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Insect remains from the fills of two Roman wells at Gross Gerau, Hessen, Germany

by Harry Kenward and Frances Large

Summary

Samples from the fills of two Roman wells at Gross Gerau, Hessen, Germany, have been analysed for insect remains. The material had been processed using 50 micron-mesh sieves. The assemblage from Well 25 was large and diverse, and was quantified. It appeared to have formed slowly during a period of disuse, and to reflect sandy soils with some dung and litter. There was rather little evidence for trees and dead wood, and fauna strongly associated with human occupation or the housing of stock was very restricted.

The assemblage from Well 36 was substantially smaller and was not identified in detail, but subjectively it appeared to have similar implications to that from Well 25.

Keywords: GROSS GERAU; HESSEN; GERMANY; ROMAN; WELL; INSECTS; BEETLES; BUGS; ENVIRONMENT; ABANDONMENT

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Introduction

Gross Gerau is situated about 25 km south of Frankfurt, Hessen, in the broad, relatively low-lying Rhine valley. This report deals with insect remains from the fills of two wells (Well 25 and Well 36) located in the back yards of houses in the *vicus* of the Roman fort. At least some layers in the fills of both wells gave preservation of biological remains, including insects, by anoxic waterlogging. The fills of Well 25 are believed to have formed during the second to third centuries AD, and those of Well 36 during the third to fourth centuries.

This study was carried out at the instigation of Angela Kreuz of the Institut der Kommission für Archäologische Landesforschung in Hessen. Following a brief assessment by the EAU in 1995, a project was commissioned to investigate the material for its archaeological implications to whatever degree was possible within a set budget. Sieved residues from two samples were submitted: Sample 13 from Well 25, and Sample 34 from Well 36.

Methods

Practical methods: The samples had been sieved to produce 500 µm and 1 mm fractions before transport to England. To reduce the task of sorting to manageable proportions, insects were extracted from the sieved residue using paraffin flotation (broadly as described by Kenward *et al.* 1980). The quantity of material so recovered was still much too large to be examined within project constraints (both financial and the time available within the authors' work programme) so only a proportion of the flot was sorted; this was effected by tipping alternate aliquots (a) into a square 'Petridish' for sorting and (b) into a jar for storage without sorting. Sorting was carried out fairly rapidly, insect material being picked out and placed on squared damp filter paper in a dish for subsequent identification. The unsorted fraction was quickly scanned for remains of any significant additional taxa.

For Sample 13, recording was essentially semi-quantitative, the minimum number of individuals (MNI) represented by the recovered remains being estimated, although numbers of individuals were counted where this could be done quickly. The scale employed for quantification was that introduced by Kenward *et al.* (1986) and evaluated by Kenward (1992); numbers of individuals represented by the extracted fossils were estimated as 1, 2, 3 'several' (about 4-9) or 'many' (10 or more). Where very large numbers were present an estimate was made. For the calculation of sample statistics, 'several' was converted to 6 and 'many' to 15; this conversion is discussed by Kenward (1992), who concludes that it produces acceptably accurate results.

Semi-quantitative recording was considered particularly appropriate to this material in view of (a) the method of extraction, 500µm mesh having been used rather than the 300µm (sometimes 250µm) normally employed for insect remains, and (b) the division of the sieved material described above. An unknown proportion of the smaller fragments will have been lost. The method of sorting and the restraint on precision of identification imposed by shortage of time also made semi-quantitative recording appropriate as did, it transpired, the nature of the insect assemblage (it appears very weakly related to human activity, see below, and thus likely to give little *archaeological* information in a strict sense).

No attempt was made to identify every fragment, especially of the less frequent taxa; the objective was to obtain archaeological information, not to compile a catalogue of species for biogeographical or climatological purposes. Instead, the abundant taxa, and those considered likely to give the most information, were targeted for close identification. Some groups were particularly difficult to identify given the available reference material. Some weeks would need to be spent working with the collection of a major museum (in Britain, The Natural History Museum, London) in order to name even a substantial proportion of the Chrysomelidae, Curculionidae and Homoptera from Gross Gerau. However, those species believed to have a narrow hostplant range which were present in significant numbers have been afforded particular attention for identification, admittedly with variable success.

Interpretative methods: Interpretation followed methods based on those outlined by Kenward (1976), subsequently modified and developed to a great extent by, for example, Kenward (1988), Hall and Kenward (1990) and Kenward and Hall (1995). The information from direct inspection of the list of species, their abundance, and documented ecology, is simplified using a series of parameters designed to characterise major ecological groups.

The measured parameters include: (a) an estimate of species-richness (or diversity), α of Fisher *et al.* (1943), for the whole assemblage and for some of its components; and (b) proportions of `outdoor' species (OB), aquatics (W), waterside species (D), phytophages (plant feeders, P), species associated with dead wood (L), moorland/heathland taxa (M), and decomposers (species associated with decomposing matter of some kind). Decomposers are subdivided into (a) species primarily associated with somewhat dry habitats (RD), (b) those found mostly in rather, to very, foul habitats (RF), and (c) a third group of species, often eurytopic, which are not easily assigned to the RF or RD groups. The category 'RT' represents the sum of all three of these groups of decomposers.

A further ecological component which was quantified was the synanthropes, i.e. those species favoured by human activity. Taxa have been assigned codes for their estimated degree of synanthropy as follows: 'sf' - facultative synanthrope, common in 'natural' habitats but clearly favoured by artificial ones; 'st' - particularly favoured by, and typical of, artificial habitats but believed to be able to survive in nature in the long term; 'ss' - strong synanthrope, essentially dependent on human activity for survival. These have been quantified by site to give corresponding categories (SF, ST, SS). All of these have been summed to give the category 'SA'. Free-living phytophages and open-field dung beetles favoured by human activity are not included. It is strongly emphasised that these codes are in many cases only a first guess which may be modified.

Although perhaps seemingly illogical, the quantification of an `outdoor' component in cases where largely natural or semi-natural assemblages are being analysed is useful when working with any deposits associated, even if rather indirectly, with human occupation.

The abundance of these ecological groups within an assemblage, or for a site as a whole, is discussed against the background of values for many other assemblages from a large number of sites. Thus, % N OB = 30 is a high value, but % N RT = 30 is low; while % N W or RF is high at 10.

The index of diversity offers a guide to the presence or absence of remains of insects which bred in or on the developing deposit (autochthones), low values indicating breeding communities, high ones faunas of mixed origins. Note that `significantly' low values differ for the various components of assemblages; the more inherently rich a component is, the higher the value of the index of diversity for a living community will be. Thus, `outdoor' communities associated with natural vegetation tend to give a high value of α, while very specialised communities, such as those of decaying matter deposited by humans, or stored grain, have low or very low ones.

The use of semi-quantitative data for calculating these statistics is discussed by Kenward (1992), who argued that it is, with caution, justifiable, especially if the numbers of individuals of very abundant taxa are estimated approximately rather than recorded as 'many'.

The following sources have principally been used for information concerning the biology and ecology of the recorded species: for Hemiptera, Southwood and Leston (1959) and Wagner (1966-7); for Coleoptera, Fowler (1887-91), Freude *et al.* (1964-83), Lindroth (1985-6), and various parts of the Royal Entomological Society's *Handbooks for the identification of British insects* (London).

Results

A complete list of invertebrates from Sample 13 is presented in Table 1. The species list is given in rank order in Table 2. Numbers have been converted from the semi-quantitative record for presentation. For technical reasons associated with the database system used for data input and retrieval, nomenclature follows Kloet and Hincks (1964 and 1977) for the Hemiptera and Coleoptera respectively, with interpolation of non-British taxa, for which Wagner (1966-7) and Freude *et al.* (1964-83) are followed. The nomenclature of Wagner and Freude *at al.* has been added to British species where differing from Kloet and Hincks to assist workers familiar with their systems. Lucht (1987), the current checklist for the Coleoptera of Central Europe, is unfortunately not available to the authors.

Main statistics for the assemblage of adult beetles and bugs (excluding Aphidoidea) are given in Table 3.

Discussion

Insect, mainly adult beetle and bug, remains were very abundant in the material provided. Preservation was generally extremely good, with retention of scales and hairs in many fossils. Colours were generally as seen in modern museum material. Much of the fragmentation observed may have been an inevitable consequence of sieving rather than an indication of taphonomic conditions in the deposit during and after formation. A few taxa were represented only by rare small fragments which could not be closely identified (eg. *Carabus* sp.), but mostly where identifications to family or genus were made it was as a result of the inherent difficulty of identifying Central European material of the group concerned (eg. *Rhyparochromus* sp., *Trapezonotus* sp. and Miridae among the bugs and, among the beetles, the weevils, Curculionidae).

Before discussing the implications of the remains it is necessary to consider whether the mesh size used has caused a significant bias in the range of remains recovered. Such bias, although probably present, may in fact be limited; there are sclerites of a wide range of small taxa, and some 'missing' ones (i.e. those which are common in British Roman deposits but absent from the Gross Gerau samples) are *not* small enough for their major sclerites to pass through a 500 μm mesh. The small number of remains of certain beetles, particularly Ptiliidae, may result from the large mesh size, however.

Sample 13 from Well 25 gave a very much larger assemblage than Sample 34 (Well 36), and will be discussed first. Most of the fauna fell into a narrow range of ecological groups; some habitats being conspicuously poorly represented. There were very few tree-associated taxa, for example, and only a small number of species exploiting dead wood (well below 1%). The latter included the two stag beetles *Lucanus cervus* and *Dorcus parallelipipedus*, both represented by remains of single individuals. The only other species primarily associated with dead wood was a single tentatively-identified specimen of *Anobium punctatum*, the woodworm beetle. The rarity of the woodworm, and the lack of any other species associated with fairly dry structural timber, seems surprising in a deposit supposedly associated with buildings.

The assemblages were dominated by 'outdoor' forms, i.e. those associated with natural or semi-natural habitats and not able to live in buildings or in large artificial accumulations of decaying matter. These contributed over half of the individuals and species. There were few aquatics (about 3%), and those which were present are highly mobile species. The most abundant member of a 'water beetle' group, *Helophorus nubilus*, is in fact terrestrial!

The beetles and bugs indicate dry, well-drained, soils with an incomplete vegetation cover. Many of the species are particularly associated with sandy places or other sharply-drained soils. Amongst the bugs, the following fell in this category: *Legnotus ?limbosus* (one individual); *?Geocoris ater* (1); *Beosus maritimus* (1); *Trapezonotus* sp. ('many'); *Rhyparochromus* sp. ('many'). The following beetles from Well 25 are strongly associated with sand: *Metabletus foveatus* ('many' individuals); *Opatrum ?sabulosum* (1); *Crypticus quisquilius* ('several'); and *Notoxus monoceros* ('several'). Some others are favoured by sandy soils: *Metabletus truncatellus* ('several'); *Helophorus nubilus* (14); and *Rhyssemus germanus* (3).

Plant feeding beetles and bugs indicated hosts as follows: nettles (*Urtica* sp.) from *Brachypterus glaber* (2) and *Cidnorhinus quadrimaculatus* ('many'); crucifers (Cruciferae) from *Ceutorhynchus ?contractus* (1) and *C. ?erysimi* ('many'); mallows and their close relatives (*Malva* and *Althea* spp.) from *Apion rufirostre* ('several') and *A. aeneum* ('many'); Polygonaceae from *?Gastrophysa* sp. ('several') and *Chaetocnema ?concinna* (8); and Papilionaceae from *Sitona* spp. (7 individuals, 4 species). Also in this category is the highly distinctive chafer *Valgus hemipterus* ('several'), noted from other sites by Friedrich (1987) and Lemdahl (1990a).

The decomposers indicated a range of habitats. Beetles associated with herbivore dung were fairly numerous, but not present in the enormous quantities seen, for example, in samples from the Bronze Age well at Wilsford, England (Osborne 1969; 1989). However, the great excess of scarabaeid dung beetles over other likely dung dwellers seen at Wilsford was echoed at the present site. There were no remains of *Platystethus arenarius* or *Sphaeridium* species for example, and dung-exploiting *Cercyon* species were rare. It is likely that this resulted from the mode of formation of the death assemblage, which it is suggested was to a substantial degree by gradual accumulation of 'background fauna' (see below), and as a result of which the larger and rather more clumsy scarabaeids may have been preferentially trapped by the well. The more abundant 'dung beetle' species at Gross Gerau were *Geotrupes ?stercorarius* (4 individuals); *Aphodius granarius* (4); an unnamed *Aphodius* species ('several'); and *Onthophagus ?ovatus* (11). There were also smaller numbers of several other species of these genera. It should be noted that some *Aphodius*, including *A. granarius*, are able to exploit foul decaying matter other than dung. Probably there was grazing land in the surroundings, but there is no reason to suggest that stock were kept in significant numbers near to (i.e. within a hundred metres or so of) the well as the analysed fill formed.

Most of the other decomposers were species found in natural or semi-natural habitats as well as in stronger association with humans (in large accumulations of organic matter ranging from hay to foul matter). Facultative synanthropes were present in modest numbers (less than 10% of the assemblage), but typical and strong synanthropes were barely represented (3% and 0.3% respectively); there was no synanthrope community of the kind seen at most occupation sites of Roman or later date in Britain (where most of the relevant analyses have been made). There were thus no good indications of the presence of large artificial accumulations of decomposing matter. There is nothing to suggest stable manure, for example, in contrast to many British Roman sites (e.g. Hall and Kenward 1990; 1998; Kenward and Hall 1997). This is very surprising at a Roman site such as Gross Gerau. Similarly, and perhaps related to the lack of stable manure (Kenward and Hall *op. cit.*), no grain pests were recorded, and there were no species associated with the storage of other foods. The lack of grain pests would seem most remarkable in a Roman site of more than the lowest status if it were actually occupied at the time the deposit formed.

In view of these observations, what does the fauna represent? Did it accumulate gradually during human occupation, or as a result of some particular event, such as backfilling, or did it enter by natural processes after the abandonment of the site, or at least a major change of use? If the first or the last was the case, did the well function as a pitfall trap, or did the insects enter by some other route - by crawling past a barrier such as a well rim, or in flight, or in drainage water, for example?

There is, as suggested above, no reason to suppose that the fill examined included dumped refuse such as stable manure or domestic waste. This is in marked contrast to two Roman wells in York (Hall *et al.* 1980; Kenward *et al.* 1986). At the stage represented by Sample 13, the well probably did not function as a pitfall trap. Although numerous Carabidae were recorded, the abundant specimens of larger species typically seen in pitfalls were not present, and other insects commonly found in pitfalls (e.g. large Silphidae and large, active Staphylinidae, particularly *Philonthus*, *Staphylinus* and *Quedius* species) were rare. A well may be expected to have been surrounded by a rim of some kind and if this was constructed of masonry it would presumably have been mortared and thus have represented a barrier to ground-living insects.

The remains were probably not dumped in surface soil. The numbers of insects seem far too large for the fauna to represent solely the current and recently dead fauna of a sandy soil, in which decay of remains would be rapid and thus numbers of corpses in good condition fairly small. Elaterid larvae, many of which live in soil, were present, but in quite small numbers, and there were few beetle or other insect larvae, ants or mites, all expected in considerable numbers in soil where adult beetles were abundant. Similarly, few earthworm egg capsules, and no remains of other soil organisms such as nematode cysts, were seen.

Thus it seems that much of the fauna either entered directly of its own accord, and thus (in view of the huge numbers) over a very long period of time, or in runoff water such as drainage from a roof or yard area. Drainage from the ground would be expected to have introduced more large ground beetles, however, so roof drainage would need to be invoked. Roof drainage during occupation would be expected to have produced far more synanthropes. There is no reason to suspect that remains entered in bird droppings, a normal component of roof-derived material (Kenward 1976); their condition was quite wrong for this, with no sign of rolling or compression. Direct entry to the deposit would have been in flight, at least a proportion of the flying insects entering the space above the mouth of the well becoming trapped, or by crawling, in which case species able to negotiate steep faces (i.e. able to climb up the postulated rim of the well) might be more common than those less good at climbing. The range and relative abundances of the recovered insects would in fact accord well with gradual entry in flight and by crawling over a barrier.

It was postulated by Hall *et al.* (1980) that the fills of the Roman Well at Skeldergate in York, England, had a compound origin as a mixture of the fauna already present in the use-phase deposits with that introduced in a series of dumps. While it is possible that this happened at Gross Gerau (relatively barren surface soil being dumped and mixed with the pre-existing remains), and while it would account for the high concentration of excellently-preserved fossils combined with a limited synanthropic fauna, there is no other evidence in favour of it. On the contrary, the lack of significant numbers of soil organisms and of partly-rotted remains argues to the contrary (see above).

Sample 34 (Well 36) gave a much smaller assemblage of remains than Sample 13; the subjective impression was of a very similar fauna with the same implications, but it was not possible to make a detailed species list within project constraints.

Conclusion

The study of the insect remains from one sample from Well 25 has lead to the conclusion that the deposit formed gradually, insects entering naturally during a period when there was little human activity in the surroundings. There was no evidence of dumping of any kind of material and the numbers of fossils were too large for an origin in soil used to backfill the well. The fauna of the sampled layer in Well 36 seems to have similar implications. This conclusion can be tested against the evidence from the sediments themselves, plant remains and the stratigraphic record.

This study has been limited by considering only the fauna from single layers in the wells. Insects have been recorded from other Roman sites in Germany by several workers (eg. Friedrich 1987; Koch 1970; 1971; Lemdahl 1990b; Schimitscheck 1975), but these studies, like the present one, have been on a relatively restricted scale. Very much more information can be obtained from well fills if vertical sequences of samples are analysed in detail, as was possible for example for the Roman well at Skeldergate, York, England (Hall *et al.* 1980). Similarly, for sites with more widespread preservation by anoxic waterlogging, an immense amount of information can be recovered by analysis of large numbers of samples, especially when results of botanical and entomological studies are closely integrated (as was done for hundreds of samples from Roman Tanner Row and Anglo-Scandinavian Coppergate, York: Hall and Kenward 1990; Kenward and Hall 1995). It is to be hoped that investigations of waterlogged urban deposits on a large scale will eventually be possible wherever they occur throughout Europe. Apart from the information gained about the individual sites, a comparative study would doubtless produce many fascinating and archaeologically-significant results.

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Table 1. Complete list of invertebrate taxa from Sample 13, Well 25, Gross Gerau, with the ecological codes assigned to them. Order and nomenclature follow Kloet and Hincks (1964-77) . Adult beetles and bugs (other than Aphidoidea and Coccidoidea) are listed first, followed by other invertebrates, the latter being marked '' and not contributing to the statistics in Table 3. Where both secure and tentative identifications for a given taxon were recorded, only the former are listed here. * = not used in calculating assemblage statistics (Table 2). For explanation of ecological codes see Table 4.*

DIPLOPODA	
*Diplopoda sp.	u
HEMIPTERA	
Sciocoris sp.	oa-p
Legnotus ?limbosus (Geoffroy)	oa-p
Sehirus ?dubius (Scopoli) [*Canthophorus*]	oa-p
*Pentatomidae sp. (nymph)	oa-p
Pentatomoidea sp.	oa-p
?Coriomeris sp.	oa-p
Heterogaster cathariae (Geoffroy)	oa-p
?Geocoris ater (Fabricius)	oa-p
Nysius sp.	oa-p
Beosus maritimus (Scopoli)	oa-p
Rhyparochromus sp.	oa-p
Trapezonotus sp. (*arenarius* complex)	oa-p
Stygnocoris sp.	oa
Scolopostethus spp.	oa-p
Lygaeidae sp.	oa-p
Miridae spp.	oa-p
Saldula sp.	oa-d
Saldidae sp.	oa-d
Corixidae sp.	oa-w
Auchenorhyncha spp.	oa-p
Psylloidea sp.	oa-p
*Hemiptera sp. (nymph)	u
*Aphidoidea sp.	u
DIPTERA	
*Syrphidae sp. (larva)	u
*Siphonaptera sp.	u
*Diptera sp. (adult)	u
*Diptera sp. (puparium)	u
HYMENOPTERA	
*Formicidae sp.	u
*Apoidea sp.	u
*Hymenoptera sp.	u
COLEOPTERA	
Carabus sp.	oa
Nebria sp.	oa
Clivina fossor (Linnaeus)	oa
Trechus ?quadristriatus (Schrank)	oa
Trechus micros (Herbst) [*Trechoblemus*]	u
Asaphidion flavipes (Linnaeus)	oa
Bembidion properans Stephens	oa
Bembidion spp.	oa
Tachys sp.	oa
Pterostichus ?cupreus (Linnaeus) [*Poecilus*]	oa
Pterostichus melanarius (Illiger)	ob
Pterostichus sp.	ob
Calathus ambiguus (Paykull)	oa
Calathus fuscipes (Goeze)	oa
Calathus sp.	oa
?Agonum sp.	oa
Amara ?aenea (Degeer)	oa
Amara ?bifrons (Gyllenhal)	oa
Amara spp.	oa
Harpalus spp.	oa
Panagaeus cruxmajor (Linnaeus)	oa
Metabletus foveatus (Fourcroy) [*Syntomus*]	oa
Metabletus truncatellus (Linnaeus) [*Syntomus*]	oa
Carabidae spp. and spp. indet.	ob
Agabus sp.	oa-w
Helophorus nubilus Fabricius	oa
Helophorus sp.	oa-w
?Coelostoma orbiculare (Fabricius)	oa-w
Cercyon analis (Paykull)	rt-sf
Cercyon atricapillus (Marsham)	rf-st
Cercyon terminatus (Marsham)	rf-st
Megasternum obscurum (Marsham) [*boletophagum*]	rt
Cryptopleurum minutum (Fabricius)	rf-st
Hydrobius fuscipes (Linnaeus)	oa-w
Hydrophilinae spp.	oa-w
Acritus nigricornis (Hoffmann)	rt-st
Onthophilus striatus (Forster)	rt
Histerinae sp.	rt
Ochthebius spp.	oa-w
Hydraena spp.	oa-w
Acrotrichis sp.	rt
Leiodidae sp.	u
Catops sp.	u
?Colon sp.	u
Catopinae sp.	u
Silphidae sp.	u
Scydmaenus sp.	u
Micropeplus fulvus Erichson	rt
Micropeplus tesserula Curtis [*Arrhenopeplus*]	rt
Metopsia retusa (Stephens) [*clypeata*]	u
Proteinus sp.	rt
Acidota sp.	oa
Lesteva sp.	oa-d
?Dropephylla sp.	u

Omalium ?rivulare (Paykull)	rt-sf
Omalium sp.	rt
Omaliinae sp.	rt
Coprophilus striatulus (Fabricius)	rt-st
Carpelimus ?bilineatus Stephens	rt-sf
Carpelimus sp.	u
Platystethus cornutus (Gravenhorst)	oa-d
Platystethus nitens (Sahlberg)	oa-d
Anotylus complanatus (Erichson)	rt-sf
Anotylus nitidulus (Gravenhorst)	rt-d
Anotylus rugosus (Fabricius) [*Oxytelus*]	rt
Anotylus sculpturatus group [*Oxytelus*]	rt
Stenus spp.	u
Paederus sp.	oa
Lathrobium spp.	u
?Astenus sp.	rt
Rugilus sp. [*Stilicus*]	rt
Paederinae spp.	u
Leptacinus spp.	rt-st
Gyrohypnus fracticornis (Muller)	rt-st
Gyrohypnus sp.	rt
Xantholinus gallicus or *linearis*	rt-sf
Xantholinus longiventris Heer	rt-sf
Xantholininae sp.	u
Philonthus spp.	u
Philonthus or *Gabrius* sp.	u
Quedius ?cinctus (Paykull) [*Quedionuchus*]	rt
Quedius sp.	u
Staphylininae sp.	u
Mycetoporus spp.	u
Sepedophilus sp. [*Conosoma*]	u
Tachyporus spp.	u
Tachinus ?signatus Gravenhorst [*rufipes*]	u
Cordalia obscura (Gravenhorst)	rt-sf
Falagria sp.	rt-sf
Aleocharinae spp.	u
Lucanus cervus (Linnaeus)	l
Dorcus parallelipipedus (Linnaeus) [*parallelopipedus*]	l
Trox scaber (Linnaeus)	rt-sf
Geotrupes ?stercorarius (Linnaeus)	oa-rf
Geotrupes ?vernalis (Linnaeus) [*Trypocopris*]	oa-rf
Aphodius ?contaminatus (Herbst)	oa-rf
Aphodius granarius (Linnaeus)	ob-rf
Aphodius ?sus (Herbst) [*Heptaulacus*]	oa
Aphodius spp.	ob-rf
Oxyomus sylvestris (Scopoli) [*silvestris*]	rt-sf
Rhyssemus germanus (Linnaeus)	oa
Onthophagus ?ovatus (Linnaeus)	oa-rf
Cetonia aurata (Linnaeus)	oa
Valgus hemipterus (Linnaeus)	oa
Elateridae spp.	ob
*Elateridae spp. (larvae)	ob
Anthrenus sp.	rt-sf
Dermestidae sp.	rt-sf
Anobium ?punctatum (Degeer)	l-sf
Ptinus ?fur (Linnaeus)	rd-sf
?Melyridae sp.	u
Brachypterus glaber (Stephens)	oa-p
Meligethes spp.	oa-p
Epuraea sp.	u
Monotoma sp.	rt-sf
Cryptophagus spp.	rd-sf
Atomaria spp.	rd
Ephistemus globulus (Paykull)	rd-sf
Phalacridae sp.	oa-p
Anommatus sp.	u
?Sericoderus lateralis (Gyllenhal)	rt-st
Orthoperus sp.	rt
?Scymnus sp. s. lat.	oa-p
?Coccinella sp.	oa-p
Coccinellidae sp.	oa-p
Lathridius minutus group [*Enicmus*]	rd-st
Enicmus sp.	rt-sf
Corticaria sp.	rt-sf
Corticarina sp.	rt
Cortinicara gibbosa (Herbst) [*Corticarina*]	rt
?Mycetophagus sp.	u
Typhaea stercorea (Linnaeus)	rd-ss
Mycetophagidae sp.	u
Aglenus brunneus (Gyllenhal)	rt-ss
Opatrum ?sabulosum (Linnaeus)	oa
Crypticus quisquilius (Linnaeus)	oa
?Mordellidae sp.	u
Oedemeridae sp.	oa
Notoxus monoceros (Linnaeus)	oa
?Anthicus spp.	rt
Gastrophysa polygoni (Linnaeus) [*Gastroidea*]	oa-p
Phaedon sp.	oa-p
Chrysomelinae sp.	oa-p
Phyllotreta nemorum group	oa-p
Phyllotreta spp.	oa-p
Longitarsus spp.	oa-p
Altica sp.	oa-p
Chaetocnema arida group	oa-p
Chaetocnema ?concinna (Marsham)	oa-p
Halticinae spp.	oa-p
Hispella atra (Linnaeus)	oa-p
Apion (Pseudapion) rufirostre (Fabricius)	oa-p
Apion (Aspidapion) aeneum (Fabricius)	oa-p
Apion spp.	oa-p
Otiorhynchus sp.	oa-p
?Trachyphloeus sp.	oa-p
Phyllobius or *Polydrusus* sp.	oa-p
Sitona hispidulus (Fabricius)	oa-p
Sitona ?humeralis Stephens	oa-p
Sitona spp.	oa-p
Hypera sp.	oa-p

Cidnorhinus quadrimaculatus (Linnaeus)	oa-p
Ceutorhynchus ?contractus (Marsham)	oa-p
Ceutorhynchus ?erysimi (Fabricius)	oa-p
Ceutorhynchus spp.	oa-p
Ceuthorhynchinae spp.	oa-p
?Baris sp.	oa-p
Gymnetron spp. [*Gymnaetron*]	oa-p
Curculionidae spp.	oa
Coleoptera spp.	u
ARACHNIDA	
*Pseudoscorpiones sp.	u

Table 2. Species lists in rank order for invertebrate macrofossils from samples from Sample 13, Well 25, Gross Gerau. The adult Hemiptera (bugs) and Coleoptera (beetles) are listed first, followed by the remaining invertebrates. Weight is in kilogrammes, ec = ecological code; n = minimum number of individuals; sq = semi-quantitative (e = estimate; - = fully quantitative, m = 'many', translated as 15 individuals; s = several, translated as 6). For translation of ecological codes, see Table 4.

Sample 13 ReM: SS
Weight: 0.00 E: 0.00 F: 0.00

Taxon	**n**	**sq**	**ec**
Longitarsus sp. A	50	e	oa-p
Xantholinus longiventris	32		rt-sf
Chaetocnema arida group	31		oa-p
Megasternum obscurum	20	e	rt
Anotylus sculpturatus group	20	e	rt
Rhyparochromus sp.	15	m	oa-p
Trapezonotus sp.	15	m	oa-p
Auchenorhyncha sp. F	15	m	oa-p
Auchenorhyncha sp. I	15	m	oa-p
Auchenorhyncha sp. N	15	m	oa-p
Auchenorhyncha sp. O	15	m	oa-p
Trechus ?quadristriatus	15	m	oa
Bembidion properans	15	m	oa
Calathus fuscipes	15	m	oa
Amara sp. A	15	m	oa
Metabletus foveatus	15	m	oa
Orthoperus sp.	15		rt
Enicmus sp.	15	m	rt-sf
Chrysomelinae sp.	15	m	oa-p
Phyllotreta sp. C	15	m	oa-p
Altica sp.	15	m	oa-p
Apion (Aspidapion) aeneum	15	m	oa-p
Cidnorhinus quadrimaculatus	15	m	oa-p
Ceutorhynchus ?erysimi	15	m	oa-p
Helophorus nubilus	14		oa
Platystethus cornutus	14	m	oa-d
Corticarina sp.	14		rt
?Trachyphloeus sp.	12		oa-p
Onthophagus ?ovatus	11		oa-rf
Lathridius minutus group	9		rd-st
Anotylus rugosus	8		rt
Chaetocnema ?concinna	8		oa-p
Omalium sp.	7		rt
Xantholinus gallicus or linearis	7		rt-sf
Philonthus or Gabrius sp.	7		u
Oxyomus sylvestris	7		rt-sf
Auchenorhyncha sp. A	6	s	oa-p
Auchenorhyncha sp. M	6	s	oa-p
Auchenorhyncha sp. T	6	s	oa-p
Pterostichus ?cupreus	6	s	oa
Calathus ambiguus	6	s	oa
Calathus sp. A	6	s	oa
Amara ?aenea	6	s	oa
Amara ?bifrons	6	s	oa
Metabletus truncatellus	6	s	oa
Cryptopleurum minutum	6	s	rf-st
Acritus nigricornis	6	s	rt-st
Cordalia obscura	6		rt-sf
Aphodius sp. B	6	s	ob-rf
Valgus hemipterus	6	s	oa
Ptinus ?fur	6	s	rd-sf
Meligethes sp. A	6	s	oa-p
Meligethes sp. B	6	s	oa-p
?Coccinella sp.	6	s	oa-p
Crypticus quisquilius	6	s	oa
Notoxus monoceros	6	s	oa
?Gastrophysa sp.	6	s	oa-p
Halticinae sp. C	6	s	oa-p
Halticinae sp. D	6	s	oa-p
Apion (Pseudapion) rufirostre	6	s	oa-p
Apion sp. C	6	s	oa-p
Apion sp. D	6	s	oa-p
Sciocoris sp.	5		oa-p
Ochthebius sp. A	5		oa-w
Gyrohypnus fracticornis	5		rt-st
Philonthus sp. A	5		u
Cryptophagus sp. A	5		rd-sf
Sehirus ?dubius	4		oa-p
Heterogaster cathariae	4		oa-p
Acrotrichis sp.	4		rt
Omalium ?rivulare	4		rt-sf
Carpelimus ?bilineatus	4		rt-sf
Anotylus nitidulus	4		rt-d
Tachinus ?signatus	4		u
Geotrupes ?stercorarius	4		oa-rf
Aphodius granarius	4		ob-rf
Ephistemus globulus	4		rd-sf
Longitarsus sp. D	4		oa-p
Ceutorhynchus sp. A	4		oa-p
Nysius sp.	3		oa-p
Lygaeidae sp.	3		oa-p
Miridae sp. A	3		oa-p
Auchenorhyncha sp. G	3		oa-p
Helophorus sp.	3		oa-w
Cercyon analis	3		rt-sf
Onthophilus striatus	3		rt
Micropeplus fulvus	3		rt
Paederus sp.	3		oa
Quedius sp. A	3		u
Tachyporus sp. A	3		u
Tachyporus sp. B	3		u
Rhyssemus germanus	3		oa
Dermestidae sp.	3		rt-sf
Phalacridae sp.	3		oa-p
Anthicus sp. A	3		rt
Longitarsus sp. C	3		oa-p
Halticinae sp. C	3		oa-p
Halticinae sp. F	3		oa-p
Phyllobius or Polydrusus sp.	3		oa-p
Ceutorhynchus sp. B	3		oa-p
Ceuthorhynchinae sp. A	3		oa-p
Gymnetron sp. A	3		oa-p
Gymnetron sp. B	3		oa-p
Pentatomoidea sp.	2		oa-p

Scolopostethus sp. B	2	oa-p
Saldula sp.	2	oa-d
Auchenorhyncha sp. D	2	oa-p
Auchenorhyncha sp. J	2	oa-p
Auchenorhyncha sp. K	2	oa-p
Auchenorhyncha sp. R	2	oa-p
Clivina fossor	2	oa
Asaphidion flavipes	2	oa
Bembidion sp. B	2	oa
Tachys sp.	2	oa
Pterostichus melanarius	2	ob
Harpalus sp. C	2	oa
Cercyon atricapillus	2	rf-st
Histerinae sp.	2	rt
Scydmaenus sp.	2	u
Lesteva sp.	2	oa-d
Coprophilus striatulus	2	rt-st
Anotylus complanatus	2	rt-sf
Rugilus sp.	2	rt
Gyrohypnus sp.	2	rt
Xantholininae sp.	2	u
Philonthus sp. H	2	u
Sepedophilus sp.	2	u
Aleocharinae sp. A	2	u
Aleocharinae sp. E	2	u
Aleocharinae sp. I	2	u
Aphodius ?sus	2	oa
Aphodius sp. A	2	ob-rf
Aphodius sp. F	2	ob-rf
Brachypterus glaber	2	oa-p
Monotoma sp.	2	rt-sf
Atomaria sp. B	2	rd
Anommatus sp.	2	u
Coccinellidae sp.	2	oa-p
Typhaea stercorea	2	rd-ss
Halticinae sp. A	2	oa-p
Apion sp. A	2	oa-p
Sitona sp. A	2	oa-p
Sitona sp. B	2	oa-p
?Baris sp.	2	oa-p
Curculionidae sp. A	2	oa
?Coriomeris sp.	1	oa-p
Legnotus ?limbosus	1	oa-p
?Geocoris ater	1	oa-p
Beosus maritimus	1	oa-p
Stygnocoris sp.	1	oa
Scolopostethus sp. A	1	oa-p
Miridae sp. B	1	oa-p
Miridae sp. C	1	oa-p
Miridae sp. D	1	oa-p
Saldidae sp.	1	oa-d
Corixidae sp.	1	oa-w
Auchenorhyncha sp. B	1	oa-p
Auchenorhyncha sp. C	1	oa-p
Auchenorhyncha sp. E	1	oa-p
Auchenorhyncha sp. H	1	oa-p
Auchenorhyncha sp. L	1	oa-p
Auchenorhyncha sp. P	1	oa-p
Auchenorhyncha sp. Q	1	oa-p
Auchenorhyncha sp. S	1	oa-p
Psylloidea sp.	1	oa-p
Panagaeus cruxmajor	1	oa
Carabus sp.	1	oa
Nebria sp.	1	oa
Trechus micros	1	u
Bembidion sp. C	1	oa
Bembidion sp. A	1	oa
Pterostichus sp.	1	ob
?Agonum sp.	1	oa
Amara sp. B	1	oa
Harpalus sp. A	1	oa
Harpalus sp. B	1	oa
Harpalus sp. C	1	oa
Carabidae sp. A	1	ob
Carabidae sp. B	1	ob
Carabidae sp. C	1	ob
Agabus sp.	1	oa-w
?Coelostoma orbiculare	1	oa-w
Cercyon terminatus	1	rf-st
Hydrobius fuscipes	1	oa-w
Hydrophilinae sp.	1	oa-w
Hydrophilinae sp. A	1	oa-w
Ochthebius sp. B	1	oa-w
Ochthebius sp. C	1	oa-w
Hydraena sp. A	1	oa-w
Hydraena sp. B	1	oa-w
Leiodidae sp.	1	u
Catops sp.	1	u
?Colon sp.	1	u
Catopinae sp.	1	u
Silphidae sp.	1	u
Micropeplus tesserula	1	rt
Metopsia retusa	1	u
Proteinus sp.	1	rt
Acidota sp.	1	oa
?Dropephylla sp.	1	u
Omaliinae sp.	1	rt
Carpelimus sp.	1	u
Platystethus nitens	1	oa-d
Stenus sp. A	1	u
Stenus sp. B	1	u
Stenus sp. C	1	u
Lathrobium sp. A	1	u
Lathrobium sp. B	1	u
?Astenus sp.	1	rt
Paederinae sp. A	1	u
Paederinae sp. B	1	u
Leptacinus sp. A	1	rt-st
Leptacinus sp. B	1	rt-st
Philonthus sp. B	1	u
Philonthus sp. C	1	u
Philonthus sp. D	1	u
Philonthus sp. E	1	u
Philonthus sp. F	1	u
Philonthus sp. G	1	u
Quedius ?cinctus	1	rt
Staphylininae sp.	1	u
Mycetoporus sp. A	1	u
Mycetoporus sp. B	1	u
Tachyporus sp. C	1	u
Falagria sp.	1	rt-sf
Aleocharinae sp. B	1	u

Aleocharinae sp. C	1		u
Aleocharinae sp. D	1		u
Aleocharinae sp. F	1		u
Aleocharinae sp. G	1		u
Aleocharinae sp. H	1		u
Aleocharinae sp. J	1		u
Lucanus cervus	1		l
Dorcus parallelipipedus	1		l
Trox scaber	1		rt-sf
Geotrupes ?vernalis	1		oa-rf
Aphodius ?contaminatus	1		oa-rf
Aphodius sp.	1		ob-rf
Aphodius sp. C	1		ob-rf
Aphodius sp. D	1		ob-rf
Aphodius sp. E	1		ob-rf
Cetonia aurata	1		oa
Elateridae sp. A	1		ob
Elateridae sp. B	1		ob
Elateridae sp. C	1		ob
Elateridae sp. D	1		ob
Elateridae sp. E	1		ob
Elateridae sp. F	1		ob
*Elateridae sp. C (larva)	1		ob
Anthrenus sp.	1		rt-sf
Anobium ?punctatum	1		l-sf
?Melyridae sp.	1		u
Meligethes sp. C	1		oa-p
Meligethes sp. D	1		oa-p
Epuraea sp.	1		u
Cryptophagus sp. B	1		rd-sf
Cryptophagus sp. C	1		rd-sf
Atomaria sp. A	1		rd
?Sericoderus lateralis	1		rt-st
?Scymnus sp. s. lat.	1		oa-p
Corticaria sp.	1		rt-sf
Cortinicara gibbosa	1		rt
?Mycetophagus sp.	1		u
Mycetophagidae sp.	1		u
Aglenus brunneus	1		rt-ss
Opatrum ?sabulosum	1		oa
?Mordellidae sp.	1		u
Oedemeridae sp.	1		oa
?Anthicus sp.	1		rt
Anthicus sp. B	1		rt
Anthicus sp. C	1		rt
Phaedon sp.	1		oa-p
Phyllotreta nemorum group	1		oa-p
Phyllotreta sp. A	1		oa-p
Phyllotreta sp. B	1		oa-p
Longitarsus sp. B	1		oa-p
Halticinae sp. E	1		oa-p
Hispella atra	1		oa-p
Apion sp. B	1		oa-p
Otiorhynchus sp.	1		oa-p
Sitona sp. C	1		oa-p
Sitona sp. D	1		oa-p
Hypera sp.	1		oa-p
Ceutorhynchus ?contractus	1		oa-p
Ceutorhynchus sp. C	1		oa-p
Ceutorhynchus sp. D	1		oa-p
Ceuthorhynchinae sp. B	1		oa-p
Curculionidae sp. B	1		oa
Curculionidae sp. C	1		oa
Curculionidae sp. D	1		oa
Curculionidae sp. E	1		oa
Curculionidae sp. F	1		oa
Curculionidae sp. G	1		oa
Curculionidae sp. H	1		oa
Coleoptera sp. A	1		u
Coleoptera sp. B	1		u
Coleoptera sp. C	1		u
Coleoptera sp. D	1		u
*Aphidoidea sp.	15	m	u
*Diptera sp. (puparium)	15	m	u
*Hymenoptera sp.	6	s	u
*Elateridae sp. B (larva)	3		ob
*Diplopoda sp.	2		u
*Pentatomidae sp. (nymph)	1		oa-p
*Elateridae sp. A (larva)	1		ob
*Apoidea sp.	1		u
*Diptera sp. (adult)	1		u
*Formicidae sp.	1		u
*Pseudoscorpiones sp.	1		u
*Siphonaptera sp.	1		u
*Hemiptera sp. (nymph)	1		u
*Syrphidae sp. (larva)	1		u

Table 3. Main statistics for assemblage of adult beetles and bugs (excluding aphids and scale insects) from Sample 13, Well 25, Gross Gerau. For explanation of abbreviations, see Table 4.

S	250
N	555
ALPHA	175
SEALPHA	12
SOB	140
PSOB	56
NOB	294
PNOB	53
ALPHAOB	105
SEALPHAOB	10
SW	12
PSW	5
NW	18
PNW	3
ALPHAW	0
SEALPHAW	0
SD	5
PSD	2
ND	10
PND	2
ALPHAD	0
SEALPHAD	0
SP	70
PSP	28
NP	173
PNP	31
ALPHAP	44
SEALPHAP	5
SM	0
PSM	0
NM	0
PNM	0
ALPHAM	0
SEALPHAM	0
SL	3
PSL	1
NL	3
PNL	1
ALPHAL	0
SEALPHAL	0
SRT	61
PSRT	24
NRT	203
PNRT	37
ALPHART	30
SEALPHART	3
SRD	8
PSRD	3
NRD	25
PNRD	5
ALPHARD	4
SEALPHARD	1
SRF	13
PSRF	5
NRF	32
PNRF	6
ALPHARF	8
SEALPHARF	2
SSA	29
PSSA	12
NSA	111
PNSA	20
ALPHASA	13
SEALPHASA	2
SSF	19
PSSF	8
NSF	86
PNSF	15
ALPHASF	8
SEALPHASF	1
SST	8
PSST	3
NST	22
PNST	4
ALPHAST	5
SEALPHAST	2
SSS	2
PSSS	1
NSS	3
PNSS	1
ALPHASS	0
SEALPHASS	0
SG	0
PSG	0
NG	0
PNG	0
ALPHAG	0
SEALPHA	0

Table 4. Abbreviations for ecological codes and statistics used for interpretation of insect remains in text and tables. Lower case codes in parentheses are those assigned to taxa and used to calculate the group values (the codes in capitals). See Table 1 for codes assigned to taxa from Gross Gerau. Indivs - individuals (based on MNI); No - number.

No taxa	S
Estimated number of indivs (MNI)	N
Index of diversity (α)	alpha
Standard error of alpha	SE alpha
No 'certain' outdoor taxa (oa)	SOA
Percentage of 'certain' outdoor taxa	PSOA
No 'certain' outdoor indivs	NOA
Percentage of 'certain' outdoor indivs	PNOA
No OA and probable outdoor taxa (oa+ob)	SOB
Percentage of OB taxa	PSOB
No OB indivs	NOB
Percentage OB indivs	PNOB
Index of diversity of the OB component	alphaOB
Standard error	SEalphaOB
No aquatic taxa (w)	SW
Percentage of aquatic taxa	PSW
No aquatic indivs	NW
Percentage of W indivs	PNW
Index of diversity of the W component	alphaW
Standard error	SEalphaW
No damp ground/waterside taxa (d)	SD
Percentage D taxa	PSD
No damp D indivs	ND
Percentage of D indivs	PND
Index of diversity of the D component	alphaD
Standard error	SEalphaD
No strongly plant-associated taxa (p)	SP
Percentage of P taxa	PSP
No strongly P indivs	NP
Percentage of P indivs	PNP
Index of diversity of the P component	alphaP
Standard error	SEalphaP
No heathland/moorland taxa (m)	SM
Percentage of M taxa	PSM
No M indivs	NM
Percentage of M indivs	PNM
Index of diversity of the M component	alphaM
Standard error	SEalphaM
No wood-associated taxa (l)	SL
Percentage of L taxa	PSL
No L indivs	NL
Percentage of L indivs	PNL
Index of diversity of the L component	alphaL
Standard error	SEalphaL
No decomposer taxa (rt + rd + rf)	SRT

Percentage of RT taxa	PSRT
No RT indivs	NRT
Percentage of RT indivs	PNRT
Index of diversity of RT component	alpha RT
Standard error	SEalphaRT
No 'dry' decomposer taxa (rd)	SRD Percentage of RD
taxa	PSRD
No RD indivs	NRD
Percentage of RD indivs	PNRD
Index of diversity of the RD component	alphaRD
Standard error	SEalphaRD
No 'foul' decomposer taxa (rf)	SRF
Percentage of RF taxa	PSRF
No RF indivs	NRF
Percentage of RF indivs	PNRF
Index of diversity of the RF component	alphaRF
Standard error	SEalphaRF
No synanthropic taxa (sf+st_ss)	SSA
Percentage of synanthropic taxa	PSSA
No synanthropic indivs	NSA
Percentage of SA indivs	PNSA
Index of diversity of SA component	ALPHASA
Standard error	SEALPHASA
No facultatively synanthropic taxa	SSF
Percentage of SF taxa	PSSF
No SF indivs	NSF
Percentage of SF indivs	PNSF
Index of diversity of SF component	ALPHASF
Standard error	SEALPHASF
No typical synanthropic taxa	SST
Percentage of ST taxa	PSST
No ST indivs	NST
Percentage of ST indivs	PNST
Index of diversity of ST component	ALPHAST
Standard error	SEALPHAST
No strongly synanthropic taxa	SSS
Percentage of SS taxa	PSSS
No SS indivs	NSS
Percentage of SS indivs	PNSS
Index of diversity of SS component	ALPHASS
Standard error	SEALPHASS
No uncoded taxa (u)	SU
Percentage of uncoded indivs	PNU
No indivs of grain pests (g)	NG
Percentage of indivs of grain pests	PNG