Reports from the Environmental Archaeology Unit, York **99/43**, 88 pp.

Insect remains as indicators of zonation of land use and activity in Roman Carlisle, England

by Harry Kenward

Summary

Systematic differences between the Roman insect fauna of four sites or groups of sites in Carlisle, Northern England, have been sought using a range of methods. The sites were: Annetwell Street; Castle Street; sites designed 'Lanes 2' (Keay's Lane A-D and Law's Lane B-D; and a final group designated 'Lanes 1' sites (Old Grapes Lane A-B and Lewthwaite's Lane A).

The cumulative impression gained by inspection at the sample assemblage level suggested a clear trend from Annetwell Street, which appears to have been a relatively clean area within the fort; through Castle Street, just outside the fort and in an area believed to have largely been devoted to servicing it, with much foul matter from stabling; to Lanes 2, which appears to have been an intensively-used essentially urban area; and then to Lanes 1, which seems to have seen substantially less intensive occupation, and perhaps had an almost rural character.

These impressions were supported in general terms by inspection and statistical analysis of derived statistics for ecological groups, both at the site level and for selected feature types. Analysis of species associations at the sites gave results requiring subtle interpretation, but again tended to underpin the broad trends inferred from analysis of sample assemblages.

Keywords: INSECTS, CARLISLE, ROMAN, ZONATION, LAND USE, ENVIRONMENT, ANNETWELL STREET, CASTLE STREET, THE LANES, OLD GRAPES LANE, LEWTHWAITE'S LANE, KEAY'S LANE, LAW'S LANE, SAMPLE STATISTICS, SPECIES ASSOCIATIONS

Author's address:

Environmental Archaeology Unit
Department of Biology
University of York
PO Box 373
York YO10 5YW
Telephone: (01904) 433848-9
Fax: (01904) 433850
Email: biol6@york.ac.uk

13 September 1999

List of Figures (separate file)

List of Tables (separate file)

Table 14. Test for significance of variation between statistics for layers at the four sites. Statistics after removal of grain pests.

Table 15. Comparison of selected main statistics (after removal of grain pests) for insect assemblages from drains and gulleys at the four sites.

Table 16. Test for significance of variation between statistics for insect assemblages from gulley and drain fills at the four sites. Statistics after removal of grain pests.

Table 17. Comparison of selected main statistics (before and after removal of G) for insect assemblages from pits at the four sites.

Table 18. Test for significance of variation between statistics for insect assemblages from pit fills at the four sites. Statistics after removal of grain pests.

Table 19. Comparison of selected main statistics (after removal of grain pests) for insect assemblages from 'floors' at Annetwell Street, Castle Street and Lanes 1.

Table 20. Test for significance of variation between statistics for insect assemblages from floors Annetwell Street, Castle Street and Lanes 1.

Table 21. The more abundant insect taxa from floors at Annetwell Street, Castle Street and Lanes 1.

Table 22. Phytophages and strongly plant-associated taxa by site.

Table 23. Records of Carabidae (ground beetles) in rank order by site.

Table 24. Ranked lists for aquatic (W) taxa by site.

Table 25. Non-synanthropic decomposers (coded 'r' but not 's'), after removal of grain pests.

Table 26. Ranked lists for foul decomposer (RF) taxa by site.

Table 27. Beetles regarded as particularly typical of stable manure communities (none are exclusive to them).

Table 28. Number of samples where 'stable manure' taxa account for 10% or more of the decomposer (RT) component, by site and feature type.

Table 29. Lanes 1. Breakdown of the synanthropic component. N - number of individuals; % - percentage of synanthropic component.

Table 30. Lanes 2. Breakdown of the synanthropic component.

Table 31. Castle Street. Breakdown of the synanthropic component.

Table 32. Annetwell Street. Breakdown of the synanthropic component.

Table 33. Summary breakdown of synanthropic component by site.

Table 34. House fauna: ranked lists by site and total number of individuals, with percentages within house component.

Table 35. Number of samples where 'house' taxa account for more than 20% of the adult beetles and bugs, by site and feature type.

Table 36. Percentages of grain pests by site.

Table 37. Significance of variations in proportions of grain pests.

Table 38. (a) Spearman's rank correlation coefficients and their significance for records of the four grain pests; (b) correlations in rank order for each site.

Table 39. Sample assemblages where N>34 and percentage of grain pests exceeds 50%.

Table 40. Phytophages and other strongly plant-associated taxa (P) in layers, by site.

Table 41. List of taxa used in the species association analyses, their abbreviations, and number of samples where N > 34.

Table 42. Number of assemblages where N >34 and % NW (aquatics) greater than 5% and 10%, by feature type and site.

Insect remains as indicators of zonation of land use and activity in Roman Carlisle, England

Introduction

Over a period of more than fifteen years, insect remains from a series of sites in Carlisle have been analysed in order to reconstruct ecological conditions and human activity. These analyses have focussed on the implications of the insect assemblages at the context, feature and site level. Most of the assemblages were of early Roman date, forming a corpus with significant potential for comparison between sites. Subjectively, they indicated considerable contrasts, the sites appearing to range from fully urbanised (Annetwell Street) to essentially rural ('Lanes 1': Old Grapes Lane and Lewthwaite's Lane), a trend which corresponded reasonably well with the other archaeological evidence. The project reported here was initiated as an adjunct to a study of insect assemblages from sites in Keay's and Law's Lanes ('Lanes 2') in order to attempt to arrive at a more objective understanding of these apparent variations (Brooks *et al.* 1996).

The project was designed to test the hypothesis that there would be a detectable gradient in the insect remains from the fortress (Annetwell Street) to rural fringes (Lanes 1), which reflected aspects of site function and environment. Attention was particularly focussed on a series of questions:

1. Can differences in human activity between the sites be deduced?

2. Can variations in ecological conditions (and thus human living or working conditions) be determined?

3. Can the vegetation - if any - of the sites be reconstructed from insects, bearing in mind the probability that most of the plant remains represent imported material and are thus of limited value in this respect?

4. Can domestic occupation (including military living quarters) be detected at any of the sites?

5. Can stabling be differentiated from (a) close-corralling (e.g. overnight) and (b) the keeping of stock in larger paddocks (probably with supplementary feed)?

The extent to which these were appropriate questions, at least phrased as above, came to be doubted during the execution of the analyses (see below).

This technical report represents an extensive account on which a publication text will be founded, and a large proportion of the derived data used in analysis have been included in a long series of tables. The species lists appear within the site reports for Annetwell Street and The Lanes (references are given below). The data archive given in the original report for the former is in an outdated format, and many codes and ecological groups have ben revised, so a new version has been produced to accompany the present *Technical Report* (Kenward 1999).

It may be noted at this point that for ease of reading 'horse' is used to mean 'equine' throughout this text, but that it is very likely that mules or donkeys were present, and probably in different proportions at the various sites.

The sites

The sites have been divided into four groups, reflecting their location (Figure 1) and the results of archaeological investigation. The groups are as follows (Table 2):

1. Within the fort, a single site, Annetwell Street. A complex of road surfaces, ditches, and buildings, often clearly of industrial use, and the East gate tower, were revealed. Numerous samples were analysed, most of them from external surfaces, floors, pits and ditches.

2. Just outside the fort, and in an area believed to have largely been devoted to servicing it, again a single site, Castle Street. A variety of structures was discovered, mostly of rather crude nature, and there were extensive deposits laid down in the open, in some cases apparently in enclosures. Most of the samples represented floors and external layers, and there were a few from pits.

3. Sites designated 'Lanes 2': Keay's Lane A-D and Law's Lane B-D. This area seems to have seen fairly intensive occupation in the phases for which insect fossils were preserved, but not to have had the range of functions or employed the variety of raw materials seen at Castle Street. Substantial structures were recorded (McCarthy *et al.* 1982), but most of the sampled material was from ditches, pits and open surfaces.

4. The 'Lanes 1' sites: Old Grapes Lane A-B and Lewthwaite's Lane A. Substantially less intensive occupation in phases providing insect assemblages, and perhaps with an almost rural character. Timber buildings were present, however (McCarthy *et al.* 1982). The samples mostly came from surface layers, with rather small numbers from pits and ditches, and very few from deposits associated with buildings.

Methods

Samples of archaeological deposits were collected by the Carlisle Archaeological Unit during excavations in 1979-84. These samples were stored in a dry warehouse for well over a decade in some cases (the Lanes sites), and were often completely dehydrated. While there was no clear evidence that this had caused serious damage to insect fossils, there may have been some reddening, and delicate remains such as those of lice may have been lost. Insects and a range of other invertebrates were extracted from subsamples of the sediment by sieving and paraffin flotation (Kenward *et al.* 1980), and identified by comparison with modern reference material and with reference to the standard works. Beetles (Coleoptera), bugs (Hemiptera), fleas (Siphonaptera) and lice (Mallophaga and Siphunculata) were identified closely, but it was impractical to make a detailed study of most other groups. Mites, Hymenoptera and puparia of Diptera were the most abundant of these other remains; a proportion of the last were named by the late Professor J. Phipps and by F. Large. Recording for Annetwell Street conformed fairly closely to 'detailed recording' as defined by Kenward (1992); material from the remaining sites was nominally 'scan recorded', although difficult identifications were often pursued further than normal using that technique in order to increase information about natural-habitats species. Lists were entered to computer storage, and now reside in a Paradox database at the EAU.

Differential ecology and land use at the sites was investigated as follows:

1. By detailed inspection of the species lists context-by context and site-by site. This had been carried out in the initial site-based projects, and the results are summarised here.

2. By examining various summary statistics for the assemblages of adult beetles and bugs from the sites, (a) at the site level and (b) broken down by feature type. These statistics represent ecological categories and are those regularly employed by the author during routine analysis; they are listed and briefly defined in Table 1. A short outline of the way

they are employed is given in the context of the Lanes 2 sites by Kenward *et al.* (1998). Some supplementary categories (e.g. 'house fauna', 'non-synanthropic decomposers' and ground beetles) have also been examined. Differences in the proportions of the main ecological categories across the sites, and by feature type, have been tested statistically using chi square; expected values were calculated from the totals for the combined sites or totals for all assemblages from each feature type as appropriate, and the tests were based on values for the statistic under review and for the sum of all other categories.

3. By more detailed examination of the structure and distribution of species within certain of these ecological categories (e.g. the plant feeders, grain pests, house fauna, and species associated with foul matter).

4. By analysis of the distribution of various species.

5. By examining species associations amongst selected beetles (and a few other insects) at the various sites. The taxa included are listed in Table 41. A Paradox procedure written by John Carrott (EAU) was used to produce tables of numbers of individuals per sample for selected taxa, chosen because they were frequently-occurring or suspected to have an important role in communities at a range of sites (some were rare at Carlisle and had to be excluded for some sites). Data for sample assemblages with less than 35 adult beetles and bugs were not included. The data were manipulated in Excel and exported as percentages to SPSS for calculation of correlation coefficients between all combinations of pairs of species. Because the distributions of numbers within taxa were extremely skewed and difficult to normalise, rendering them unsuitable for analysis using a parametric measure, correlation was measured using Spearman's rank correlation coefficient, a non-parametric function. This inevitably reduced the resolution of the results. The resulting correlation matrix was used to plot 'constellation diagrams' by hand for each site, using $p<0.05$ and $p<0.01$ levels derived from the SPSS output. These diagrams were based on taxa with ten or more records in the selected dataset (although it was observed that, surprisingly, even where there was only one or a few records of a taxon, it usually showed strong correlations with 'ecologically appropriate' taxa). In order better to understand organisation withing the constellation diagrams, an attempt was made to identify groups of taxa with multiple internal linkages, but rather fewer external ones. The most successful approach was to add taxa to groups only if they were linked to two taxa already placed in the group *and* which were themselves linked together, forming a triangle ('three-way linkages').

For most substantial site data sets, the number of species was sufficiently large, and the distribution of numbers among them sufficiently even, to render percentages as effectively independent values. However, the grain pests, both singly and as a group, were often very abundant in the samples from the sites in Carlisle, so that their variations had a substantial effect on the percentages of other taxa. For this reason, the analyses were re-run using percentage of the total number of individuals after substraction of grain pests (percentages of grain pests were necessarily still based on total N). It was not practicable to exclude assemblages where N-NG was less than 35, but the results suggest that this was acceptable.

The constellation diagrams based on representation of significant linkages between pairs of taxa did not give very clear groupings for the data from Carlisle, but rather showed broad ecological trends across a network of connections. The trends appeared to represent gradation from more to less foul decaying matter, and from indoor to outdoor depositional environments.

6. By the use of two multivariate statistical methods: cluster analysis and

multidimensional scaling, applied to main statistics and to records of species. In each case the whole data set or subsets of it, selected by feature type, were used. For analyses based on species records, the taxa employed in species association analysis were used, since (a) the software employed could not handle large numbers of taxa (b) previous experience has shown that records of rare taxa, often recorded by chance rather than as a result of real ecological differences in depositional environments, are merely a source of confusion ('noise') in such analyses, and (c) these taxa accounted for a large proportion of the adult beetles and bugs recorded from most samples.

Results for (3) and (4) are mentioned where appropriate in the text, but the remainder of the analyses are considered in separate sections.

For the purpose of analysis, the contexts for which insect analyses have been carried out have been divided into a series of categories:

1. Well-represented context types

(a) Layers: These are deposits interpreted as having formed in the open. They certainly include both build-ups and dumps, the latter representing both waste disposal and make-up.

(b) Pit fills: The fills of cuts interpreted as pits, or probably pits, together with some fills of small cuts of less certain nature. The fills, it should be noted, clearly included both primary waste and backfill layers, but it has not been practical to distinguish between these, not least since they appear to merge. A few pit fills were from cuts within buildings, and these have not been distinguished in the bulk of the analyses, partly because of the difficulty of being sure that they were contemporaneous with the associated floors, or whether they may have represented disuse.

(c) Drain, ditch and gulley fills: Fills of linear cuts, usually clearly intended for drainage but in some cases less obviously so. These fills were almost always clearly backfills, often of surface deposits. Some lay within the outlines of buildings; as for pits they have not been distinguished in view of the uncertainty in determining whether they lay within a functioning building.

(d) Floors: Deposits formed within buildings, including both made floors and the litter and trample accumulated on them.

2. Other context types represented in small numbers

(a) Dumps: Thick deposits interpreted as resulting from disposal of waste material or spoil, often for the purpose of levelling. Some such layers are probably included in the 'layer' category, above.

(b) Old ground surfaces (OGS): Layers interpreted as representing surfaces which were stable enough for the development of vegetation.

(c) Structural contexts: Contexts closely associated with buildings, such as beam-slots.

(d) Turves: Material appearing in the field to represent the remains of stacked turves (sods).

(e) Well fills: Fills of deep cuts interpreted as having been water sources; none appear to represent use phases, but rather backfill dumps of waste material or surface deposits.

Other context types: These included a range of deposits described as 'construction', 'demolition', hearths, 'post trenches', 'animal burrows'.

Data analysis has been carried out using Paradox 7, Excel 97 and SPSS for Windows release 7.0.

Results

The numbers of insect assemblages examined and, as a guide to the quality of the material, the numbers including 20 or more adult beetles and bugs, are presented by site and feature type in Table 2. The number of assemblages examined, and the total number of individuals, are both sufficiently large for comparison between the sites. Some individual contexts types are sufficiently well represented in terms of both numbers of samples and numbers of recovered insects for meaningful comparison at that level. However, for others there is uneven representation among the samples, or few insects were recovered, and comparison requires caution or is inappropriate.

The main statistics for the assemblages of adult beetles and bugs (excluding Aphidoidea and Coccidoidea) are given, again by site and by feature type, in Tables 3-6, and in re-worked form, after subtraction of the abundant grain pests, in Tables 7-10.

Note that, in these tables, the staphylinid *Anotylus nitidulus* has been restricted to the 'RT' category (that including all species associated with decaying matter). It has previously (although with reservations) been included in the 'D' (waterside/damp ground) category as well as 'RT'. This change reflects its now irrefutable occurrence in urban rotting matter of various kinds in the past. Modern records suggest this beetle to be typical of waterside and fenland litter in Britain, and the species is certainly not at all common in northern England (the writer having failed to find it in more than two decades, for example). However, it was abundant on occupation sites in the past, both in towns, eg. in York (Kenward 1978, 44; Kenward and Hall 1995) and at some rural sites, e.g. at North Cave (Allison *et al.* 1997, where it was the most abundant decomposer species) and at Wharram Percy (Girling and Robinson 1988 AML 36/88), where it was abundant in one sample. It surely must have typically occurred in artificial accumulations of foul matter in the past. It is conceivable that two morphologically similar species with different habitat preferences exist, the wetland species having survived to the present day in Britain, the foul-matter species having been dependent on some special kind of artificial accumulations of decaying matter in the past, and having now become extinct or at least extremely rare.

Context-by context analysis

The results of the analysis of insect assemblages during the site-based projects may be summarised as follows:

Annetwell Street

The deposits revealed during excavations at Annetwell Street, in the area of the fort gate, were rather extensively sampled, and numerous analyses for insect remains carried out; sample-by sample accounts are given by Kenward and Large (1986) and Large and Kenward (1987a-c; 1988a-e), and a revised data archive is provided by Kenward (1999; the version released by Kenward (1998) contains errors and should be disregarded). The technical reports for the insect analyses carried out on samples from Annetwell Street are now very out-of-date and many of the interpretations need to be revised in the light of subsequent methodological developments. The data have been re-examined briefly to prepare the following summary, but detailed re-interpretation is not practicable. Grain pests were abundant, or dominant, in a very large proportion of the samples. In rare cases they were so numerous as to suggest direct disposal of spoiled grain rather than entry via stable manure (or scatter of such material) or the feeding of animals in the open.

Samples from the timber phase of the fort (late 1st-2nd centuries) generally gave good to excellent preservation, and insects were occasionally very numerous. More typically, however, small groups of remains with no clear character were recovered, and most probably represented background fauna or trample. Floors were generally clean, as few insects were recovered but without evidence of their loss by decay. Here and there hints of decaying matter were found, and a few floor deposits gave larger groups of insects, with indications of the accumulation of litter, rarely foul.

Surface deposits, some of them associated with roads and others formed in open areas, often gave few remains, or assemblages which were probably background fauna, conditions during their formation seeming to have been rather clean. Here and there foul matter was present, sometimes probably dumped or scattered stable manure or the litter from keeping stock close-confined in the open. Some 'demolition layers' gave rich faunas. One included abundant decomposers indicating fairly dry litter, with few grain pests - perhaps ejected stored hay or fresh stable manure. As with the floors, however, such rich accumulations of decaying matter on external surfaces seem to have been the exception at Annetwell Street.

Pitfills gave very varied faunas, often including few remains and perhaps representing backfills of surface soil; such pits may not have been dug primarily for waste disposal. A few were clearly used for disposal. One contained a fauna indicating fresh stable manure or spoiling hay, while another produced a group of decomposers likely to have occurred in rotting stable manure (although, unusually, grain pests were rare).

Fly puparia were usually present in rather small numbers, if recorded at all. There were, however, two groups of puparia of the housefly, *Musca domestica*, indicating very unpleasant matter, but not necessarily more than small patches of it.

There were six records of a bedbug, probably *Cimex lectularius*, the form attacking humans (although the identification could not be confirmed). Two of these were from the East Gate Tower. These bugs probably provide the only evidence from insects for humans living in the buildings excavated at Annetwell Street. Fleas were rare (seven records of 'Siphonaptera'), but this was probably because they were overlooked during recording. House fauna seems to have come from stores or stables when it was abundant, and living floors were probably generally kept clean.

As at Castle Street, insect preservation effectively ceased when the structures at Annetwell Street were replaced in stone. A large group of samples from deposits associated with third century buildings was examined, but no insect remains were recovered. Presumably good drainage, cleanliness and better waste disposal prevented preservation within the studied area by this stage. Overall, this site seems - not surprisingly in view of its location - to have been decidedly cleaner than the others considered here. It is likely that some classes of remains were under-recorded at this site, and that fleas and lice in particular were overlooked; comparisons of the abundance of such remains between sites is thus to be avoided.

Castle Street

This is the only one of the sites considered here to have reached full publication (McCarthy 1991a-b). The extensively-excavated site lay a short distance (50 m or less) to the SE of the fort at Annetwell Street, and thus seems likely to be dedicated to servicing it; the area is regarded as an annexe. Deposits of the Roman period which produced useful insect assemblages were dated from the late first (Period 2) through to the late second centuries (Period 8); the results are summarised by Allison *et al.* (1991a-b) and sample-by-sample accounts provided in three reports by Kenward and Morgan (1985a-c). As at Annetwell Street, the later, stone, phases of the fort were poorly represented by deposits with anoxic waterlogging. The earliest deposits, an old ground surface, were unfortunately not examined for invertebrate remains. Some pit fills formed between the early 70s and the late 70s or early 80s AD, gave assemblages suggesting the presence of stable manure, and already by this stage grain pests were important, supporting the hypothesis that they were inevitably dispersed in supplies for the army. The human flea (*Pulex irritans*) was also present at this stage (and throughout much of the Roman sequence), and the human louse (*Pediculus humanus*) was found in first century deposits.

Stable manure was suggested to be present in some layers at Castle Street in the original report, and re-examination of the data suggest that it was probably common, although clear stable manure groups including a well-developed foul matter component were unusual (Tables 27-28). Generally it seems that foul matter was cleared away before large populations of foul decomposers built up (in contrast to, for example, Tanner Row, York, Hall and Kenward 1990, and Ribchester, Lancashire, Large *et al.* 1994, although in these other cases the deposits examined were probably dumps away from occupation). An exception at Castle Street was a building of the late first century, deposits from which gave clear indications of stable manure, together with housefly (*Musca domestica*) puparia, and a *Damalinia bovis* (cattle louse), the last of which may have come from a live beast or indirectly with skins. Grain pests, now considered generally to be indicators of stable manure or horse dung rather than of grain stores at first hand, were common throughout the Roman period at the Castle Street site, and sometimes very much the most abundant beetles (Tables 36 and 39). Moulted skins (exuviae) of the bug *Craspedolepta nervosa* were found in many of the deposits; these are thought almost certainly to have come from cut grassland vegetation, presumably hay for livestock on the site. Buildings ranged from clean to quite mucky, mostly the former.

External layers at Castle Street included a thick organic-rich layer of the late first/early second century, probably a series of dumps, with foul matter insects including housefly puparia, a second, blanketing, foul dump deposit, an organic deposit in a muddy, puddled area, and a deposit of turf whose fauna and flora suggested origins in poor pasture land. Even allowing for the fact that sampling and analysis were probably biased in favour of such conditions, the external surfaces on the site do seem to have been allowed to become quite unpleasant at times, although in some cases probably in periods of re-arrangement or short-term low-grade use. A second 'turf' layer was associated with the construction of one of the early first century buildings; the identification was made on the content of dung beetles and water and waterside beetles, strongly suggesting material cut from rather damp grazing land with some pools. Pits seem not to have been the standard means of waste disposal, although one pit may have received litter from within a house.

Overall, the invertebrate remains (and of course the other biota) of the Castle Street site have contributed a rather good picture of conditions just outside the Roman fort in the first and second centuries: buildings which were generally reasonably well cleaned out, surfaces which at times became mucky, periods when organic waste was dumped during levelling, and the all-pervading influence of horses, both their fodder (grain and hay) and faeces being present in many of the deposits. (Human gut nematodes were, in strong contrast, never abundant, underlining the different (and adaptively advantageous) attitudes to herbivore and human faeces which persist in human society even today.) This site can perhaps be seen as a producer area for the sort of refuse seen in Roman deposits at Tanner Row in York (Hall and Kenward 1990).

Lanes 2

It appears that this area of the Lanes was, in the parts of the Roman period represented by the deposits examined for insect remains, very much concerned with livestock, probably mainly horses or other equines. (Unfortunately the only parasite of equines recorded was a single tentatively identified egg of the intestinal worm *Oxyuris equi* (Schrank).) There was evidence - from grain pests, house fauna, characteristic decomposers, and 'hay' fauna - of dumped stable manure from a few samples. In addition, many assemblages included a range of remains (including elements likely to have been imported in turf) which probably originated in this material. Other deposits seemed to have originated as surface accumulations in disturbed areas with scattered plants, where equine dung or scattered stable manure was present. In many cases it was not clear whether the insect assemblages represented stable manure as such, and sometimes it seemed possible that the layers included only dung deposited directly on to the ground in the open, which by chance contained fauna eaten by horses with hay or grain. Grain pests were sometimes very abundant (Table 39).

A substantial number of the assemblages had a high proportion of outdoor fauna. Some were seemingly dominated by a rather random fauna (probably much of it 'background fauna'); such assemblages were recovered from many of the cuts, perhaps representing insects from the adjacent open ground which had arrived naturally or in soil dumped from adjacent surfaces. The typical environment of the Lanes 2 sites seems to have been disturbed open ground with rare and scattered plants, with various amounts of filth - in some cases surely dung - on the surface.

Most of the samples from Lanes 2 gave few, and more often no, eggs of intestinal parasitic nematodes. Only in two cases (both pitfills) were more than traces of *Trichuris* present. In one case, it was possible to make sufficient measurements to identify these eggs as *T. trichiura*, the species found in humans. Human faeces thus do not appear to have been a significant component of the deposits.

Lanes 2 yielded abundant evidence of insect parasites of humans. About 20 subsamples of Roman date gave heads of human fleas (*Pulex irritans*) or less diagnostic body parts which were probably of that species. Human fleas are commonly found in archaeological stable manure associations, and seem to have bred in the litter on stable floors in the past. Human lice (*Pediculus humanus*) were found in two samples. Preservation probably limited recovery of the very delicate lice at Lanes 2 - many samples had dried out in storage and there were hints that insects had oxidised after excavation. However, there was a record of the pubic louse (*Pthirus pubis* (L.)) from Roman layers (and a second from medieval deposits; these remains are discussed by Kenward in press). Bearing in mind the small quantities recovered, even the remains of these more intimate parasites of humans cannot be regarded as evidence for large quantities of domestic waste, however.

Insect parasites of livestock were poorly represented at Lanes 2. There were some records of non-diagnostic remains of the genus *Damalinia*, various species of which are parasitic on particular domestic mammals, and one of the sheep ked *Melophagus ovinus*. The former may have been rare because they had been lost to the fossil record (that these lice are extremely delicate has been mentioned above), but the puparia of *M. ovinus* are very robust and unlikely to have decayed, suggesting that they were genuinely rare at the sites.

The evidence from Lanes 2 raised the possibility (suggested by records from a number of sites of Roman to post-medieval date in Britain) that aquatic insects and water fleas were brought in water, or even via dung of horses which had drunk from ponds, ditches or troughs with a fauna of beetles and cladocerans. In a few cases it seems likely that aquatics may have lived on site, in fills of gulleys and a single pit, and perhaps in pools on one surface deposit. Otherwise, most of the aquatic insects may have been background fauna. The heath/moor component appears rather likely to have originated in material used in stabling. Other possibilities are that it was imported in turf used for construction, eaten by livestock in the field, or brought in vegetation intended for fodder, animal bedding, or some other purpose.

Examined on a context-by-context basis, the insect assemblages from the Lanes 2 sites suggest characteristics somewhere between those of Castle Street and Lanes 1. Most of the fauna seems to have originated in stables or - more often - on external surfaces in yards. There is no evidence for the sort of 'field boundary' ditches seen at Old Grapes Lane. On the other hand, there were rather few highly-developed 'stable manure' assemblages.

Lanes 1

Kenward *et al.* (1992a) reported analysis of a body of samples from Old Grapes Lane A. This site gave a fascinating picture of land use on the fringes of Roman Carlisle, contrasting strongly with that from the military and civilian heart of the settlement. There was little evidence from Phase 3, dated to the earliest Roman period, although some of the deposits seem to have formed in the open. Grain pests (*Oryzaephilus surinamensis*, *Cryptolestes ferrugineus* and *Sitophilus granarius*) were already present at this stage, but the somewhat limited evidence suggests that the full range of occupation-site synanthropes had not arrived, and that they may have been substituted for by facultative forms (the latter being natural-habitats species invading opportunistically in the absence of insects better-suited to artificial habitats). Phases 4 to 6 were dated to the early Roman period. Although few samples of Phase 4 were examined, several additional synanthropic species were recorded, including *Cryptophagus scutellatus* and the human flea (*Pulex irritans*). This period also produced an assemblage which included a range of elaterid (click beetle) larvae and some adult beetles (including *Xantholinus* sp. and *Hoplia philanthus*, the latter identification confirmed since the report was produced) suggesting the possibility that turf had been incorporated. A small group of samples from 'soil deposits' of Phase 5 together suggested grazing land in which there was some open water; one sample in particular gave large numbers of the dung beetle *Aphodius prodromus*.

There were numerous samples from Phase 6, including floors, soils and ditch fills. The former group included one assemblage which suggested a stable, another which may have come from a stable which was frequently cleaned out, and a third which indicated a fairly clean, dry structure, so that there was probably some diversity of use. The ditch fills also produced varied results, indicating that the cuts were in some cases damp but not water-filled, with little dumping but something resembling a stockyard adjacent. Others appeared to have received dumps, which in one case may have included spoiled grain (containing, in addition to the commonest three grain pests, *Palorus ratzeburgi*, probably indicating fairly advanced decay of a mass of grain). Another gave some further strong synanthropes, including *Typhaea stercorea*, *Aglenus brunneus*, *Alphitobius diaperinus* and *Tenebrio obscurus*, with the grain pests, again suggesting spoiling grain from within a structure, but perhaps in this case from stable manure. One ditch appeared to have held water at least occasionally. External surfaces gave a variety of assemblages, not surprisingly, but they, together with a lens of material containing pig lice (*Haematopinus apri*), contributed to the general impression that stock-rearing was an important activity. Fills of putative post-pits indicated, both from the nature of the sediment and the biota (*Daphnia* and water beetles), that the cuts were left open and infilled slowly. The remaining Roman phases gave little evidence, although one deposit may have formed where there were grazing animals.

A large proportion of the assemblages from the Old Grapes Lane A site gave had a rich and abundant 'outdoor' fauna, often with substantial contributions from aquatic and waterside habitats, herb communities likely to occur in grassland or disturbed places, moorland/heathland, and dung. It seems likely that much of this fauna originated in areas where there was dung, in grazing land, paddocks, and perhaps byres or stables. A single *Damalinia bovis* (cattle louse) was recorded, but this cannot stand as evidence that cattle were kept in fields bounded by the ditches at the site. Other remains perhaps originated in stabling for horses, although this was by no means as clear as for some other sites; the 'stable manure' insect community was only weakly represented. Insects which may have been imported in cut, hay-like, vegetation were occasionally present, but in numbers too small to be clearly significant. Puparia of the sheep ked, *Melophagus ovinus,* were recorded, but these are not clear evidence for the keeping of their host animals at the site (they may have originated from wool or fleeces which were cleaned there). In a single case there was somewhat more substantial evidence for the keeping of pigs, in the form of the *Haematopinus apri* lice mentioned above. (A further hint that pigs were important at this site came from the eggs of nematode parasites of vertebrates. *Ascaris* (the maw-worm) was rather better represented in relation to *Trichuris* (the whip-worm) than normal in assemblages of eggs from deposits containing what is believed to be human excrement. While it is possible that this is an insignificant result of the small numbers of eggs observed, a high relative count for *Ascaris* eggs has been associated with pig faeces. Unfortunately none of the contexts with a high proportion of *Ascaris* eggs contained sufficient well-preserved *Trichuris* to allow firm identification using measurements.)

A few of the assemblages contained a 'house fauna' component of beetles believed to be typical of deposits formed within humble human dwellings and outhouses, including stables. There were a few fleas, some of them tentatively or certainly identified as the human flea, *Pulex irritans*, and at least two human lice (*Pediculus humanus*) were found. These numbers were too small to stand as definite evidence for occupation floors (or ejectamenta from them), though, and it seems as likely that these taxa originated in outhouses used to shelter animals as in houses *sensu stricto*. House fauna was certainly limited by comparison with central Carlisle sites.

Investigation of material from the nearby Old Grapes Lane B site was on a much more limited scale (Kenward *et al.* 1992b). Late first century material indicated the presence of stock, probably stable manure in view of the presence of a well developed house fauna component (including a human flea) in one of the samples. The four 'typical' grain pests (*Oryzaephilus surinamensis*, *Cryptolestes ferrugineus*, *Palorus ratzeburgi*, *Sitophilus granarius*) were already present, together with a limited range of other synanthropes. Traces of heathland or moorland taxa were recorded. Early-mid second century well fills contained several kinds of water flea resting eggs and numerous aquatic insects, suggesting that such species were able to colonise, and the fauna also probably indicated stable manure (identified on the basis of house fauna, a human flea, grain pests and decomposers favoured by foul open textured matter). There were remains of *Melophagus ovinus* (sheep ked), whose origin might lay in wool cleaning or (unusually in this case) live sheep on the site.

The third Lanes 1 site for which analysis has been completed was at Lewthwaites Lane (Kenward *et al.* 1992c). Here, a series of Roman deposits was analysed, most of them apparently surface-laid. Much of the material was of late first century date, and even at this early stage the familiar range of grain pests was present, together with a number of other synanthropes. The overall impression was of mainly open areas with some weeds, a little stable manure, dung, or scatter from stabling being present. One assemblage included grain pests and beetles suggesting rather dry, mouldy, plant debris - perhaps the driest extreme of stable manure, or straw. Peat was indicated, perhaps having been used for stable litter. Deposits dated to the late first/early second century gave rather more substantial indications of stable manure, with hay and peat. The synanthropic decomposer fauna was much better developed than in the earlier material, although this may have been a result of habitat availability rather than inability to colonise. Perhaps the most striking material from the site was a series of 'deposits' of probable early second century date. Three of these gave evidence for the importation of turf. One appeared to represent turf from a damp area by water (perhaps even occasionally flooded), since there were more water beetles than seem likely to have arrived by chance. Two others were remarkable for their rich heath/moor component. A late 2nd century pit fill gave abundant grain pests and house fauna, but only very limited indications of foul matter; such species had perhaps only had time to colonise, and not to breed before a stable was cleared out and the litter dumped in the pit.

In summary, then, the context-by-context analysis of the insect assemblages from the four sites have given a clear impression of a trend from relatively clean conditions dominated by human occupation at Annetwell Street, through rather filthy conditions at Castle Street, an intensively trampled occupation area (again probably dominated by horses) at Lanes 2, to what may have been an almost rural area, though strongly influenced by human activity and perhaps a range of livestock, at Lanes 1.

Analysis using the main statistics and overall species composition

Most of the detailed comparison presented in this report is based on the main statistics used routinely in the EAU, with the addition of some further categories (particularly 'house fauna', 'ground beetles', and 'non-synanthropic decomposers'). Clearly, inspecting data at this level masks assemblage heterogeneity, and masks variation within the records through time for each site and between sites where they are grouped, with dangers of over-simplification. However, from an entomological point of view, chronological change was limited at all of the sites within the periods represented by abundant remains. Probably the only substantial chronological changes during the Roman period, so far as the insects are concerned, were (a) the initial establishment of the fort and its associated settlement, poorly represented in the sample record, and (b) the eventual replacement of most structures in stone, with associated improvements in drainage and cleanliness, which effectively removed opportunities for preservation of insects.

Limitations of the data

The analyses carried out during the site projects have given rise to a set of more-or-less subjective deductions, outlined above, which may be tested here. There are some difficulties, however. In particular, the numbers of contexts of any one type examined for each site is frequently small, and there is very uneven representation of the various context types across the sites (Table 2). (The problem is even greater if chronological phases are considered.) Thus, there were numerous floors at Castle Street and Annetwell Street, but few or none at the other sites, while few pits were sampled (or, presumably, available for sampling) at Castle Street and Lanes 1. These variations in the abundance of context types reflect fundamental differences between the sites, however, and cannot be regarded as accidents of excavation. Their influence on the statistics at the site level is consequently regarded as a source of useful information about overall conditions, rather than of bias.

The material was recorded by four people (Lesley Morgan, Frances Large, Enid Allison and HK) over a long time period, during which there was increasing refinement of methodology and broadening of the range of organisms identified, . There may thus have been some variation in the standard of recording of certain groups between projects, fleas, lice, beetle larvae, scale insects and bug nymphs probably being poorly recorded at Annetwell Street. Material from Castle Street, the first of the sites studied, was re-examined to some extent by Enid Allison some years after the main phase of recording, but detailed systematic recording of these categories of remains was not possible (in any case, experience with other sites, notably 16-22 Coppergate, York, suggests that lice and other very fragile fossils in 'flots' are easily destroyed in storage, particularly by dehydration). However, there is little reason to doubt that there is any significant difference in the way the adult beetles and bugs were recorded. (The only possible exception here is that small numbers of the spider beetle *Tipnus unicolor* may have been overlooked or under-recorded at Annetwell Street and Castle Street, see below.)

Comparison of main statistics at the site level

Main statistics at the site level show clear spatial trends (Tables 3-12). Most of the following discussion deals with the statistics derived after subtraction of grain pests, which both swamp the faunas and perturb the proportions of other groups by their variations. The proportion of the grain pests themselves varied greatly from sample to sample (a good number of the assemblages including more than 50% of such insects, Table 39), and differs substantially between the sites (from 21% at Lanes 2 to 38% at Castle Street); this component is discussed in more detail below.

'Outdoor fauna'

The proportion of species requiring outdoor, usually natural, semi-natural or agricultural, habitats was highest at Lanes 1 (34% after subtraction of grain pests), a little lower at Lanes 2 (30%), and substantially lower at Castle Street and Annetwell Street (20% and 21% respectively); the differences were significant at the 99% level (Table 12). These figures probably to an extent reflect differences in the development of vegetation and other habitats (e.g. open water) at the sites. However, the 'outdoor' forms doubtless included 'background fauna' (sensu Kenward 1975, 1976), varying according to the distance to semi-natural habitats, as well as insects imported with material such as hay and turf. The outdoor fauna at Castle Street and Annetwell Street, in particular, may consist largely of such naturally or artificially transported remains. Water beetles were significantly proportionally more abundant at both Lanes sites, and significantly less so at Annetwell Street (Table 12); the numbers at Castle Street were less than expected assuming an even distribution across the sites, but not significantly so.

The outdoor fauna included a very large number of taxa, mostly in small numbers. For ease of presentation and comparison, this component has been divided into plant-feeders (phytophages, Table 22), ground beetles (Carabidae, Table 23), and aquatics (Table 24). The foul-matter category (RF, Table 26) includes a range of outdoor taxa, particularly the scarabaeid dung beetles (mostly *Aphodius* spp., with some *Geotrupes* spp.). Similarly, the non-synanthropic decomposers (Table 25) to some extent reflect outdoor habitats.

There is rather little pattern to be discerned in the distribution of outdoor species across the sites, aquatics and dung beetles dominating in each case, together with plant feeders having a wide range of hosts (and quite possibly being of transported origin).The ground beetles were perhaps most notable for their small numbers, and there was only limited evidence for well-developed populations at any of the sites. Some of the Carabidae were almost certainly imported in turf (notably *Dyschirius globosus* and *Bradycellus ruficollis*). Some of the ground beetles (Table 23) found at Castle Street and Annetwell Street probably lived in open areas on the sites (e.g. *Trechus obtusus* and *T. quadristriatus*, *Clivina fossor* and *Pterostichus melanarius*). *Trechus quadristriatus/obtusus* at the Lanes sites appear to be the best candidates for established populations of ground beetles, however (see totals for these species at the ends of the lists in Table 23). These beetles, with *T. quadristriatus* probably the commoner, seem to tolerate areas heavily disturbed by human activity, and are frequent, although not abundant, in many occupation site deposits. This synanthropic aspect of the beetles' ecology is not mentioned by Lindroth (1985, 122-3) in his summary of their ecology, but in HK's experience *T. quadristriatus* (at least) tends to occur both in shady urban yards and in compost heaps.

The total numbers of individuals are very low for most taxa of plant-feeders (Table 22). The exceptions are:

(a) Some compound taxa, e.g. Auchenorhyncha spp. (froghoppers and their allies), *Apion* spp.(clover weevils and related taxa), *Longitarsus* spp. and Halticinae spp. (flea beetles), *Meligethes* spp. (pollen beetles), and Chrysomelinae spp. (leaf beetles). These each appeared to include several to many species, each represented by a few individuals; they are thus of limited significance.

(b) *Phyllopertha horticola*, the 'garden chafer' (in fact mainly found on marginal grazing land) at these sites perhaps of background origin or imported in hay or turf (further investigation of the significance of this beetle in archaeological deposits is required).

(c) Modest numbers of some heath/moor taxa likely to have been brought in turf. Notable among these are *Macrodema micropterum*, *Scolopostethus* sp. (probably mostly *decoratus*), *Ulopa reticulata* and *Micrelus ericae*.

Some plant-feeding insects perhaps lived on the sites, exploiting weeds (e.g. *Phyllotreta nemorum* group on crucifers), but populations of such taxa were undoubtedly small (other than any subsumed in the compound taxa mentioned above). Stinging nettle (*Urtica dioica*) would be predicted to have been an important weed at sites with abundant rotting organic matter including dung, yet nettle-feeders were only recorded in insignificant numbers (less than thirty adult individuals from the sites as a whole, mostly *Brachypterus* spp.). Thus, there is no evidence for more than the most impoverished and scattered weed flora at any of these sites.

Taxa such as the *Helophorus* species, *Phyllopertha horticola* and *Sitona* species seem very likely have arrived in flight and died accidentally. However, alternative explanations are available: the *Helophorus* may have been brought to the site in water or in the guts of livestock (having been accidentally ingested when they drank), and *P. horticola* and *Sitona* spp. may have come in hay or turf. Others were almost certainly imported (e.g. the heath/moor taxa mentioned above), although the evidence at Castle Street and Annetwell Street is less clear than for Lanes 1. The species association analyses cast a little light on these questions (see below).

The outdoor fauna at Lanes 2 had a broadly similar character to that at Castle Street and Annetwell Street, and probably indicates very sparse and scattered vegetation, the large proportion being a result of the relatively large number of surface-laid deposits at the site. Indeed, at Lanes 2, even many of the pit and ditch fills appeared to include surface soil, with its own fauna and its load of 'background' corpses. There was evidence for imported materials from the outdoor component at Lanes 2, for there was a suite of moorland or heathland beetles and bugs, and click beetle larvae, probably brought in soil from such places. This component (only the more characteristic species of which are coded 'm') was rather more strongly developed at Lanes 1, and some assemblages included whole communities of such insects. Turf may have been brought for construction or levelling, or for use as an absorbent material in stables, the latter appearing to be a distinct possibility.

Although subjectively the data for the Lanes 1 assemblages suggest some rather better-developed local vegetation (13% phytophages, as opposed to 8-10% at the other sites, Table 11), it is hard to support this objectively from the list of plant-feeders at site level (Table 22); a sceptic might reasonably argue that most of the outdoor fauna was background fauna, or imported in hay or turf.

Aquatics

Aquatics were not very abundant at any of the sites (2-5% of the site assemblage after subtraction of grain pests). Some individual contexts gave substantially higher values, mostly at the two Lanes sites, where eleven layers at Lanes 1 and eleven pit fills and six layers at Lanes 2 gave more than 5% aquatics (Table 42). Overall, aquatics were relatively numerous at the Lanes sites (5% of the site assemblage in each case), rarer at Castle Street (3%) and least abundant at Annetwell Street (2%), the values for the Lanes sites and Annetwell Street diverging significantly from the expected values (Tables 11-12). These variations probably relate in part to the presence of ditches and pits holding temporary water at the Lanes sites, but might also result from the greater abundance of other groups at the more urban sites, particularly Castle Street (numerical 'swamping'). *Helophorus* spp. were abundant at each site, but these (and most of the other aquatics represented) are very migratory and probably an important part of the background fauna (supported by its association at three of the sites with what are regarded as 'outdoor' and migratory elements in the species association analyses, see below). They may have bred in, or merely have been attracted to, temporary water in cuts and on surfaces. However, an origin for at least some of the aquatics in drinking water for stock has been suggested above, and is for Castle Street supported by the results of the species association analyses (below). The proportion of the outdoor fauna contributed by aquatics (W as a percentage of OB) was rather constant (16-17%) except at Annetwell Street, where it amounted to 11%. This may indicate a different origin of the outdoor component at Annetwell Street, but the evidence is hardly convincing. There was little variation in the damp ground and waterside fauna; it was sparse in each case (Table 11).

Decomposer fauna

Species associated with decaying matter (decomposers, RT) showed some variation between the sites, the two groups of Lanes sites having 54% and 51% (corrected for grain pests), Castle Street 63% and Annetwell Street 59% (Table 11); the values represented significant deviations from the mean at $p<0.01$ (Table 12). It is suspected that the proportion at The Lanes was depressed by other components (the difference roughly corresponding to the variation in outdoor fauna, for example), but the values at Castle Street and Annetwell Street probably reflect substantial differences in the amount of filth allowed to persist long enough for a large fauna to develop. The material responsible may usually have been dung and stable manure (below), but probably included a wide range of litter and waste from numerous organic-based activities. While much the same range of species was present at each site, Annetwell Street stands apart when the components of the decomposer group are considered separately (Table 11). The two Lanes sites and Castle Street had fairly similar proportions of species associated with dry and foul decomposing matter (12-14% RD, 10% RF), but there were far more individuals of species associated with drier habitats at Annetwell Street (22%, $p<0.01$), and far fewer which are typical of foul matter (5%, $p<0.01$).

The obvious conclusion is that foul matter was not tolerated for long at Annetwell Street; the 'dry' decomposers may have originated in buildings or stored materials (the latter is supported to an extent by variations in the grain pests and house fauna, see below). The ranked list of RF taxa from the sites support this to a degree (Table 26). All of the sites have large numbers of *Cercyon haemorrhoidalis*, *Platystethus arenarius* and *Aphodius* spp., all rapid opportunistic colonisers of dung, an inevitable material on open surfaces in a horse-dependent society, and probably very common in the background fauna. However, variations in the numbers of *Cercyon atricapillus*, more typical of developed communities in material resembling stable manure, may be significant. Although among the more abundant foul-matter taxa at Lanes 1, at Rank 10, its numbers were not great (Table 26), possibly because much of the foul matter at these sites was on open ground. At Lanes 2 it lay at Rank 4, but at Castle Street, in contrast, it was much the most abundant foul decomposer. Its importance was far less at Annetwell Street, where it lay at Rank 10. It is suggested that this reflects an intolerance of persistent decomposing matter within the fort, contrasting with an abundance of old stable manure at Castle Street. This hypothesis is very much supported by the numbers of individuals of other taxa regarded as typical members of the community of decomposing stable manure (Table 27). The total of this group as a percentage of N-G (abbreviations explained in Table 1) rises from 5% at Lanes 1, through 9% at Lanes 2, to 20% at Castle Street, then falls steeply to 8% at Annetwell Street. This variation is equally striking when the 'stable manure' component is calculated as a percentage of all decomposers: 10% for Lanes 1, 17% for Lanes 2, 33% for Castle Street and 13% for Annetwell Street (Table 27). The differences are somewhat less clear when 'peaks' of stable manure are considered (Table 28): Castle Street had (just) the *lowest* proportion of assemblages where stable manure contributed more than 10% of the RT component (Table 28A-B). This is probably a result of 'swamping' by abundant decomposers from drier habitats, however, and there are also indications that stable manure was more important at Lanes 2 than suggested by analysis at site level. Assemblage peaks of stable manure taxa as a percentage of N-NG (rather than of the decomposer component) were most numerous at Castle Street and Lanes 2 (Table 28C).

Synanthropes

There is a steady rise in the proportion of synanthropic insects (those favoured by human activity) from Lanes 1 to Annetwell Street (Table 11), this component (after removal of grain pests) accounting for 30% of the fauna at Lanes 1, 35% at Lanes 2, 37% at Castle Street and 45% at Annetwell Street. There were significantly ($p<0.01$) fewer synanthropes than expected at both Lanes sites, and significantly more at Annetwell Street. The pattern is less obvious if the grain pests (which are of course strongly synanthropic themselves) are included, the percentages being 45, 58, 60 and 58 ($p > 0.05$), but nevertheless the variation in the importance of artificial habitats is clear.

A breakdown within the synanthropic component (Tables 29-33) suggests that there were substantially more facultative synanthropes at Lanes 1 and Annetwell Street than at Lanes 2 and Castle Street. If grain pests are removed, only Lanes 1 shows an excess (61% of all synanthropes, compared with 47-51% at the remaining sites). The reverse pattern is seen among the typical synanthropes (34% of all synanthropes at Lanes 1, 46-48% at the other sites). This is what might be expected when a less intensively exploited site is compared with more heavily modified ones.

Variations in the strong synanthropes are determined primarily by the abundant grain pests, which were proportionally rarer at Lanes 1 (47% of all synanthropes), more abundant at Lanes 2 and Castle Street (60-62%), and least abundant at Annetwell Street (42%). This pattern is interpreted as largely reflecting variations in the amount of stable manure at the sites, grain pests originating from horse feed. (There may have been cases where spoiled grain was disposed of directly, see below.) Stable manure was undoubtedly present in at least limited amounts at Lanes 1, but its fauna was perhaps diluted by that from other decomposer communities; activities at Lanes 2 and Castle Street probably were in various ways very much concerned with horses; while at Annetwell Street horses were doubtless present, either in passage or in secure accommodation, but old stable manure would have been less acceptable. This is discussed elsewhere in the context of the stable manure insect community and foul decomposers.

Grain pests

An internal analysis of the grain pest component amplifies the conclusions drawn from the synanthropes as a whole (Tables 36-38). The proportion of grain pests in the whole fauna is substantially lower for Lanes 1 and Annetwell Street (21-24%) than for the other sites (35-38%), and it is suggested that this primarily reflects differences in the amount of horse manure becoming incorporated into deposits at the sites. However, there are also differences in the proportions of the four grain pest species across the sites (Tables 36-37). *Palorus ratzeburgi* shows little variation (5-7% of the G component). *Sitophilus granarius* is strikingly more abundant at Annetwell Street (15%, $P<0.01$), but significantly rarer than expected at Lanes 2 (6%, $p<0.01$). *Cryptolestes ferrugineus* is more abundant at Annetwell Street than at the other sites (41% against 30-34%, $p<0.01$). By contrast, *Oryzaephilus surinamensis* is much less abundant at Annetwell Street than elsewhere (38% versus 53-58%, $p<0.01$). A consideration of the biology of these three beetles (summarised by Aitken 1975) suggests that the differences can be related to conditions and activities at the sites. Although all commonly occur in bulks of stored grain, *O. surinamensis* is a scavenger which would have tolerated fairly spoiled grain and which probably would have persisted and bred in cereal debris (and other materials) in stable manure. *S. granarius* requires grain in relatively good condition (it feeds on the starchy endosperm) and would soon die out in spoiled grain in stable manure. *C. ferrugineus* is also adept at attacking whole grains through minor abrasions in their coats, and may be less tolerant of wet conditions than the other scavengers. Thus, it appears that there was relatively fresh grain at Annetwell Street (perhaps even in storage and conceivably for human use, and occasionally dumped because it was 'weevily'), but that the grain at the other sites was in poorer condition or rotting (probably in horse feed, or more likely in stable manure).

The species association analyses might be expected to cast some light on this problem. The Spearman's rank correlation coefficients for the four grain pests are given in Table 38. Each site gave a different pattern of association, but explanations of the variation easily become contrived. However, what may be suggested on the basis of these statistics is that the grain pests do not always seem to have arrived in the deposits as a close-knit group in constant proportions, but that different species, at least sometimes, came by different routes.

Grain pests were very abundant in some samples, forming over 50% of numerous assemblages and sometimes a much larger proportion (Table 39). It seems possible that some of these assemblages indicate deposits containing large amounts of spoiling grain, perhaps dumped directly rather than arriving via stable manure. These pests may still have been in spoiling animal feed rather than grain intended for human use, however.

House fauna

House fauna (Kenward and Hall 1995, 662-667) was present in appreciable quantities at each site, but the proportion varied sharply between Annetwell Street, where it contributed 22% of the fauna after removal of grain pests, and the remaining sites, where it contributed 12-14% and numbers were absolutely much smaller (Table 34). One taxon dominated at each site: *Lathridius minutus* group (probably mostly *L. pseudominutus*). This mould-feeder is associated with a range of decomposer habitats, with a preference for material which is not too foul. At these sites it probably bred in external accumulations of litter, as well as indoors. Its proportion varied a little, being highest at Lanes 2 and Annetwell Street (42-44%; 34-36% at the other sites).

Two house fauna species show variations which may be ecologically significant (but may result from variations in the numbers of other taxa). The woodworm beetle, *Anobium punctatum*, shows a steady decline in proportions from Lanes 1 (13% of house fauna) to Castle Street (9%), with a steep drop to 3% at Annetwell Street. This is counter to what might have been predicted, since there was apparently more structural timber at the last two sites than elsewhere. The explanation is probably that *A. punctatum* lived in a wide range of wood, including fences and posts, in addition to infesting buildings. Indeed, the beetle is reported to be unable to colonise wood for many years (until the timber has been modified by fungal action), or to become abundant until buildings are 20 or so years old (e.g. Bletchly 1967; Hickin 1975), so perhaps the less well-maintained sites presented more old wood suited to it. The constant refurbishment at Annetwell Street may have robbed the beetle of habitat. Heartwood of oak is unsuitable for the beetle until considerably modified by fungal action (*ibid.*), so perhaps a predominance of better-quality structural timber at Annetwell Street was a second factor. If the percentage of *A. punctatum* in the whole fauna is calculated, it is found to be much more abundant at Lanes 2 than elsewhere (1.77%, as opposed to 0.56-0.76%, Table 34). It is possible that there were large, long-lived timber buildings at Lanes 2 (e.g. that described by McCarthy *et al.* 1982), which could support growing populations of the beetle. At Lanes 1 it may have exploited fences and light structures which were neglected for long periods.

The second house fauna taxon whose relative importance varied appreciably is *Xylodromus concinnus*, a rove beetle, which (like *L. minutus* group) is found in a range of habitats but apparently strongly associated with buildings in the past. Its proportion ranged from 6% at Lanes 1, through 7% at Lanes 2, to a peak of 18% at Castle Street, falling to 11% at Annetwell Street (Table 34). This may reflect its association with accumulations of fairly open-textured decaying matter, probably including the drier parts of stable manure, which from other evidence seems to have been particularly abundant at Castle Street (see above). It may also have been a denizen of poorly-stored grain, being well known from warehouses in the 20th century (e.g. Hinton 1945), and thus have arrived in horse feed.

If the various unidentified *Cryptophagus* species are added together (which would be appropriate since the allocation of the letters A, B, etc., does not necessarily relate to the same species between samples), the genus can be seen to contribute a varying proportion, with 19% at Lanes 2 and 25-28% at the remaining sites. These beetles were probably associated with fairly dry decaying matter (including hay) and decaying wood, as well as with stored products (including the grain in which the abundant grain pests lived). There is no obvious cause for the observed pattern, which may be confused by the amalgamation of taxa with different ecological requirements.

Some of the house fauna, and some plant feeders, may have arrived in hay. The species association results offer a little support, for at Castle Street, a 'house fauna' group was linked via *Anobium punctatum* to *Apion* spp., and thence to *Sitona* spp. and *Ephistemus globulus* and to *Typhaea stercorea*. The weevils *Apion* and *Sitona* are prime candidates for importation in hay (Kenward and Hall 1997), and *T. stercorea* seems particularly to have occurred in stored hay. However, the results for the other sites offer little support for this argument.

A problem to be addressed is the likelihood that very clean houses would be invisible in the entomological record, unless floor deposits were found which fortuitously contained preserved remains (as at Coffee Yard, York, Robertson *et al.* 1989). The few woodworm and spider beetles dispersing from such structures might be lost into the general accumulation of fauna. It is just possible that the isolation of *Ptinus fur* in some of the species association analyses (below) reflects its occurrence as the beetle most typical of clean buildings.

Summary of evidence from statistics for ecological groups at the site level

At the level of whole sites, the main statistics offer substantial evidence of variations in conditions and activities across the town. There is a clear trend in the proportion of outdoor fauna from Lanes 1 through Lanes 2 to Castle Street and Annetwell Street. There is little evidence that plant communities became established more than occasionally at any of the sites, even at Lanes 1. Aquatic insects were significantly more abundant at the Lanes sites, reflecting the presence of ditches or gulleys. However, this group may have arrived in more than one way, including as background fauna and *via* water drunk by livestock. Although there was decomposing matter at each site, this component had a similar composition at the Lanes sites and at Castle Street; Annetwell Street, however, gave a substantially greater proportion of species associated with drier habitats, interpreted as indicating lower tolerance of foul matter. It appears that stable manure was allowed to remain long enough at Castle Street for substantial insect populations to develop. It may have been less abundant at Lanes 2, and even less so at Lanes 1 and Annetwell Street. Perhaps inevitably, horse droppings lay on surfaces at each site long enough for rapid invaders to arrive, but dung may usually have been cleared quickly at Annetwell Street. Horses seem to have been kept at Lanes 2 and Castle Street. They probably were kept at Lanes 1, too, but perhaps in larger pens with some overgrazed vegetation. The proportion of the fauna contributed by the synanthropic component increased steadily from Lanes 1, through Lanes 2 and Castle Street, to Annetwell Street (when grain pests are included), and this is interpreted as reflecting increasing intensity of human utilisation of the sites. This is reflected in the relative abundance of house fauna at Annetwell Street when compared with the remaining sites.

Discussion of main statistics by deposit type

Four context types are sufficiently well represented at most of the sites to justify comparison: layers, pit fills, ditch, drain or gulley fills, and floors (Table 2). It must be emphasised that, as for the sites as a whole, there was substantial variation between sample assemblages from contexts assigned to any particular deposit type. Thus, in general, only an averaged set of conditions is being deduced in this section - valuable in broad site comparisons but potentially deceptive if the variation within feature types is forgotten.

Layers

Layers, it might be argued, represent the context type most likely to reflect the conditions experienced 'underfoot' by the occupants of a site, and (again, it may be argued) to be the least affected by special usage, as opposed to the combined affects of a broad range of activities. They thus may be more usefully comparable between sites than other context types (with the exception, perhaps, of floors). It is fortunate that deposits formed on surfaces in the sites in Carlisle often show adequate to good preservation of insect remains by anoxic waterlogging; this is something which could not be relied upon at many sites.

The outdoor component of layers at Lanes 1 was larger than for the other sites (31%; 36% when grain pests removed, Tables 3-10, 13). For the remaining sites, the proportions were 16-20% (22-27% without grain pests, these variations being significant at the 99% level, Table 14). The subjective impression when preparing the site report for Lanes 1 was of surfaces with some vegetation, sometimes perhaps grazed turf, with scattered decaying matter and nearby ditches or ponds contributing aquatics. (This conclusion receives little support from analysis at site level, however, see above.) Aquatics contributed 6% of the fauna (-G) of the layers at Lanes 1, as at Lanes 2, suggesting the availability of open water, but the proportion at the other sites was 3-4%, which may not be far from what is normal in background fauna (compare data given by Kenward 1975; 1976; 1978, 45).

Although there were numerous ''outdoor' insects from layers at Lanes 1 (846 individuals and at least 68 taxa), there was rather little clear information about any vegetation which may have grown on them. Plant-feeders (and other taxa strongly associated with living plants) from layers are listed in Table 40. The data are not very informative. As discussed above, the problem lies partly in the fact that many of the more abundant taxa are only identified to genus (e.g. *Longitarsus* sp., the second most abundant taxon at Lanes 1) or worse (Auchenorhyncha spp., leafhoppers, at all the sites), and which thus have a wide range of hosts. The second difficulty is that many of the plant-associated insects were almost certainly imported (e.g. *Micrelus ericae*, *Macrodema micropterum* and *Ulopa reticulata* at Lanes 1, all presumably from turf or peat). Much the most numerous specifically-identified plant-associated insect in the layers at Lanes 1 was the distinctive chafer *Phyllopertha horticola* (34 individuals). This beetle may have been breeding in poor turf on the site, which would have profound implications about the local environment. However, it may have been abundant in background fauna or have been brought in turf (it occurs in huge numbers locally in the emergence season (eg. Milne and Laughlin 1956; Ormerod 1898; Taylor and Thompson 1928). Insects with vetches, clovers and their relatives as hosts were rather abundant (particularly *Apion* spp., but also various *Sitona* spp.), but these may have been brought in hay (entering the deposits in spoiled hay or via stable manure or dung, Kenward and Hall 1997). Overall, then, the phytophages tell remarkably little about vegetation on surfaces at Lanes 1. One reason may be that there was little of it, but another, perhaps more plausible, explanation is that plants were so heavily grazed and trampled by livestock that they supported few insects.

The problem of identifying local vegetation is even more profound for the other sites, for which the total numbers of plant-associated insects in layers were much smaller (Tables 13 and 40), and the impression is that background fauna and imports predominated, the only plants growing nearby being - at most - a few scattered weeds. At Annetwell Street, where about 50 phytophage taxa were present in layers (many of these have been combined in Table 40), *Apion* spp. were the most abundant (20 un-named individuals and three *A. craccae*). These may have been background fauna, but some quite possibly arrived in hay. Layers at Castle Street yielded less than 40 taxa coded 'p' (again many have been combined in the table), but no single species was represented by more than three individuals. There were no hints at all of a local flora. At Lanes 2 this component was also very restricted in the layers, with about 30 species, all represented by four or less individuals and offering no more than a hint of scattered weeds.

Other components of layers gave some information, although tending to correspond to data for the sites as a whole. Decomposers (Table 13) were more abundant at Lanes 1 (70% after removal of grain beetles) than at the other sites (55-60%), and within this component 'rd' taxa were far more abundant at Annetwell Street (24%) than elsewhere (10-15%). Foul-matter taxa were about equally proportionally abundant in layers at three of the sites (11-13%), but substantially rarer at Annetwell Street (6%).

Drains and gulleys

Main statistics for the combined assemblages from features identified as ditches, drains and gulleys at the four sites are given in Table 15. They give rather little information. The total number of individuals from such features at Lanes 1 and Castle Street was rather small, especially after subtraction of grain pests. By inspection there was only limited variation in the fauna of the sites, and this was reflected in the paucity of significant results in the chi square tests (Table 16). The outdoor component was rather larger at Lanes 2, and there were rather more aquatics at Lanes 2 and Castle Street. Foul matter (RF) taxa were proportionally substantially more abundant at Castle Street ($p<0.01$), presumably because foul waste, probably stable manure, was used to backfill the cuts.

Pits

Data for pits are summarised in Table 17. They largely follow the trends seen in the data for the fauna of the sites as a whole. Outdoor fauna (OB) was proportionally more abundant at the two Lanes sites (28% and 33% after subtraction of G) than at Castle Street (23%) and Annetwell Street (18%). The deviations at Lanes 2 and Annetwell Street were significant at $p<0.01$ (Table 18). At the Lanes, pit cuts were either left open for longer or received waste rich in outdoor insects, from surfaces, perhaps. Although the decomposer component was approximately constant across the sites (56-60%), 'dry' decomposers (RD) varied significantly; they contributed 27% of the fauna (-G) at Lanes 1 and 22% at Annetwell Street, but only 12% at Castle Street and 9% at Lanes 2, undoubtedly reflecting the nature of waste material at the sites. Facultative synanthropes were less abundant at Lanes 2 than elsewhere (15% compared with 21-25%), probably reflecting intensity of use of the site. Typical synanthropes (ST) were proportionally more abundant at Annetwell Street than at other sites (22% compared with 14-16%, $p<0.01$), and foul-matter taxa (RF) rarer (4% *versus* 8-10%, p<0.01). Overall, it appears that pit cuts at Annetwell Street received less objectionable - or if foul, fresher - material than those at the other sites. This accords with the deduction from other evidence that foul matter was not allowed to accumulate to any great extent at Annetwell Street.

Floors

Floors were patchily represented among the samples, with none from Lanes 2, very few from Lanes 1, but rather more from Castle and Annetwell Streets (Table 2). Main statistics are summarised in Table 19. Perhaps even more than for other feature types, these statistics hide substantial variation and, on the basis of analysis of sample assemblages, floors at each site ranged from clean to filthy.

The small group of remains from floors at Lanes 1 differed substantially from the material from Annetwell Street and Castle Street. Outdoor forms (OB) contributed 34% of the individuals (after removal of grain pests) at Lanes 1, significantly more than the mean for the sites as a whole (p<0.01, Table 20); they accounted for 16-20% at the other two sites. Within the outdoor component, aquatics and plant feeders were much better represented at Lanes 1; the latter significantly so (p<0.01). Wood-feeders were significantly less abundant, however (p<0.01). Decomposer (RT) taxa were substantially rarer at Lanes 1 (46% against 59-69%, p<0.01), as were typical synanthropes (11%, compared with 19-23%, p<0.01). RD taxa were significantly rarer at Castle Street (14% against 22-25%, p<0.01). It is not clear why these differences exist, but outdoor fauna may have been imported with stable litter at Lanes 1, and floors at Castle Street were, on average, clearly rather mucky.

The more abundant taxa from floors at the sites are listed in Table 21. It is worth noting that the *combined* assemblages of individuals from the samples from floors at each site (45 of them in the case of Annetwell Street) might have been recovered from 10-20 kg of the richest floor deposits of Anglo-Scandinavian date in York (e.g. Kenward and Hall 1995), so concentrations were evidently generally not very high. The four assemblages from Lanes 1 gave a total of 221 individuals of adult beetles and bugs (from 4 kg of sediment), and this group cannot reasonably be used in inter-site comparison, although it is worth noting that there were relatively low numbers of grain pests. Concentrations of remains in floors at Castle Street (128/kg overall; 20 kg analysed) were five times higher than at Annetwell Street (25/kg; 53 kg analysed). Even without examining the composition of the fauna, a difference of this magnitude strongly suggests very different use of buildings.

Grain pests were the predominant group in floors at both these sites, with the species in the same order of abundance (*Oryzaephilus surinamensis*, *Cryptolestes ferrugineus*, *Sitophilus granarius* and *Palorus ratzeburgi* in descending order, Table 21). At Castle Street, decomposers were proportionally more abundant (69% RT after removal of grain pests, as opposed to 59% at Annetwell Street) and there appeared to be stable manure communities, representing conditions which were clearly foul in many cases. At Annetwell Street, although stable manure elements were present, there was much less evidence for foul matter (5% RF compared with 9% at Castle Street, p<0.05), and (proportionally) almost twice as many insects associated with drier matter, including stored products (25% RD, compared with 14%, p<0.01). The last statistic reflected the greater importance of 'house fauna' at Annetwell Street, together with the other evidence pointing to use of buildings by humans rather than livestock. Unfortunately, the recording (and, for lice, probably preservation) of ectoparasites of humans was not ideal, so they cannot be used in arguments concerning human domestic occupation at Roman Annetwell Street in the way that there were for buildings of a later period at Coppergate, York (Kenward and Hall 1995).

Summary of evidence by deposit type

In summary, examination of the data within deposits types strongly supports the inference drawn at the level of entire sites that these were substantial differences between conditions in the four areas represented, and clarifies the likely causes of those variations.

Species association analyses

The 'constellation diagrams' summarising the significant ($p<0.05$ and $p<0.01$) correlations between taxa for these sites proved too complex to be resolved into discrete groups; there were usually several links between them and in some cases all or most of the taxa formed a single swarm, albeit with ecologically meaningful internal structure. Nevertheless, they gave a valuable indication into the way ecological groups occurred together in the deposits, providing useful evidence of differences between the sites. The diagrams derived from percentages after removal of grain pests were sometimes clearer (e.g. Figure 3); variations in numbers of grain pests had, for certain sites, obscured important relationships among the other taxa.

It is important to remember that the correlation coefficient measures only the frequency with which taxa occur together (with an attached significance value). Species do not occur in neat communities, so some will have links into several, while others will have few or no links because they occurred in such a wide range of habitats. Further links will reflect the occurrence of species together in more than one habitat, even though both occur in a wide range of situations. Others still will result from co-occurrence of habitats, the taxa not forming components of any single community. The isolation of *Anobium punctatum* at Annetwell Street, and of *Ptinus* at Lanes 2, is doubtless in part a result of the ubiquity of these insects, but perhaps also of the robustness of their remains, making them likely to be redeposited (the distribution of *A. punctatum* in this way was posited by Kenward and Large 1998).

Lanes 1

Based on percentages of N

The analysis produces a constellation diagram with:

1. A quite strong grouping consisting of taxa requiring outdoor habitats, decomposers more typical of rotting matter, ranging from litter to dung, in the open, and eurytopic decomposers.

2. The grain pests, linked to (1) via *Falagria* and with no other significant external correlations.

3. Linked to (1) by *Corticaria*, *Leptacinus* and *Anotylus tetracarinatus*, what may be a weak house/store/stable building group (*Ptinus fur*, *Anobium punctatum* and *Cryptophagus*), leading via the last to *Lathridius minutus* group, *Atomaria*, *Xylodromus concinnus* and *Cryptophagus scutellatus.* Attached to this are *Apion*, perhaps brought with hay, and *Anthicus* and *Typhaea stercorea*, perhaps colonisers of the stored material.

These groups were connected by multiple links.

Based on percentage of N-NG

The diagram is somewhat different. The use of 3-way linkages did not resolve any clear groups, although a restricted group of 'house' fauna taxa had only a single 3-way link to the main cluster. The grain pests have several links (including two 3-way linkages) into the large group of taxa represented by (1) above, via *Aphodius*, *Cercyon analis*, *Platystethus arenarius*, *Falagria*, and *Oxytelus sculptus*, all likely to have exploited fairly foul decaying matter. What may have been a weak house fauna group was linked to (1) only by *Leptacinus* and *Corticaria*; *Apion* was linked to it, leading to the suspicion of an origin in hay.

While there was doubtless stable manure at Lanes 1 (as indicated by inspection at the assemblage level), the species association analysis suggests, as do other data, that it was not a predominant habitat at the site. There was probably not a well-developed house fauna, either (much of it may have come with stable manure), and the indications are that foul matter was mainly in the open air. The origin of the grain pests is uncertain, but their links into group (1), and lack of connection to house fauna or the more characteristic stable manure decomposers, rather suggest that they may often have originated in horse dung.

Lanes 2

Based on percentages of N

At $p<0.05$, all taxa in the analysis except *Ptinus fur* form a single group, most taxa being tied in to several others. At $p<0.01$, a clearer picture emerges, with three groups connected to each other by one or no links. The groups are as follows:

1. The four common grain pests, together with *Anobium punctatum*, *Xylodromus concinnus* and *Typhaea stercorea*. The last three may represent fauna from the grain store; *Acrotrichis*, which is appended to *Oryzaephilus surinamensis*, does not obviously fit here in ecological terms.

2. *Cercyon unipunctatus*, *C. analis*, *Carpelimus bilineatus*, *Oxytelus sculptus*, *Anthicus*, *C. atricapillus* and *Falagria*. The last two have strong links to *Platystethus arenarius*, which probably lived with them in fairly moist to rather drier open-textured foul matter. *P. arenarius* is the only link between this group and (3) at $p<0.01$. This group almost certainly either represents the fauna of stable manure, or of its equivalent accumulating on open ground. It has several links at $p<0.05$ into group (1), and some of the taxa have one or several links into the next group. Many taxa in (3) would have co-existed with (2), but also have been part of other communities, which were commoner at the present site.

3. Almost all of the remaining taxa form a tangled web at $p<0.05$, with a branching and anastomosing framework at $p<0.01$. Some would certainly have lived in the same habitats as species in (1) and (2), but the present group probably represents taxa which lived preferentially in open-air habitats, principally rotting matter and a few plants on soil surfaces, perhaps together with background fauna.

4. *Ptinus fur*, in splendid isolation, either because it occurred in a very wide range of habitats, or because its distinctive and tough remains were redistributed by wind and trample (see above).

Based on percentages of N-NG

The same general picture emerged, but with rather more clarity. The groups were still connected by multiple links, however. Three-way linkages clarified boundaries somewhat. Grain pests and likely scavenging associates, apparently including *Aglenus brunneus*, merged into fauna of decaying matter which was probably like stable manure, and both ran into what appeared to be a group from drier material (*Cryptophagus*, *Lathridius minutus* group, *Enicmus* and *Atomaria*). *Apion* was strongly joined into this last group, raising the suspicion that it may have been from hay. The remaining taxa formed an ‘outdoor’ group, with aquatics, ground beetles, foul decomposers and probably background fauna elements (*Phyllopertha horticola* may exemplify the last category). The outdoor group was rather isolated from the rest of the taxa, although still connected via five links.

It appears that at Lanes 2 a large part of the fauna lived in open-air habitats, with abundant decaying matter and a very limited weed flora. There was probably stable manure as such, but the fauna believed typical of such material may at least sometimes have lived in spreads of litter in the open. House fauna may not have been important at the site, its components living in drier litter and being imported in rather poor grain used for feed. *Ptinus* gained a link to *Aglenus* at $p<0.05$ in this re-analysis, suggesting that grain stores and stables may have been among its habitats.

Castle Street

Based on percentage of N

The small number of assemblages from this site meant that few taxa occurred in ten or more samples (the minimum set for these analyses), limiting the usefulness of the analysis. Although at $p<0.01$ there are numerous links between groups, the constellation diagram can be resolved into:

1. A group of taxa likely to occur together in material resembling stable manure, with a moderate number of internal links and rather few external ones. The plant-feeding *Meligethes* and *Phyllotreta nemorum* group are linked to foul decomposers (*Platystethus arenarius*, *Cercyon haemorrhoidalis*) in this group. The plant-feeders perhaps represent the fauna of weeds colonising surfaces on which manure was left to lie in the open, while the foul decomposers invaded the manure. The genus *Tachyporus*, linked here, is eurytopic but would be a characteristic component of the fauna in litter and at the base of plants on open surfaces. *Stenus* spp., *Tachinus* spp., *Acrotrichis* spp., *Omalium rivulare*, *Clambus* spp. and *Omalium caesum/italicum* form a rather isolated decomposer subgroup, which is hard to place in any one habitat type - unless some or all lived in well-decayed stable manure.

2. Linked to (1) by eurytopes (*Anotylus rugosus*, *Enicmus* sp., *Atomaria* spp.), a weak 'house fauna' group (*Ptinus fur*, *Cryptophagus* spp., *Lyctocoris campestris*, *Xylodromus concinnus*, *Lathridius minutus* group).

3. Linked to *Anobium punctatum*, which is itself linked to (1) by eurytopes, what *may* be a hay community (*Apion* and *Sitona* spp., perhaps brought in cut vegetation, and *Typhaea stercorea* and *Ephistemus globulus*, perhaps colonisers of stored hay).

4. Linked into (2) and (3) at various points, what is probably an 'outdoor' and/or background group: *Aphodius* spp., *Anotylus nitidulus*, *A. tetracarinatus*, *Helophorus* spp. and *Carpelimus pusillus* group, leading into:

5. The grain pests. Links from these to *Helophorus* spp. and *Anotylus nitidulus* (regarded as probably of background origin) are surprising. Possibly the grain beetles often entered deposits via dung, together with water beetles from water, and dung dropped onto open surfaces was subsequently invaded by *A. nitidulus*, and two taxa linked to it: *Aphodius* spp. and *Anotylus tetracarinatus*.

Based on percentages of N-G

Basing the analysis in percentage of individuals after subtraction of grain pests produced a clarification of the constellation diagram, giving broadly the same groupings. In view of the relatively limited data for this site, linkages at a value of 0.25 were added to the diagram. These tightened the groupings internally (giving, broadly, groups representing decomposers likely to have occurred in dung and stable manure, house fauna, and grain pests), but added significantly to the links between them. The impression was gained that although the groups were ecologically distinct, they probably often entered deposits together.

At Castle Street, stable manure decomposers appear to have been a distinct component of local insect communities, probably being associated with house fauna from the stable buildings. A large proportion of the fauna probably exploited stable manure after ejection into the open. A range of other habitats was doubtless present, but none were probably very important. Houses for humans may not have contributed much of the fauna. Dung deposited in the open rather than via stable manure may have been invaded by some taxa, and others may represent the fauna of hay. There may have been little regard for cleanliness on many surfaces.

Annetwell Street

Based on percentages of N

The analysis resolved into three groups:

1. The four grain pests, with no significant external linkages.

2. *Anobium punctatum*, with no significant linkages.

2. All the remaining taxa. The complexity of linkages among these, even at $p<0.01$, is such that little structure can be resolved. At this level there is some zonation of the diagram into (a) areas with taxa likely to have represented 'outdoor' habitats together with background fauna and (b) others where 'indoor' species clump. *Cryptophagus*, *Lathridius minutus* group, *Ptinus fur*, *Xylodromus concinnus* and *Lyctocoris campestris* form a separate group of house fauna taxa, connected to the remainder only via *Ptenidium* at $P<0.01$. Stable manure taxa are scattered.

Based on percentages of N-NG

Little change resulted from the re-analysis. The grain pests acquired a connection to the rest of the fauna at $p<0.05$ via *Typhaea stercorea*, which may have lived in hay, or in the drier parts of stable manure, or in stored grain, in any of which it would have found suitable habitats. *Aphodius* was also attached to this grain association, perhaps because members of this genus quickly invaded dung containing the remains of grain pests eaten by stock, which had been dropped on open surfaces. The four house fauna taxa gained external links but lost that to *Ptenidium*. Again, all the remaining taxa formed a single swarm, and *A. punctatum* was isolated. *A. punctatum* had no correlations even approaching significance at $p<0.05$. The main swarm could just be resolved using 3-way linkages, giving groups which may represent decomposers exploiting stable manure or similar material on the one hand, and outdoor habitats and background fauna on the other.

There seems to be little doubt that this analysis reveals a site fauna predominated by a mixture of species from stable manure, perhaps including hay insects and secondary invaders of stable manure in the open, with background fauna. The decomposers seem unlikely to have formed distinctive communities very often at this site. There was no large clearly demarcated house fauna group, and the taxa normally placed in this group may have had mixed origins, arriving in various combinations in stable manure, grain, and from buildings used by humans. The closely-associated house fauna component was limited, and may have comprised taxa able to exist in fairly clean conditions. A number of typical house fauna taxa occurred in less than ten of the samples used in the analysis and were consequently excluded - but the very fact of their rarity suggests limited development of indoor communities. It is not clear whether the grain component originated separately - perhaps in dung which was exploited by a few rapid colonisers before it was cleaned up - or in stable manure.

Summary of results of species association analyses

Although in very general terms taxa had similar relationships at each site, reflecting their ecological requirements and the contrast of indoor and outdoor deposition and dry to moist decaying matter, there were substantial differences in detail, particularly in the clarity with which groupings could be resolved. These differences are believed to reflect substantial differences in site environment and usage. At Annetwell Street, there was evidence of stable manure, but little to suggest that it persisted for long periods in a foul state so as to acquire a rich fauna. Large quantities of foul matter do not seem to have lain in the open very often, and indeed there was little to suggest that persistent outdoor habitats of any kind were normally present (there may have been a few weeds, but much of the outdoor component may have been background fauna). This contrasts with the results for Castle Street, where stable manure decomposers and house fauna, probably from the stable buildings, were fairly clear groups, and there was evidence of filth in the open, perhaps dumped or scattered stable manure. At Lanes 2, a large part of the fauna seems to have lived in the open, with decaying matter on surfaces and a very limited weed flora. Stable manure probably existed locally, but there may more often have been accumulation of litter rather like it, but formed on open surfaces. There may have been little in the way of indoor habitats for insects, a limited house fauna perhaps arriving in poorly-stored feed grain. At Lanes 1, also, there was doubtless some stable manure, but there was rarely much in the insect assemblages to suggest the fauna of buildings, foul matter being allowed to lay in the open. Grain pests may have regularly arrived direct in horse dung here, as perhaps they did at Annetwell Street.

Analyses using multivariate statistics

No clear patterns emerged from analyses using cluster analysis and multidimensional scaling. In some cases there was a tendency for assemblages from the sites to be clumped in cluster analyses, although only to a limited extent. More often, assemblages from all the sites were intermingled, even when single feature types were examined. Multidimensional scaling based on assemblage main statistics where sample N was greater than 35 produced vague results, producing loose overlapping clumps by site for floors, for example, but an apparently random distribution for pits. It appears that the heterogeneous nature of the insect assemblages within sites and feature types masked any systematic trends which might otherwise have been detectable using conventional multivariate methods.

Conclusions regarding specific topics

In the introduction to this report five questions concerning the sites were identified; conclusions regarding them are brought together here. The various analyses employed in the study have strongly supported the initial hypothesis of gradation in land use, and consequently ecological conditions, across the four sites, but some surprising aspects have emerged.

1. Can differences in human activity between the sites be deduced? The answer to this question is yes, but largely in terms of the way animals were kept, levels of cleanliness, and the evidence for human living quarters. In addition, there appears to have been a different level of exploitation of peatland or heathland resources at the sites.

2. Can variations in ecological conditions (and thus human living conditions) be determined? This question is very much tied into (1), because of the nature of the detectable activities at the sites. The study supports the initial model, suggesting considerable variations in the amount of filth tolerated at the sites, variations perhaps related to the presence (or quality of) human living quarters. There were differences in the importance of (presumably temporary) aquatic habitats at the sites, always supposing that most of the aquatics were not imported, either in water for stock, or actually within the bodies of livestock, having been accidentally drunk.

3. Can the vegetation of the sites be reconstructed from insects? The answer must be 'no', not because of failure of the analyses, but rather because there appears to have been almost no vegetation at any of the sites. Many plant-associated insects were clearly imported in raw materials such as turf and hay. There may possibly have been rare, scattered, weeds, and there may have been overgrazed and trampled turf at the Lanes 1 sites, but the evidence is not very convincing.

4. Can domestic occupation (including military living quarters) be detected at any of the sites? There is a considerable problem of visibility of human living quarters at these sites, in strong contrast with, for example, some Anglo-Scandinavian phases at Coppergate, York (Kenward and Hall 1995). Much of the 'house fauna', which stood as clear evidence of deposition within buildings used by humans at Coppergate, may in Carlisle have been deposited in stable manure, or in spoiled grain and hay. This was certainly the case at two other Roman sites submitted to extensive analysis of insect remains: Tanner Row in York (Hall and Kenward 1990) and the fort at Ribchester (Large *et al.* 1994). If there *was* accommodation for humans at The Lanes or Castle Street, it seems to have been invisible or indistinguishable from stables. The reason for invisibility would be a high standard of cleanliness in well-constructed houses, so that few insects could colonise and the corpses of any that did would not accumulate over long periods in floor layers. For Anglo-Scandinavian Coppergate, it was argued that the presence of human fleas (*Pulex irritans*) and lice (*Pediculus humanus*) *together* indicated human domestic occupation. Records of fleas and lice are rather rare at the Carlisle sites, although fleas were noted fairly regularly from Lanes 2. Unfortunately, as discussed above, the lack of records may be an artefact of recording, rather than reflecting real differences in their former abundance; this may be complicated by inter-site variations in the suitability of average preservational conditions for the very fragile lice. Whatever the cause, these parasites offer no clarification of the question of living accommodation. There is, however, one piece of evidence from another parasite - the bed bugs (*Cimex ?lectularius* L.) from Annetwell Street, which - if the slight possibility that they are related taxa from doves or bats is eliminated - clearly indicate overnight occupation by sleeping humans.

5. Can stabling be differentiated from (a) close-corralling (e.g. overnight) and (b) the keeping of stock in larger paddocks (probably with supplementary feed)? These three methods of confining stock can be seen as forming a continuum, from tightly closed stables through open-sided ones, to pens of increasing size, to paddocks and open fields. The evidence from Carlisle suggests that most of this range of methods was employed in the vicinity of the fort. Although unfortunately the evidence cannot be said to be certain, it appears that there were conventional stables at Castle Street, and to varying extents at the other sites. Dung appears to have dropped onto the ground at Annetwell Street and the two sets of Lanes sites. Lanes 2 may have at least occasionally seen the penning of horses in the open, and Lanes 1 their confinement in larger paddocks.

Acknowledgements

I am grateful to the many people who helped in collecting, handling, storing and transporting preparing samples from these sites, to Enid Allison, Frances Large and

Lesley Morgan (of, or formerly of, the EAU) for collaboration in recording the insect assemblages. Mike McCarthy, John Zant and Ian Caruana (of the former Carlisle Archaeology Unit) are thanked for providing information. The work on species associations was carried out using methods developed in collaboration with John Carrott. Terry Crawford and Calvin Dytham (Department of Biology, University of York) are thanked for advice concerning statistical methods. Allan Hall (EAU) offered numerous useful comments on the text. The work was funded mainly by English Heritage, through the Ancient Monuments Laboratory and the Carlisle Archaeology Unit; further support was given by Palaeoecology Research Services, the contract branch of the EAU.

References

NOTE: most of the Reports from the Environmental Archaeology Unit, York referenced here are available online at http://www.york.ac.uk/inst/chumpal/EAU-reps/eaureps-web.htm

Aitken, A. D. (1975). *Insect travellers* **I**, *Coleoptera*. London: HMSO.

Allison, E. P., Hutchinson, A., Jones, A. K. G., Kenward, H. K. and Morgan, L. M. (1991a). *passim* in McCarthy, M. R., The structural sequence and environmental remains from Castle Street, Carlisle: excavations 1981-2. *Cumberland and Westmorland Antiquarian and Archaeological Society Research Series* **5** (fascicule 1).

Allison, E. P., Hutchinson, A., Kenward, H. K., Jones, A. K. G., and Morgan, L. M. (1991b). *passim* in volume and fiche in McCarthy, M. R., The Roman waterlogged remains and later features at Castle Street, Carlisle: excavations 1981-2. *Cumberland and Westmorland Antiquarian and Archaeological Society Research Series* **5** (main volume).

Allison, E., Carrott, J., Hall, A., Kenward, H., Large, F., McKenna, B. and Robertson, A. (1997). Publication draft: Plant and invertebrate remains from Iron Age and Romano-British deposits at North Cave, East Yorkshire. *Reports from the Environmental Archaeology Unit, York* **97/37**, 43 pp.

Bletchly, J. D. (1967). *Insect and marine borer damage to timber and woodwork*. London: HMSO.

Brooks, C. M., McCarthy, M. R. and Kenward, H. K. (1996). *A research design for insect remains from the northern end of The Lanes, Carlisle, Cumbria*. Carlisle: Carlisle City Council.

Girling, M. and Robinson, M. (1988). The insect assemblages from the pond sediments at Site 30, Wharram Percy, Yorkshire. *Ancient Monuments Laboratory Report* **36/88**.

Hall, A. R. and Kenward, H. K. (1990). Environmental evidence from the Colonia: General Accident and Rougier Street. *The Archaeology of York* **14** (6), 289-434 + Plates II-IX + Fiche 2-11. London: Council for British Archaeology.

Hickin, N. E. (1975). *The insect factor in wood decay* (3rd edn. revised by R. Edwards). London: Associated Business Programmes.

Hinton, H. E. (1945). *A monograph of the beetles associated with stored products* **1**. London: British Museum (Natural History).

Kenward, H. K. (1975). Pitfalls in the environmental interpretation of insect death assemblages. *Journal of Archaeological Science* **2**, 85-94.

Kenward, H. K. (1976). Reconstructing ancient ecological conditions from insect remains: some problems and an experimental approach. *Ecological Entomology* **1**, 7-17.

Kenward, H. K. (1978). The analysis of archaeological insect assemblages: a new approach. *The Archaeology of York* **19** (1), 1-68 + plates I-IV. London: Council for British Archaeology.

Kenward, H. K. (1992 for 1991). Rapid recording of archaeological insect remains - a reconsideration. *Circaea, the Journal of the*

Association for Environmental Archaeology **9**, 81-8.

Kenward, H. (1998). Data archive: insect assemblages from Annetwell Street, Carlisle. *Reports from the Environmental Archaeology Unit, York* **98/1**, 107 pp.

Kenward, H. (1999). Data archive: Insect assemblages from Annetwell Street, Carlisle (revised edition). *Reports from the Environmental Archaeology Unit, York* **99/32**, 126 pp.

Kenward, H. (in press). Pubic lice (*Pthirus pubis* (L.)) were present in Roman and Medieval Britain. *Antiquity*.

Kenward, H. K., Allison, E. P., Dainton, M., Kemenes, I. K. and Carrott, J. B. (1992). Evidence from insect remains and parasite eggs from Old Grapes Lane A, The Lanes, Carlisle: Technical report. *Ancient Monuments Laboratory Report* **78/92**.

Kenward, H. K., Dainton, M., Kemenes, I. K. and Carrott, J. B. (1992a). Evidence from insect remains and parasite eggs from the Old Grapes Lane B site, The Lanes, Carlisle: Technical report. *Ancient Monuments Laboratory Report* **76/92**.

Kenward, H. K., Dainton, M., Kemenes, I. K. and Carrott, J. B. (1992b). Evidence from insect remains and parasite eggs from the Lewthwaites Lane A site, The Lanes, Carlisle: Technical report. *Ancient Monuments Laboratory Report* **77/92**.

Kenward, H. K. and Hall, A. R. (1995). Biological evidence from Anglo-Scandinavian deposits at 16-22 Coppergate. *The Archaeology of York* **14** (7), 435-797 + xxii + loose figures. York: Council for British Archaeology.

Kenward, H. and Hall, A. (1997). Enhancing bioarchaeological interpretation using indicator groups: stable manure as a paradigm. *Journal of Archaeological Science* **24**, 663-673.

Kenward, H. K., Hall, A. R. and Jones, A. K. G. (1980). A tested set of techniques for the extraction of plant and animal macrofossils from waterlogged archaeological deposits. *Science and Archaeology* **22**, 3-15.

Kenward, H. K. and Large, F. D. (1986). *Insect remains from the Annetwell Street site, Carlisle. Report 1. Selected samples from Level X.* Archive deposited at Environmental Archaeology Unit, Carlisle Archaeology Unit and Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **86/20**]

Kenward, H. and Large, F. (1998). *Insects in urban waste pits in Viking York: another kind of seasonality. Environmental Archaeology* **3**, 35-53.

Kenward, H., Large, F. and Carrott, J. (1998). The archaeological significance of insect and other invertebrate remains from Keay's and Law's Lanes, The Lanes, Carlisle. Technical report. *Reports from the Environmental Archaeology Unit, York* **98/32**, 126 pp.

Kenward, H. K. and Morgan, L. (1985a). *Insect remains from the Castle Street site, Carlisle. Archive report 1. Periods 2 and 3.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **85/22**]

Kenward, H. K. and Morgan, L. (1985b). *Insect remains from the Castle Street site, Carlisle. Archive report 2. Periods 3/4-5.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **85/23**]

Kenward, H. K. and Morgan, L. (1985c). *Insect remains from the Castle Street site, Carlisle. Archive report 3. Periods 6 to 11 and post-Roman.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **85/24**]

Large, F., Kenward, H., Carrott, J., Nicholson, C. and Kent, P. (1994). Insect and other invertebrate remains from the Roman fort at Ribchester, Lancashire (site code RB89): Technical report. *Reports from the Environmental Archaeology Unit, York* **94/11**, 171 pp.

Large, F. D. and Kenward, H. K. (1987a). *Insect remains from the Annetwell Street site, Carlisle. Report 2. Samples from Level VI.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **87/14**]

Large, F. D. and Kenward, H. K. (1987b). *Insect remains from the Annetwell Street site, Carlisle. Report 3. Samples from Level IV.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **87/15**]

Large, F. D. and Kenward, H. K. (1987c). *Insect remains from the Annetwell Street site, Carlisle. Report 4. Period 3A structures.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **87/16**]

Large, F. D. and Kenward, H. K. (1988a). *Insect remains from the Annetwell Street site, Carlisle. Report 5. Period 3 structures.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **88/15**]

Large, F. D. and Kenward, H. K. (1988b). *Insect remains from the Annetwell Street site, Carlisle. Report 6. Samples from Period 3 roads.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **88/16**]

Large, F. D. and Kenward, H. K. (1988c). *Insect remains from the Annetwell Street site, Carlisle. Report 7. Miscellaneous samples from Period Pre-3 to Period 4.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **88/17**]

Large, F. D. and Kenward, H. K. (1988d). *Insect remains from the Annetwell Street site, Carlisle. Report 8. Level X structures.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **88/18**]

Large, F. D. and Kenward, H. K. (1988e). *Insect remains from the Annetwell Street site, Carlisle. Report 9. Miscellaneous samples from Level VII, Level IX, Level X and Period 3.* Deposited at Carlisle Archaeological Unit, Ancient Monuments Laboratory. [*Reports from the Environmental Archaeology Unit, York* **88/19**]

Lindroth, C. H. (1985). The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna *Entomologica Scandinavica* **15**(1). Leiden and Copenhagen: Brill.

McCarthy, M. R. (1991a). The structural sequence and environmental remains from Castle Street, Carlisle: excavations 1981-2. *Cumberland and Westmorland Antiquarian and Archaeological Society Research Series* **5** (fascicule 1).

McCarthy, M. R. (1991b). The Roman waterlogged remains and later features at Castle Street, Carlisle: excavations 1981-2. *Cumberland and Westmorland Antiquarian and Archaeological Society Research Series* **5** (main volume).

McCarthy, M. R., Padley, T. G. and Henig, M. (1982). Excavations and finds from The Lanes, Carlisle. *Britannia* 13, 79-89 + Plates I-IV.

Milne, A. and Laughlin, R. (1956). Biology and ecology of the garden chafer, *Phyllopertha horticola* (L.). 1. The adult and egg production. *Bulletin of Entomological Research* **47**, 7-22.

Ormerod, E. A. (1898). *Handbook of insects injurious to orchard and bush fruits with means of prevention and remedy.* London: Simpkin, Marshall, Hamilton, Kent and Co.

Robertson, A., Tomlinson, P. and Kenward, H. K. (1989). Plant and insect remains from Coffee Yard, York. *Reports from the Environmental Archaeology Unit, York* **89/12**.

Taylor, T. H. and Thompson, H. W. (1928). A garden chafer attack. *Annals of Applied Biology* **15**, 258-263.