
skull+horn core	2	-	-	10	26	111	65	18	7	239
skull	3	9	2	8	25	145	70	34	20	316
mandible	1	6	2	3	12	51	48	18	12	153
maxillar tooth	-	-	-	2	1	16	8	4	2	33
mandibular tooth	-	2	1	-	1	12	12	4	7	39
max or mand tooth	-	-	-	-	0	-	-	1	-	1
hyoid	-	-	-	1	0	6	-	2	-	9
atlas	-	-	-	-	3	1	2	3	3	12
axis	-	-	-	-	0	1	-	2	1	4
sternum	-	-	-	-	0	-	1	-	-	1
scapula	-	1	2	-	5	19	8	13	6	54
humerus	-	1	-	5	2	4	15	6	2	35
radius	-	2	1	3	2	12	11	4	1	36
radius+ulna	-	1	-	-	0	-	2	1	-	4
ulna	1	-	-	2	2	5	3	1	2	16
metacarpal	-	-	-	2	0	1	-	-	-	3
carpal	-	-	-	-	0	4	3	1	1	9
pelvis	-	1	-	-	5	17	15	11	2	51
femur	1	-	-	-	2	10	16	9	1	39
tibia	1	4	3	4	8	20	15	4	5	64
calcaneus	-	-	-	3	2	5	5	2	2	19
astragalus	-	1	1	1	1	5	5	3	1	18
tarsal	-	-	-	-	0	2	2	-	-	4
metatarsal	-	3	2	5	3	21	7	5	3	49
metapodial indet.	-	1	-	-	0	3	4	2	1	11
phalanx 1 a/p	-	-	-	-	1	1	2	1	2	7
phalanx 1 ant	-	-	-	2	0	2	6	-	-	10
phalanx 1 pos	-	-	-	2	2	3	6	1	-	14
phalanx 2 a/p	-	-	-	-	1	-	3	-	1	5
phalanx 2 ant	-	-	-	-	0	2	2	2	-	6
phalanx 2 pos	-	-	1	-	1	7	1	-	1	11
phalanx 3 a/p	-	-	-	1	2	9	7	3	-	22
sacrum	-	-	-	-	1	-	2	-	-	3
Total	11	35	17	61	116	526	374	161	84	1385

Table 7: Ageing of cattle mandibles (age classes after O'Connor, 1988, but other 'ageable' specimens included as well; see 'Methods').

age class				Period					
	1-3	3	4	5	6	7	8	9	Total
juvenile	-	-	-	3	3	4	4	1	15
O'Connor juvenile	-	-	-	3	2	2	2	-	9
O'Connor subadult	-	-	-	-	-	1	1	-	2
subadult	-	-	-	-	5	-	-	-	5
adult	1	-	-	-	2	-	-	-	3
O'Connor adult	-	1	1	-	8	2	1	1	14
O'Connor elderly	-	1	-	-	-	1	-	-	2
Total	1	2	1	6	20	10	8	2	50

Table 8: Epiphysial fusion in cattle in periods 6 and 7 (p= proximal; d= distal). Isolated epiphyses included.

Element	Period 6			Period 7		
	fused	fusing	unfused	fused	fusing	unfused
scapula	0	0	2	1	0	0
pelvis	2	0	0	5	0	0
phalanx 1	6	0	0	12	1	0
phalanx 2	9	0	0	4	1	1
humerus d	2	0	0	4	1	2
radius p	4	1	0	4	0	0
metacarpus	0	0	0	0	0	0
metatarsus	2	0	3	1	0	1
metap. indet.	0	0	2	0	0	2
tibia d	2	2	3	2	0	3
calcaneum	0	0	3	1	0	3
femur d	0	0	4	3	1	3
femur p	0	0	2	1	0	6
radius d	0	0	2	1	0	3
humerus p	0	0	1	1	0	2
tibia p	1	2	3	2	0	2
ulna p	0	0	1	0	0	0

Table 9: Percentage of fused epiphyses of cattle in each of three 'epiphyses classes' (age of fusion after Habermehl, 1975). In the determination of percentages fusing epiphyses were considered as unfused.

age of fusion	% fused	
	period 6	period 7
early-fusing (up to c. 12 months)	88	83
mid-fusing fusing (2-2.5 yrs.)	29	33
late-fusing (3.5-4 yrs.)	5	31

Table 10: Ageing of horn cores (age classes after Armitage 1982). The 'transitional' stages (e.g. 2-3, 4-5) include specimens which could not be referred unambiguously to one of the stages.

Age stage	N
1+2	32
2-3	26
3+4	107
4-5	19
5+6	50

Table 11: Frequency of butchery marks in different skeletal elements of cattle.

Skeletal element	N with butchery marks	total N	% with butchery marks
horn core	7	89	7.9
skull+horn core	69	254	27.2
skull	25	324	7.7
mandible	58	163	35.6
hyoid	1	9	11.1
atlas	11	14	78.6
axis	4	5	80.0
sternum	0	1	0.0
scapula	37	61	60.7
humerus	19	40	47.5
radius	21	41	51.2
radius+ulna	2	4	50.0
ulna	6	19	31.6
metacarpal	3	3	100.0
pelvis	43	54	79.6
femur	28	41	68.3
tibia	20	66	30.3
calcaneus	9	19	47.4
astragalus	17	18	94.4
carpal	1	9	11.1
tarsal	2	4	50.0
metatarsal	13	53	24.5
phalanx 1	0	32	0.0
phalanx 2 a/p	2	13	15.4
phalanx 3 a/p	0	31	0.0
sacrum	4	4	100.0

Table 12: Tooth wear in cattle mandibles and loose teeth at Heigham St. (wear stages after Grant, 1982).

ID	period	dp4	P4	M1	M2	M3
2555	3.2			m	l	
2580	3.2					g
2583	3.2				m	k
2581	4		g	l	k	k
2596	5.2	b				
2533	6		b			
2549	6		h	n	m	l/m
2550	6		f	k	j	
2574	6					b
2575	6					e
2576	6				g	b
2577	6					d
2579	6					c
2582	6			k	g	e
2594	6	c		V		
2595	6	c				
2548	7				m	
2553	7			j		d
2584	7			j	f	E
2587	7				j	g
2593	7			V		
2600	7	d				
2551	8			k	h	c
2585	8			k		
2592	8		f	j		
2598	8	c				
2552	9					c
2590	9					E
loose teeth						
2815	3.1					j
2837	6		a			
2842	6	b				
2813	7					b
2814	7					h
2816	8					m
2818	8					g

Table 13: Skeletal element distribution of sheep by period.

skeletal element	Period									
	1	3	1-3	4	5	6	7	8	9	Total
skull	-	-	-	2	1	3	3	5	1	15
mandible	-	-	-	-	2	2	1	1	1	7
maxillar tooth	-	-	-	-	-	-	-	-	-	0
mandibular tooth	-	-	-	-	-	-	-	-	-	0
hyoid	-	-	-	-	-	-	-	-	-	0
atlas	-	-	-	-	-	-	-	-	-	0
axis	-	-	-	-	-	-	-	-	-	0
scapula	-	-	-	-	1	2	8	2	-	13
humerus	-	-	-	-	-	3	2	6	2	13
radius	-	-	1	1	1	5	3	2	2	15
ulna	1	-	1	-	-	1	-	-	-	3
metacarpal	-	-	-	2	2	25	6	3	3	41
carpal	-	-	-	-	-	-	-	-	-	0
pelvis	-	-	-	-	2	1	3	2	-	8
femur	-	1	-	-	1	1	2	-	1	6
tibia	-	-	-	-	-	4	4	2	-	10
calcaneus	-	-	-	-	-	-	1	2	-	3
astragalus	-	-	-	-	-	1	-	1	-	2
tarsal	-	-	-	-	-	-	-	-	-	0
metatarsal	-	-	-	2	-	26	4	3	4	39
phalanx 1 a/p	-	-	-	1	2	2	1	-	1	7
phalanx 2 a/p	-	-	-	-	-	-	-	-	-	0
phalanx 3 a/p	-	-	-	-	-	-	-	-	-	0
sacrum	-	-	-	-	-	-	-	-	-	0
Total	1	1	2	8	12	76	38	29	15	182

Table 14: Skeletal element distribution of sheep/goat by period.

skeletal element	Period									
	1	3	1-3	4	5	6	7	8	9	Total
skull	-	-	2	2	2	20	23	14	3	66
mandible	-	-	-	-	4	38	24	13	4	83
maxillar tooth	-	-	-	-	-	2	3	3	1	9
mandibular tooth	-	2	-	2	-	6	2	7	4	23
hyoid	-	-	-	-	-	4	2	1	-	7
atlas	-	-	-	1	2	1	-	1	-	5
axis	-	-	-	-	-	1	2	1	-	4
scapula	-	-	-	-	1	7	4	2	2	16
humerus	-	1	-	-	-	-	1	-	1	3
radius	1	2	1	1	4	3	7	3	1	23
ulna	-	-	1	-	-	3	2	3	-	9
metacarpal	-	-	-	2	-	7	3	1	1	14
carpal	-	-	-	-	-	-	-	-	-	0
pelvis	2	1	1	4	3	5	15	8	1	40
femur	2	-	1	-	1	9	12	4	4	33
tibia	1	1	-	1	1	13	10	5	5	37
calcaneus	-	-	-	-	-	-	-	-	-	0
astragalus	-	-	-	-	-	-	-	-	-	0
tarsal	-	-	-	-	-	-	-	-	-	0
metatarsal	1	-	-	-	-	3	4	1	2	11
phalanx 1 a/p	-	-	-	-	-	2	-	-	-	2
phalanx 2 a/p	-	-	-	-	-	-	-	-	-	0
phalanx 3 a/p	-	-	-	-	-	1	1	-	-	2
sacrum	-	-	-	-	1	-	-	-	1	2
Total	7	7	6	13	19	125	115	67	30	389

Table 15: Number of closed, fusing, and open epiphyses in sheep (p= proximal; d= distal). Isolated epiphyses included.

	period 6			period 7			period 8		
skeletal element	N fused	N fusing	N unfused	N fused	N fusing	N unfused	N fused	N fusing	N unfused
scapula	2	0	0	6	0	0	3	0	0
pelvis	5	0	0	7	0	0	3	0	1
phalanx 1	3	0	1	1	0	0	0	0	0
phalanx 2	0	0	0	0	0	0	0	0	0
humerus d	3	0	0	2	0	0	5	0	1
radius p	3	0	0	3	0	0	3	0	0
total up to *c.* 12 months	16	0	1	19	0	0	14	0	2
metacarpus	17	0	0	0	0	0	1	0	1
metatarsus	14	0	0	2	0	0	1	0	0
tibia d	0	1	1	4	0	1	1	0	0
calcaneum	0	0	0	1	0	0	2	0	0
total *c.* 24 months	31	1	1	7	0	1	5	0	1
femur d	1	0	2	0	2	1	0	0	1
femur p	1	0	1	0	0	0	0	0	2
radius d	1	0	3	1	0	1	4	0	0
humerus p	0	0	0	0	0	0	0	0	1
tibia p	0	1	1	0	1	0	0	1	0
ulna p	1	0	0	0	0	1	1	0	0
total *c.* 36-42 months	4	1	7	1	3	3	5	1	4

Table 16: Percentage of fused epiphyses of sheep in each of three 'epiphyses classes' (age of fusion after Habermehl, 1975). In the determination of percentages fusing epiphyses were considered as unfused.

% epiphyses fused	period 6	period 7	period 8
early-fusing (up to *c.* 12 months)	94	100	87.5
mid-fusing (18-24 months)	93	88	83.3
late-fusing (36-42 months)	33	14	50

Table 17: Ageing of sheep mandibles by period (age classes after O'Connor 1988, but other ageable specimens included as well; see 'Methods').

age class			period			
	5	6	7	8	9	Total
juvenile	-	-	-	1	-	1
O'Connor juvenile	-	-	1	-	-	1
O'Connor immature	1	1	-	1	1	4
O'Connor subadult	1	1	-	-	-	2
adult	1	-	1	1	-	4
O'Connor adult	2	19	9	5	2	38
O'Connor elderly	-	1	-	-	-	2
Total	5	22	11	8	3	53

Table18: Tooth wear in sheep mandibles at Heigham St. (wear stages after Grant, 1982).

ID	period	dp4	P4	M1	M2	M3
2973	3					h
2972	4					b
2848	5.1		h	h	g	g
2854	5.1	g		c		
2869	5.1	n		g	d	C
2911	5.1		j	m		
2915	5.1				g	g
2845	6	k		h	g	V
2846	6			j	h	f
2849	6			l	h	g
2850	6			l	h	g
2851	6		g	g	g	d
2852	6		h	k	h	g
2855	6		g	m	g	g
2858	6			h	g	b
2860	6		j	m	h	g
2864	6		j	k	g	g
2866	6	g		d	C	
2868	6			m	h	g
2873	6		e	g	g	c
2874	6			h	g	f
2875	6			g	f	b
2876	6		g	h	g	g
2877	6			h	g	f
2905	6		f	g	g	c
2910	6				j	g
2916	6				g	g
2918	6					f
2919	6			g	e	
2921	6					g
2925	6		g	g		
2934	6		j			g
2937	6					j
2938	6		g	h	g	
2940	6					g
2853	7		j	m	l	j
2856	7			g	g	e
2857	7			g	f	b
2862	7		h	k	g	g
2863	7		j	l	h	g
2867	7	f		E		
2871	7		j	l	h	g
2872	7			g	f	b
2904	7				j	g
2908	7		j	m	h	
2917	7				f	
2923	7		h	k		
2927	7					d
2942	7				g	g
2970	7					g
2859	8		e	g	g	b
2861	8			m	j	g
2865	8			m	k	g
2907	8		f	g	f	c
2914	8		g			
2924	8			g	g	g
2931	8	g		g	V	
2967	8					c
2969	8					e
2971	8					c
2847	9	g		e	V	

ID	period	dp4	P4	M1	M2	M3
2870	9		e/f	g	f	d
2909	9				g	c
2966	9					g
2968	9					g

Table 19: Frequency of butchery marks in different skeletal elements of sheep.

Skeletal element	N butchery marks	Total N	% with butchery marks
skull	22	85	25.9
mandible	16	94	17.0
atlas	4	5	80.0
axis	4	5	80.0
hyoid	0	7	0.0
scapula	4	29	13.8
humerus	0	16	0.0
radius	6	39	15.4
ulna	1	12	8.3
pelvis	28	50	56.0
femur	1	42	2.4
tibia	12	57	21.1
calcaneus	1	5	20.0
astragalus	0	4	0.0
metacarpal	0	58	0.0
metatarsal	1	50	2.0
phalanx 1 a/p	0	9	0.0
phalanx 3 a/p	0	2	0.0
sacrum	2	2	100.0
Total	102	571	17.9

Table 20: Skeletal element distribution of pig by period.

skeletal element	Period										
	1	2	3	1-3	4	5	6	7	8	9	Total
skull	-	-	-	1	1	2	9	9	5	-	27
mandible	-	-	-	-	-	2	12	7	5	2	28
maxillar tooth	-	-	-	-	-	-	-	1	1	-	2
mandibular tooth	-	-	-	-	-	1	2	4	2	1	10
max or mand tooth	-	-	-	-	-	-	1	-	-	-	1
hyoid	-	-	-	-	-	-	-	-	-	-	-
atlas	-	-	-	-	-	1	1	-	-	-	2
axis	-	-	-	-	-	-	-	-	-	-	-
scapula	-	-	1	-	1	2	6	3	2	1	16
humerus	4	-	1	-	1	3	2	5	4	-	20
radius	4	-	-	-	-	-	3	1	1	1	10
ulna	3	-	1	-	1	-	5	4	1	2	17
carpal	-	-	-	-	-	-	1	-	-	-	1
metacarpal 2	-	-	-	-	-	-	-	-	-	-	-
metacarpal 3	1	-	-	-	-	-	4	-	1	-	6
metacarpal 4	-	-	-	-	-	-	3	-	2	-	5
pelvis	1	-	1	-	1	1	2	1	1	2	10
femur	1	-	-	-	-	1	7	6	2	4	21
tibia	-	1	-	1	-	1	4	2	4	1	14
fibula	-	-	-	-	-	-	1	-	-	1	2
calcaneus	-	-	-	-	-	1	-	2	1	-	4
astragalus	-	-	-	-	-	-	-	-	1	-	1
tarsal	-	-	-	-	-	-	-	-	-	-	-
metatarsal 2	-	-	-	-	-	-	-	-	-	-	-
metatarsal 3	1	-	-	-	-	-	-	1	-	-	2
metatarsal 4	1	-	1	-	-	-	1	1	-	1	5
metapodial periphereal	2	-	-	-	-	-	9	2	2	2	17
metapodial indet.	1	-	-	-	-	-	-	-	1	-	2
phalanx 1 a/p	1	-	-	-	-	-	-	-	-	-	1
phalanx 2 a/p	-	-	-	-	-	-	-	-	1	-	1
phalanx 3 a/p	1	-	-	-	-	-	-	-	-	-	1
sacrum	-	-	-	-	-	-	-	-	-	-	-
Total	21	1	5	2	5	15	73	49	37	18	226

Table 21: Absolute number of fused, fusing, and unfused epiphyses in pig (p= proximal; d= distal). Isolated epiphyses included.

Element	closed	fusing	open	total
scapula	2	-	3	5
pelvis	1	-	1	2
phalanx 1	-	1	-	1
phalanx 2	-	-	1	1
humerus d	7	1	2	10
radius p	7	-	-	7
metapodials 3,4	-	-	16	16
tibia d	-	-	5	5
femur d	-	-	11	11
femur p	-	-	2	2
radius d	-	-	4	4
humerus p	-	-	4	4
tibia p	-	-	2	2
ulna p	-	-	7	7

Table 22: Tooth wear in pig mandibles at Heigham St. (wear stages after Grant, 1982).

pig	period	m4	P4	M1	M2	M3
1978	6				m	f
1979	7		a	j	e	V
1980	7		a			
1982	6		a	h	d	V
1983	6		a	h	d	V
1984	6		b	j	f	E
1985	6			e	a	C
1987	6	g		a	C	
1988	7					a
1989	9	e		a		
1990	5.1	g		b		
1991	8		d			
1997	9				V	
2018	8	l				

Table 23: Frequency of butchery marks in different skeletal elements of pig.

Skeletal element	N butchery marks	Total N	% with butchery marks
skull	4	28	14
mandible	8	31	26
atlas	1	2	50
scapula	2	16	13
humerus	10	21	48
radius	2	11	18
ulna	2	17	12
pelvis	4	12	33
femur	4	21	19
tibia	2	14	14
fibula	0	2	0
calcaneus	1	4	25
astragalus	0	1	0
carpal	0	1	0
metacarpal 3	0	6	0
metacarpal 4	0	5	0
metatarsal 3	0	2	0
metatarsal 4	0	5	0
metapodial periphereal	0	17	0
metapodial indet.	0	2	0
phalanx 1 a/p	0	1	0
phalanx 2 a/p	0	1	0
phalanx 3 a/p	0	1	0

Table 24: Number of fragments of horse by skeletal element and phase.

skeletal element	Period						
	1-3	4	5	6	7	8	Total
skull				2			2
mandible		1					1
maxillar tooth				1	1	1	3
atlas						1	1
scapula						1	1
humerus			1				1
radius			1				1
astragalus			1				1
tarsal			1				1
metatarsal 3			1				1
phalanx 1 ant				1	1		2
phalanx 1 pos	1						1
phalanx 2 pos	1						1
Total	2	1	5	4	2	3	17

Table 25: Number of fragments of dog by skeletal element and phase.

skeletal element	Period						
	4	5	6	7	8	9	partial skeleton Context 179 (Period 4)
skull	-	-	-	1	-	-	-
mandible	-	-	-	2	-	-	-
maxillar tooth	-	-	-	1	-	-	-
mandibular tooth	-	-	-	-	-	1	-
axis	-	1	-	-	-	-	-
humerus	-	-	1	-	-	-	-
radius	-	-	-	-	-	-	1
ulna	-	-	-	-	-	-	1
metacarpal 2	-	-	-	-	1	-	-
pelvis	1	-	-	-	-	-	2
femur	-	-	-	-	-	-	2
tibia	-	-	1	-	-	1	-
metatarsal 2	-	-	-	-	-	-	1
metatarsal 3	-	-	-	-	-	-	1
metatarsal 4	-	-	-	-	-	-	1
metapodial indet.	1	-	-	-	-	-	-
ribs	-	-	-	-	-	-	2
lumbar vertebra	-	-	-	-	-	-	6
Grand Total	2	1	2	4	1	2	17

Table 26: Number of fragments of rabbit by skeletal element and phase.
** Four metapodials belong to the same individual*

skeletal element	period					
	4	6	7	8	9	Total
femur	-	-	1	-	1	2
humerus	-	1	-	-	-	1
metapodials	-	-	5	5*	-	10
pelvis	-	-	1	3	-	4
radius	-	-	-	1	-	1
tibia	1	-	1	-	-	2
ulna	-	-	-	1	-	1
Total	1	1	8	10	1	21

Table 27: Number of fragments of domestic fowl by skeletal element and phase.

	phase					
Skeletal element	4	5	6	7	8	Total
coracoid	-	1	-	-	-	1
scapula	-	-	-	-	1	1
humerus	1	1	1	-	2	5
radius	-	-	1	1	1	3
ulna	-	-	-	1	1	2
pelvis	-	1	1	1	1	4
femur	-	2	2	1	1	6
tibiotarsus	-	-	1	2	-	3
tarsometatarsus	1	-	1	-	1	3
Total	2	5	7	6	8	28

Table 28: *Number of fragments of domestic fowl by age class and period.*

	phase					
age class	4	5	6	7	8	Total
adult	2	4	5	5	8	24
juvenile	-	1	2	1	-	4
Total	2	5	7	6	8	28

Table 29: *Number of fragments of domestic goose by skeletal element and phase.*

skeletal element	phase						
	4	5	6	7	8	9	Total
carpometacarpus	2	-	1	4	-	-	7
coracoid	-	1	-	-	-	-	1
femur	-	1	-	-	1	-	2
furcula	-	-	-	1	-	-	1
humerus	-	1	1	-	-	-	2
phalanx 1 ant.	-	-	-	1	-	-	1
tarsometatarsus	1	-	2	-	-	-	3
tibiotarsus	-	-	2	-	1	1	4
Total	3	3	6	6	2	1	21

Table 30: *Number of fragments of duck by skeletal element and phase.*

skeletal element	phase				
	3	5	6	8	Total
coracoid	-	1	-	-	1
femur	-	1	1	-	2
humerus	-	1	-	-	1
mandible	1	-	-	-	1
skull	-	-	-	1	1
tibiotarsus	-	1	-	1	2
Total	1	4	1	2	8

Figure 1: Location of the city of Norwich.

Figure 2: Map of medieval Norwich; the suburb of Heigham is in the northwest, outside the city walls (modified from Ayers 1994).

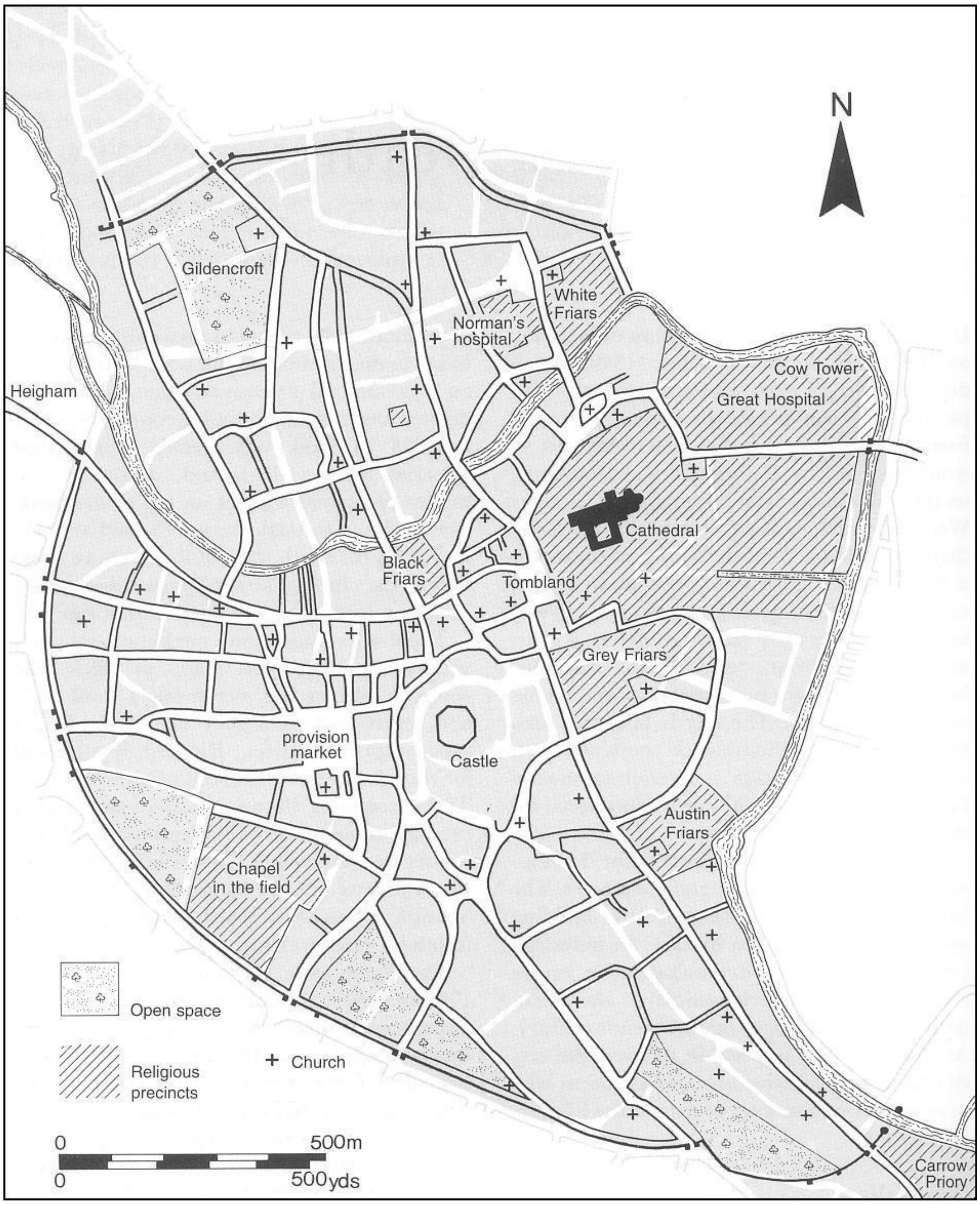


Figure 3: Relative abundance of the main domestic species (number of fragments).

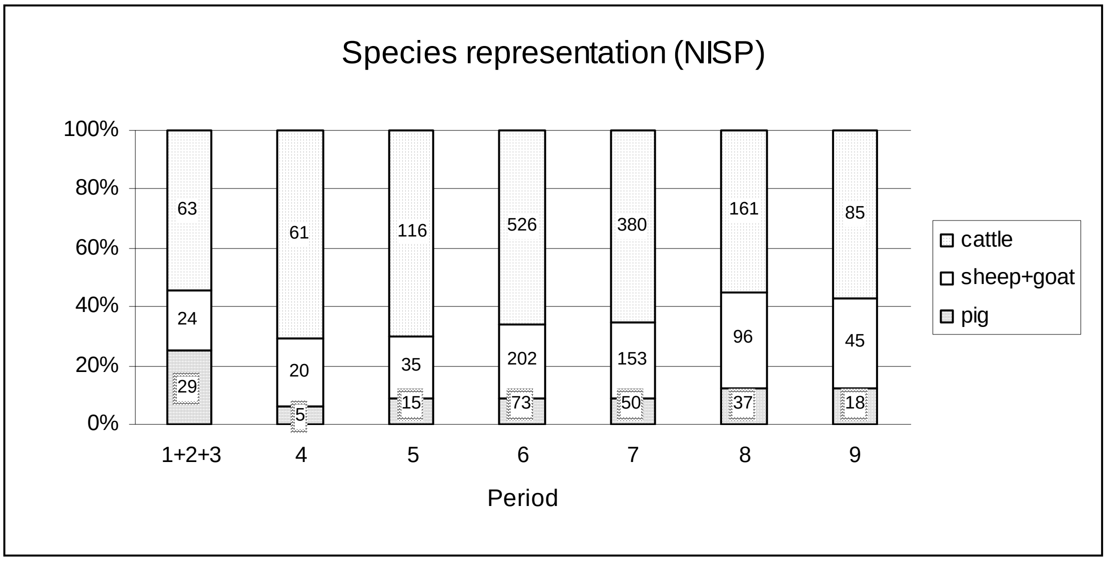


Figure 4: Relative abundance of the main domestic species (bone weight).

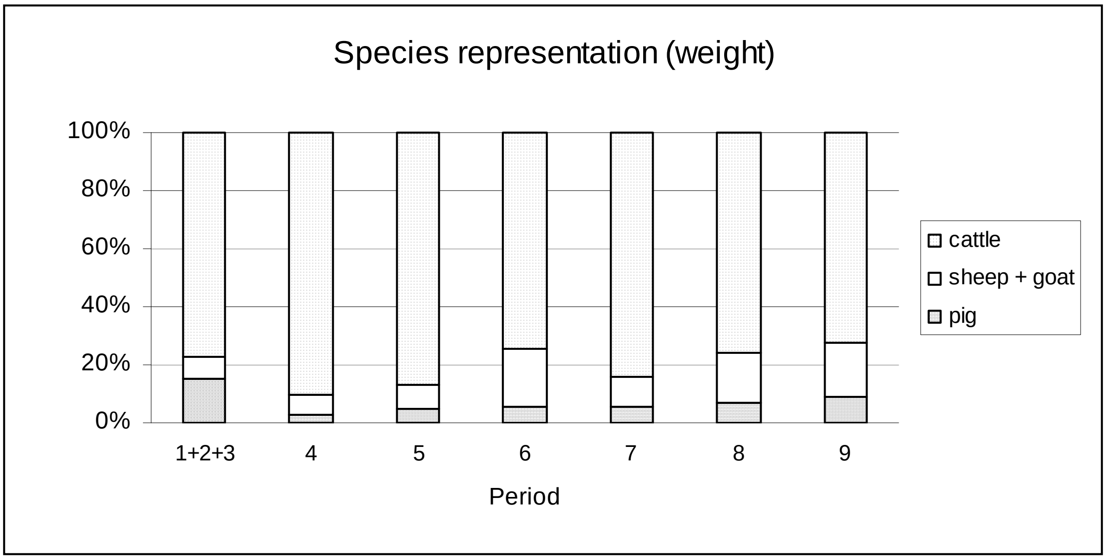
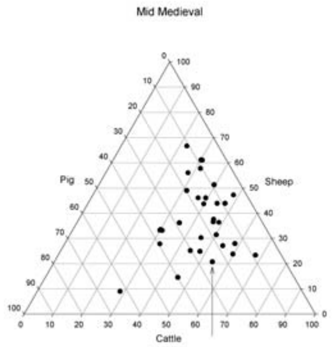
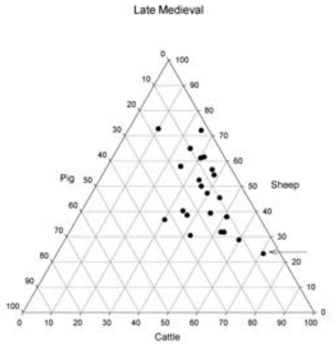


Figure 5: Relative abundance of cattle, sheep, and pig in medieval and post-medieval sites (except for Heigham St., data after Albarella & Davis, 1996).


Mid Medieval


Late Medieval

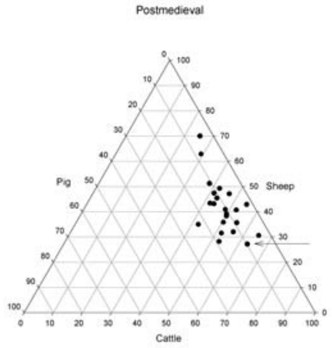

Postmedieval

Figure 6: Element representation of cattle in Heigham St. (% of number of identified cattle fragments).

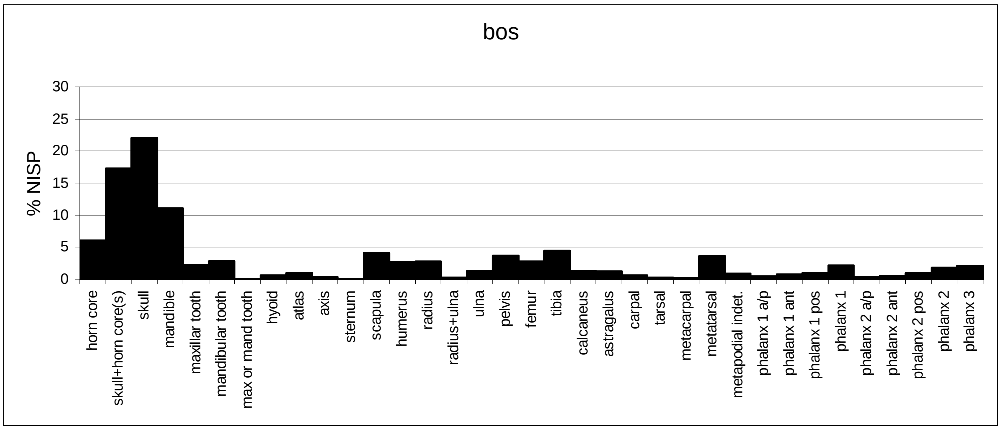


Figure 7: Element representation of cattle in Heigham St. (number of identified fragments). In this graph skull fragments without horn cores and horn core fragments with no attached skull are omitted.

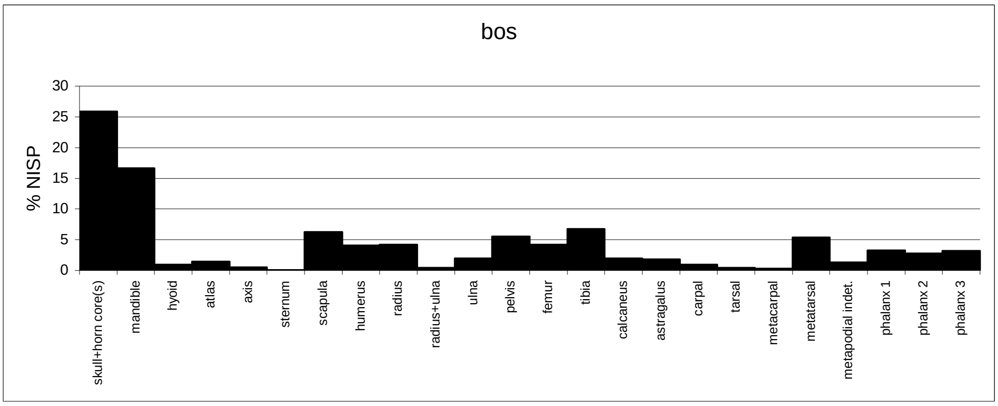


Figure 8: Skeletal representation of cattle in the different excavation areas ('tenements').

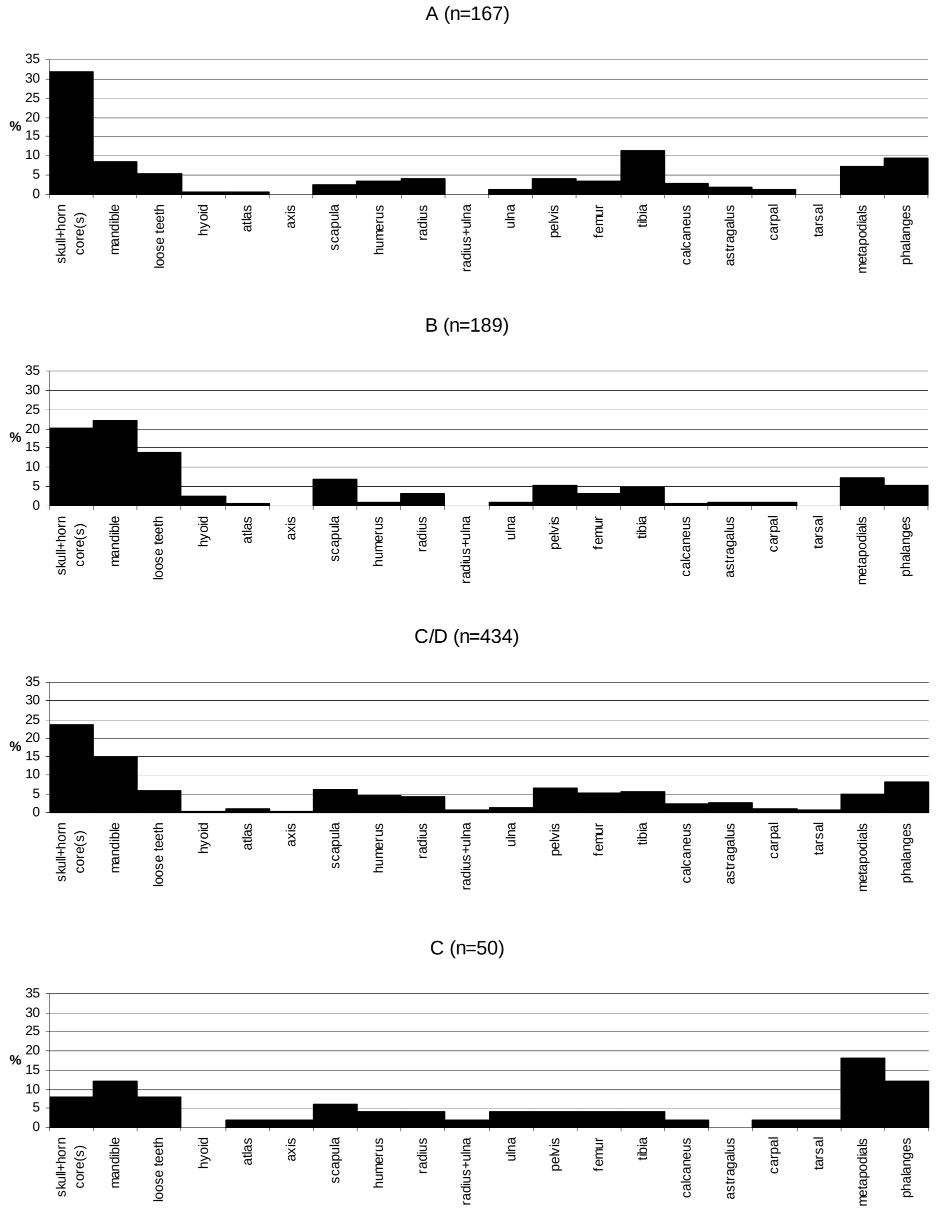
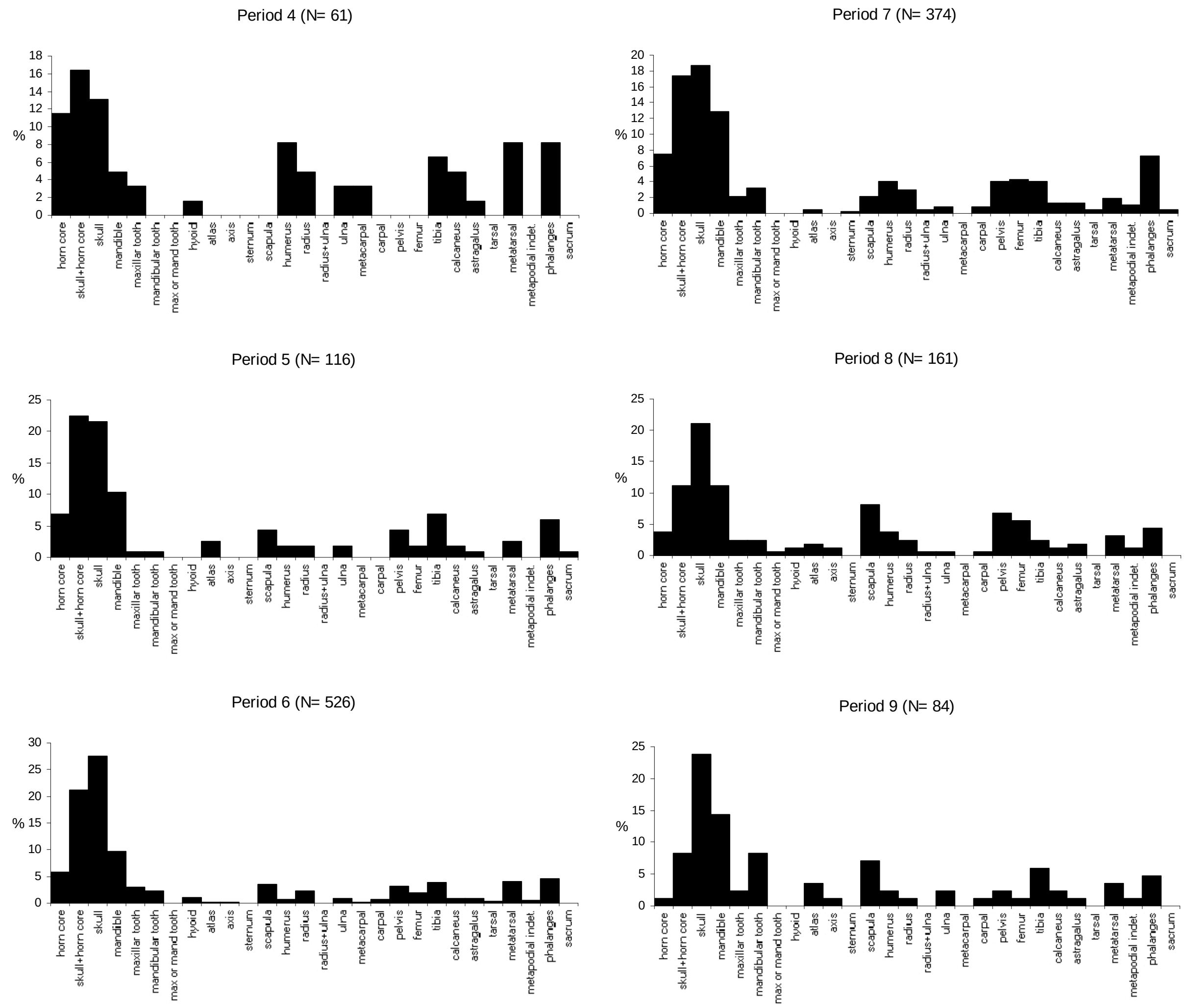


Figure 9: Skeletal representation of cattle by period.


Period 4 (N= 61)

Period 7 (N= 374)

Period 5 (N= 116)

Period 8 (N= 161)

Period 6 (N= 526)

Period 9 (N= 84)

Figure 10: Ageing of cattle mandibles from periods 6, 7, and 8 (age groups after O'Connor, 1988 but other ageable specimens included as well; see 'Methods').

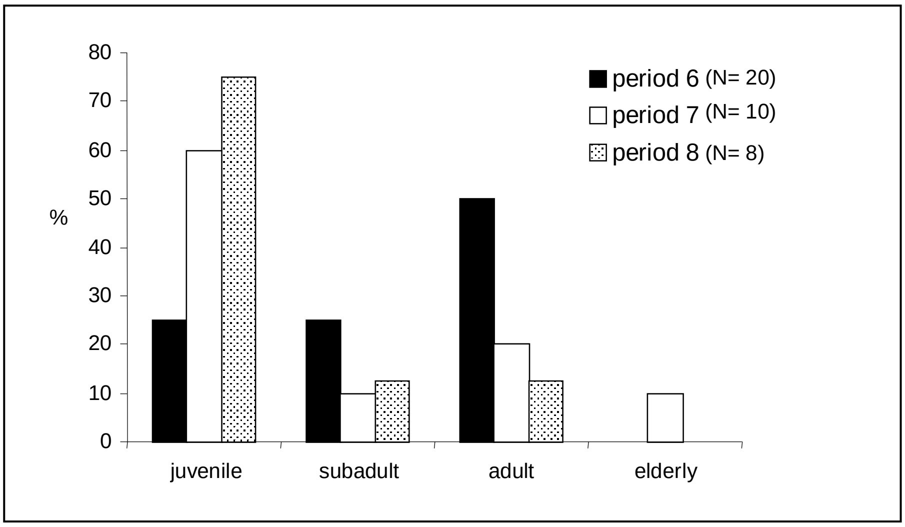


Figure 11: Ageing of cattle horn cores from periods 6 and 7 (age stages after Armitage 1982).

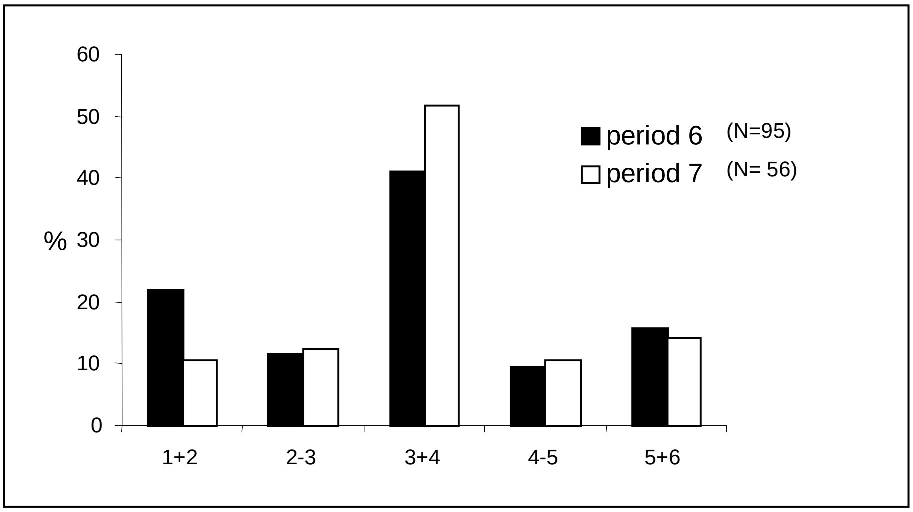


Figure 12: Cattle, phalanx I (proximal width against smallest width of shaft).

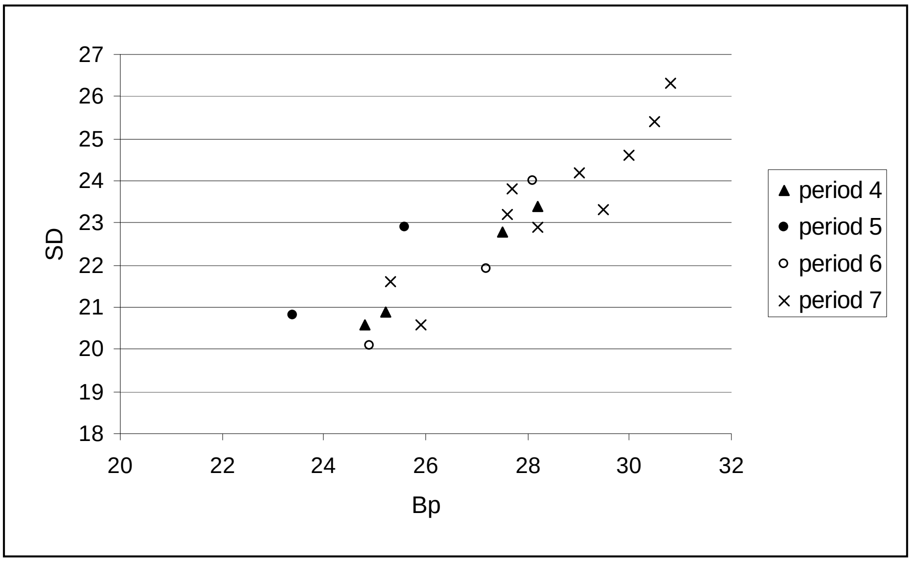


Figure 13: Cattle horn cores, major basal diameter v. minor basal diameter.

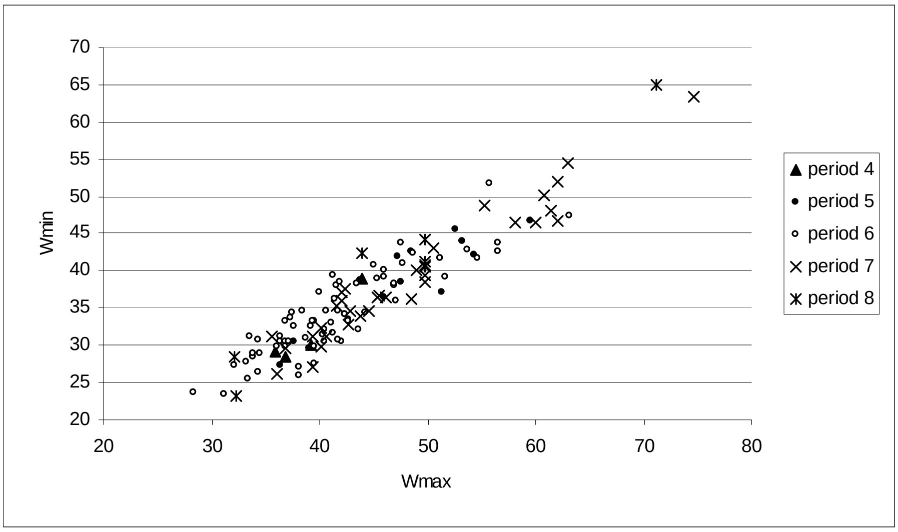


Figure 14: Shape of cattle horn cores (dorso-basal diameter/length v. oro-aboral diameter/length).

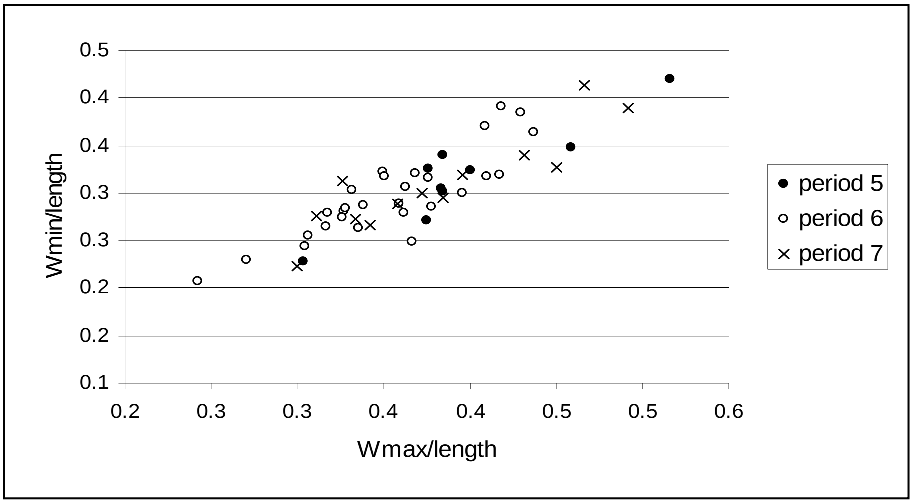


Figure 15: Skeletal representation of sheep in the different excavation areas ('tenements').

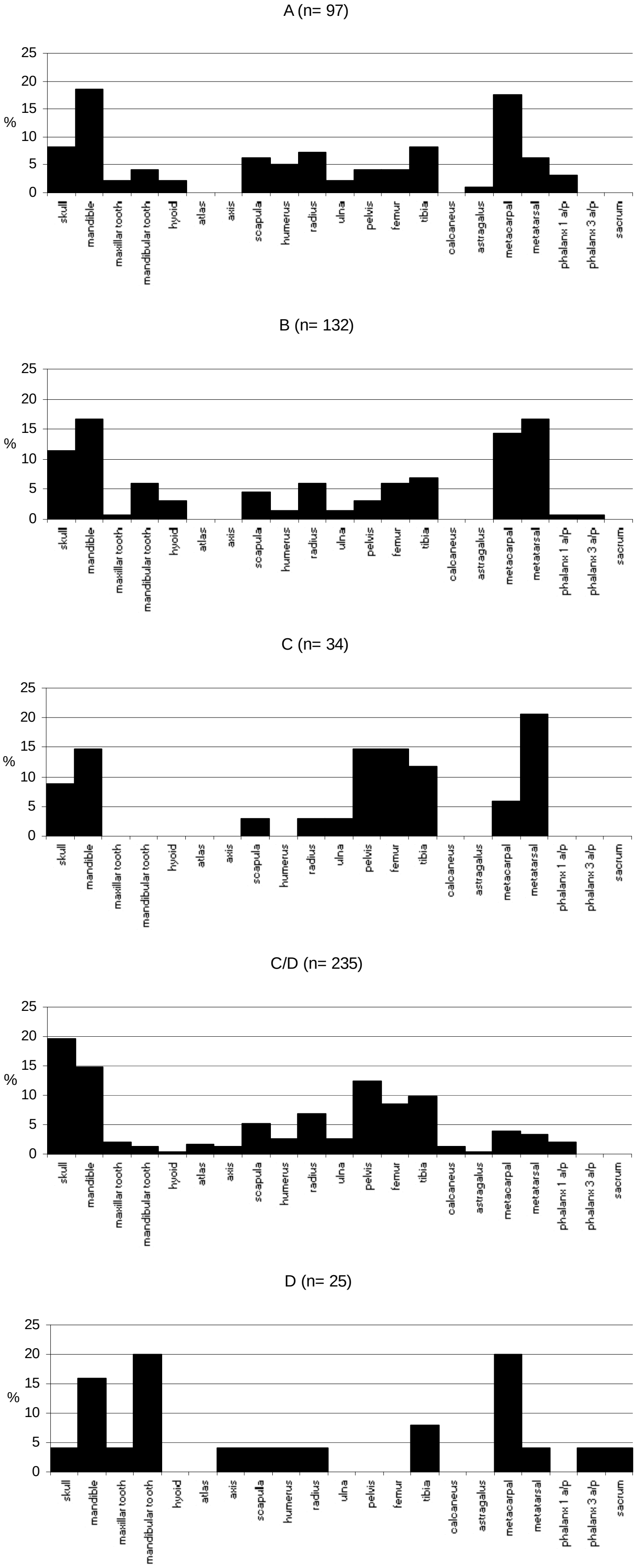
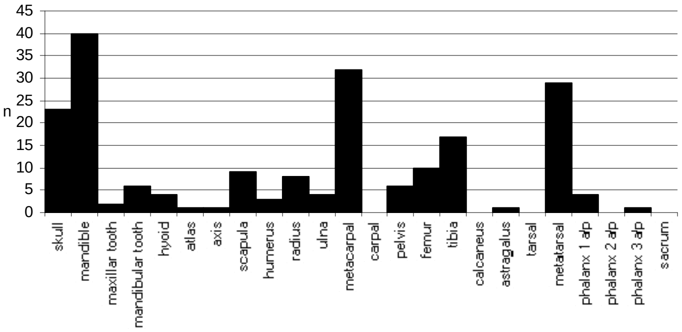
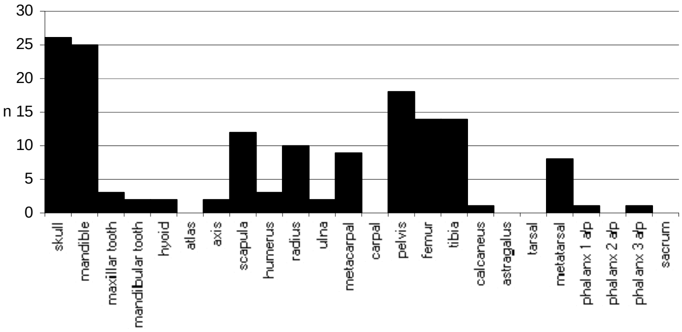


Figure 16: Skeletal representation of sheep in periods 6, 7, and 8.

Period 6 (N= 201)



Period 7 (N= 153)



Period 8 (N= 96)

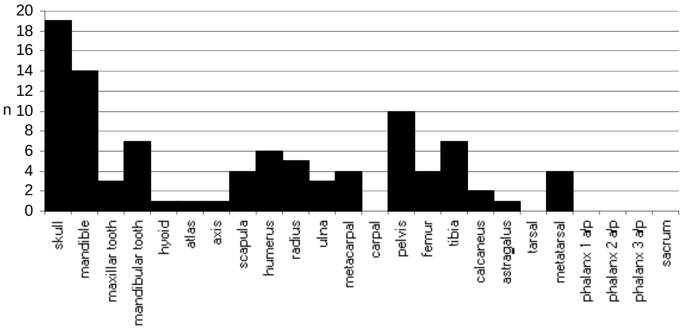


Figure 17: Ageing of sheep mandibles in periods 6, 7, and 8 (age groups after O'Connor, 1988 but other ageable specimens included as well; see 'Methods').

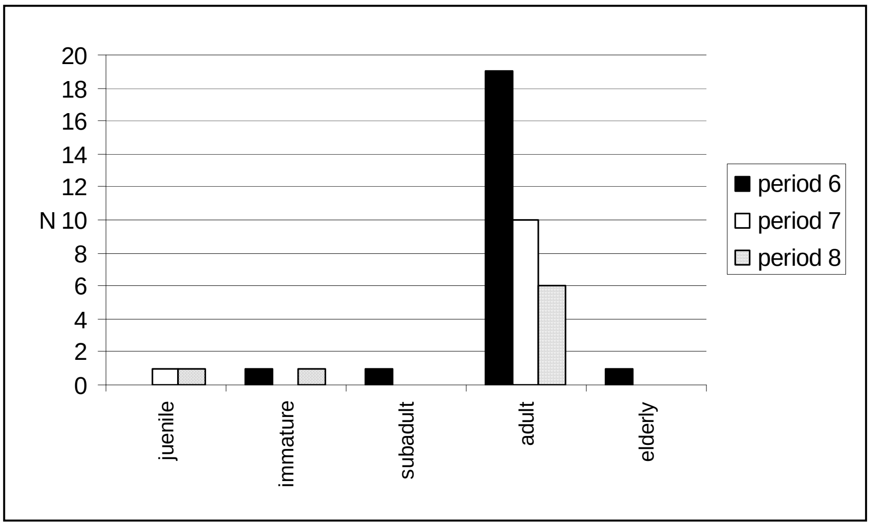


Figure 18: Wear stages of the M_3 in sheep mandibles for periods 6, 7, and 8 (wear stages after Grant 1982).

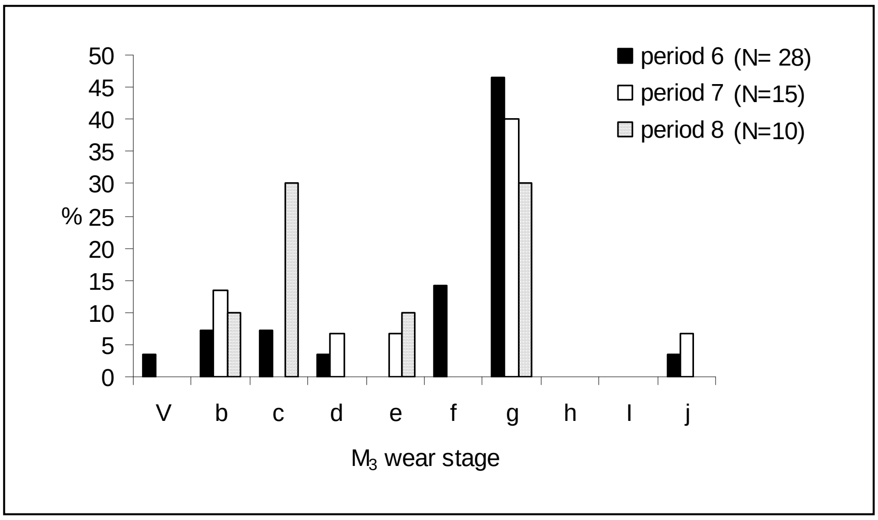


Figure 19: Variation in sheep measurements in Heigham Street. Comparison of width measurements with a standard sample (Davis, 1996), using the log ratio technique (Payne and Bull, 1988). Measurements used: Astragalus GL, femur and humerus SD, metacarpus and metatarsus Bd, radius Bp, scapula SLC, and Tibia Bd.

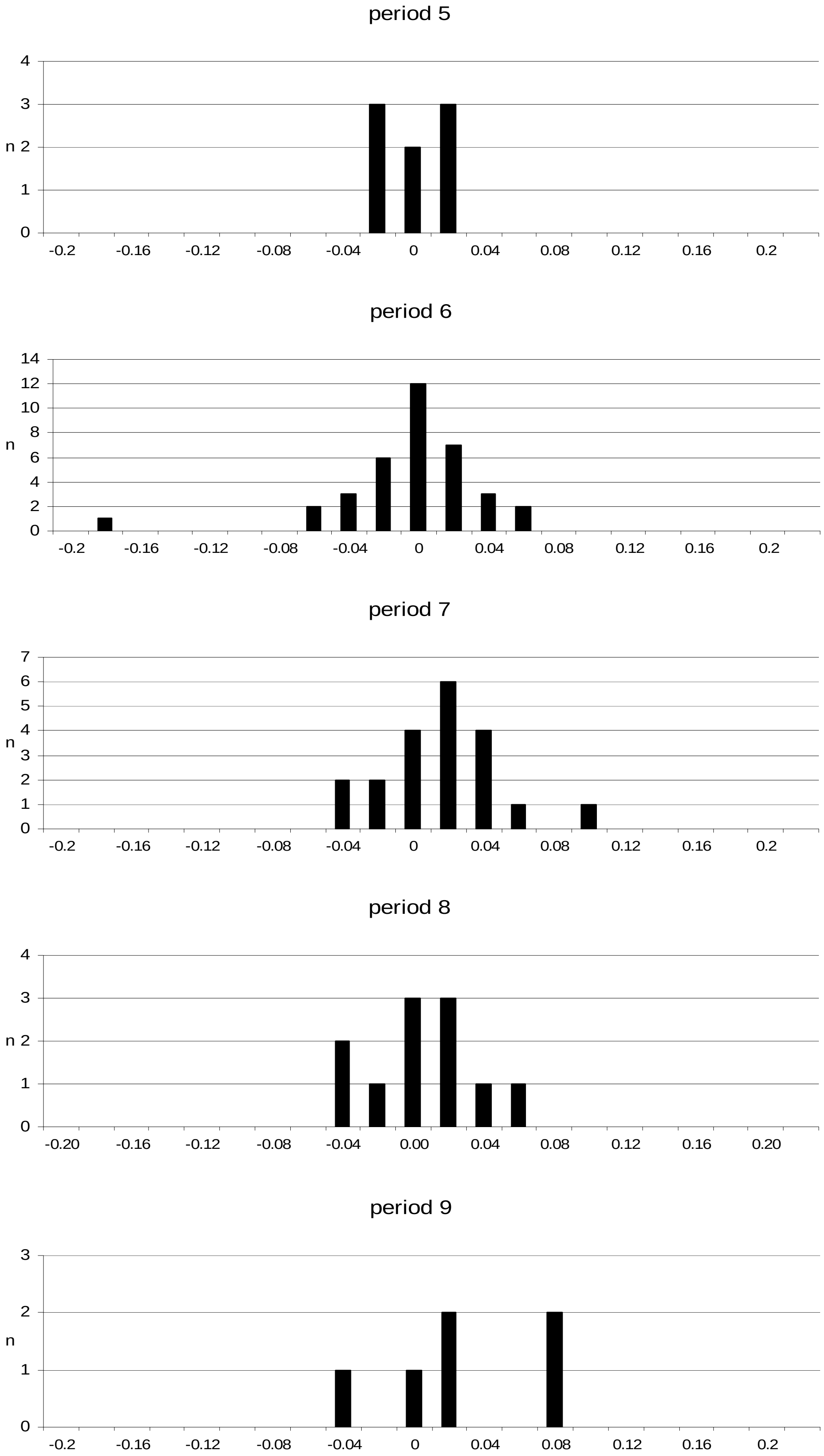
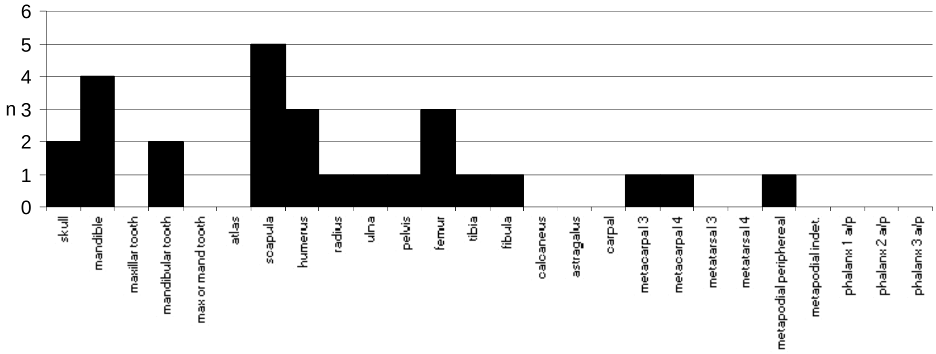
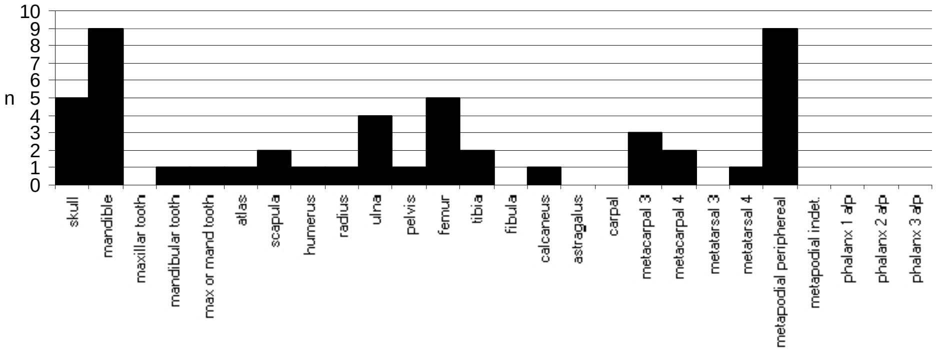


Figure 20: Skeletal representation of pig in the different excavation areas ('tenements').

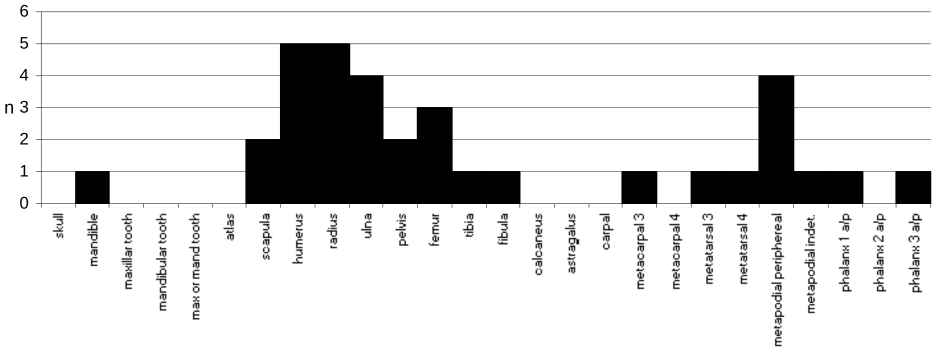
A (n= 27)



B (n= 49)



C (n= 34)



C/D (n= 86)

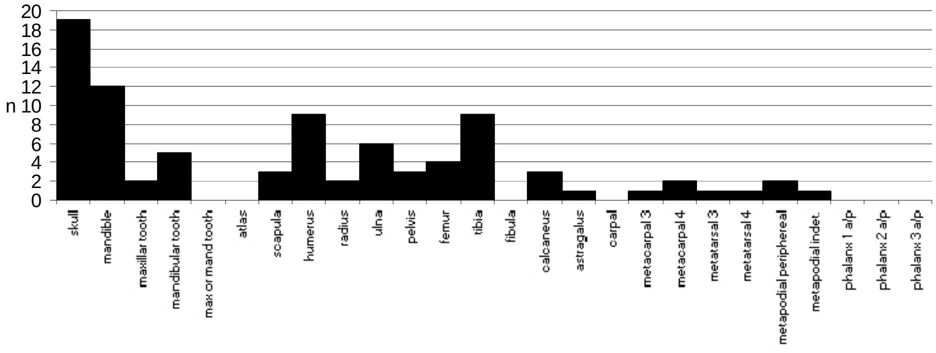


Figure 21: Ageing of pig mandibles (age groups after O'Connor, 1988 but other ageable specimens included as well; see 'Methods').

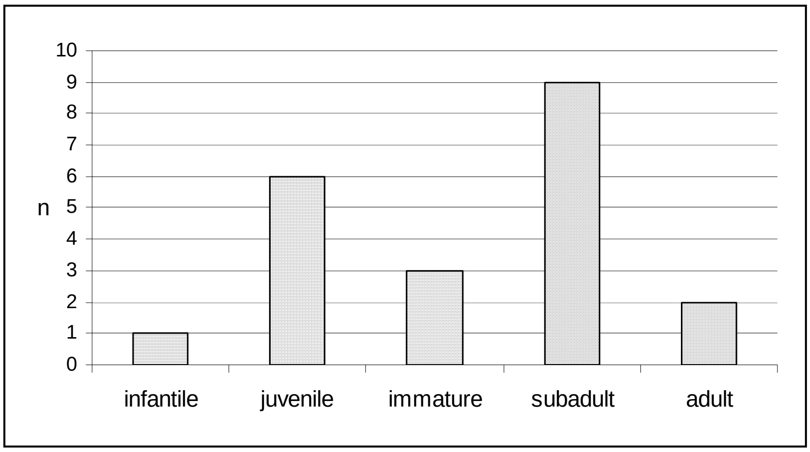


Figure 22: Variation of pig measurements in Heigham Street. Comparison between specimens from medieval and post-medieval periods (1-6 and 7-9 respectively) using log-ratio method (Bull & Payne, 1988, with standard in same reference). Measurements included: scapula GL, humeus Bd, radius Bp, ulna DPA, and astragalus Gl.

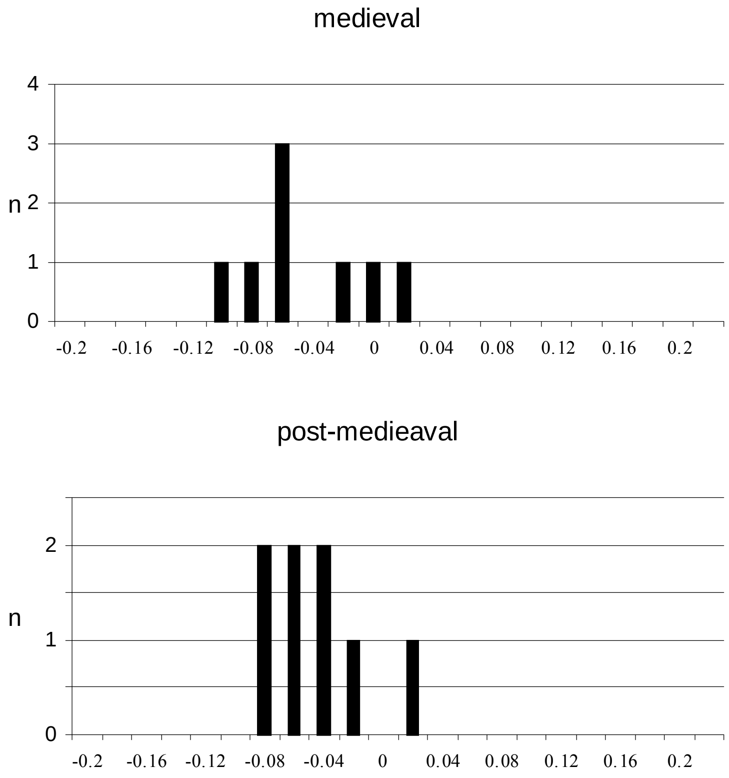


Figure 23: Skeletal representation of horse.

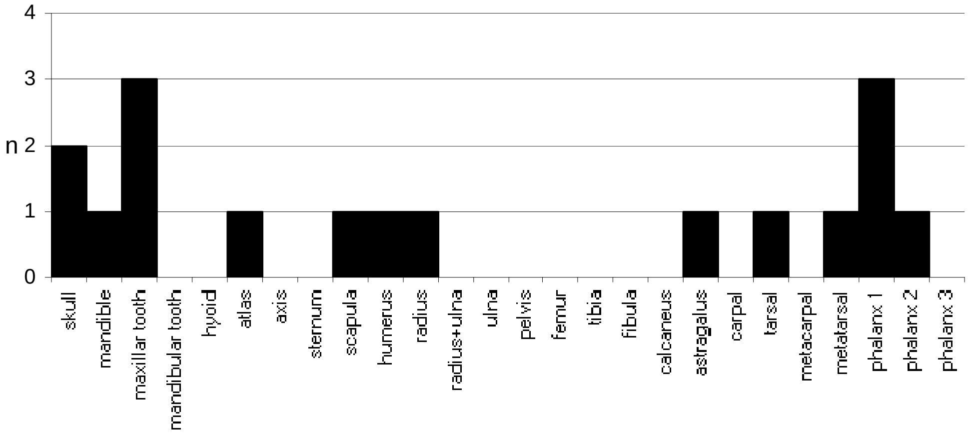


Figure 24: Skeletal representation of dog.