Assessment of insect remains from a colonial well (JR2158; Structure 177) at James Fort, Jamestown, Virginia

Gary Andrew King, Allison Bain, and Frédéric Dussault*

Laboratoire d'archéologie environnementale, CELAT, Université Laval, Québec, QC
Canada G1K 7P4

Pronotum of Saw-toothed Grain Beetle from Sample AA

Assessment of insect remains from a colonial well (JR2158; Structure 177) at James Fort, Jamestown, Virginia

Summary
Three subsamples from the fills of a colonial timber-lined well were selected for detailed analysis for insect remains. Insects were abundant and generally excellently preserved and the biota was comprised of both native and alien species. A range of beetles associated with perishable commodities were recovered, while litter and decomposer species were also prevalent. In addition to synanthropic fauna, individuals believed to be representative of the natural environment were present.

Keywords: JAMESTOWN; JAMES FORT; COLONIAL WELL; INSECT REMAINS; ARCHAEOENTOMOLOGY

***Gary King (corresponding author) :** CELAT Research Centre, Université Laval, Pavillion Charles-de Koninck 1030, av. Des Sciences-Humaines, local 6211, Québec, QC, G1V 0A6, CA; email: gking500@googlemail.com;

Introduction

The Jamestown Rediscovery staff submitted three one litre samples of soil to the Environmental Archaeology Laboratory at Université Laval, Québec, Canada for evaluation of archaeoentomological potential. The samples were taken from contexts associated with Structure 177, JR2158; believed to be James Fort's second well of 1611. The dates of the contexts were determined through a combination of archaeological and historical accounts. The recovery of a halberd that belonged to Lord Delaware, who arrived at the fort in June 1610, indicates that the well was not abandoned until after 1610 (Danny Schmidt, pers. comm.). Moreover, the chimney constructed on top of the well layers is associated with the Governor's residence, which places the filling of the well prior to 1617 (Deetz *et al*. 2008). Through evaluation of the insect remains, it was hoped that a more in-depth understanding of the living conditions and environment could be derived, which could contribute to the archaeological and environmental data collated by other specialists.

Methodology

The sediment samples were inspected in the laboratory broadly following the procedures of Kenward *et al*. (1980; 1986) and modified by Bain (2001), for the recovery of invertebrate macrofossils (samples were sieved to 300 microns and floated in admixture kerosene). The invertebrate remains in the resulting residue and washover were sorted and examined using a low-power binocular microscope. Identification of insect remains was carried out through comparison with material in the reference collection of the Université Laval's Environmental Archaeology Laboratory and the Réné Martineau Insectarium at the Canadian Forestry Services Centre in Québec City. Taxonomy and nomenclature for the coleopteran (beetle) remains (Table 1) follows Arnett and Thomas (2000) and Arnett *et al*. (2002).

Results

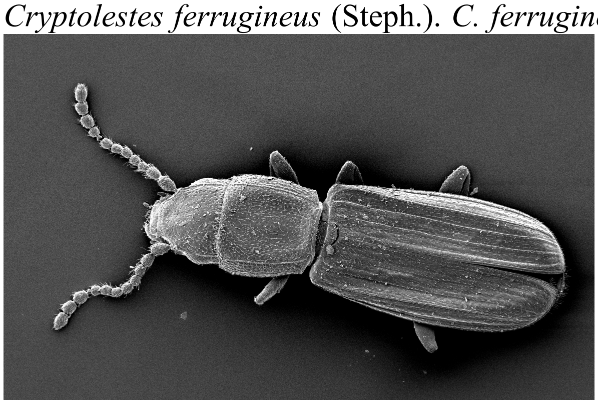
Context 2158 Z (an arbitrary stratigraphic level made *circa* 11' below the surface, near top of modern water table, approximately mid-well depth)

Sample 3 (treatment of the 1 L sample resulted in 20 ml light fraction and 110 ml heavy fraction)

Moist, dark brown, clayey-sand (soaked in Arm and Hammer mixture for two days prior to washing in order to facilitate separation of clay clumps)

The washover yielded very small fragments of bone, wood (50%), and charcoal (20%). The light fraction produced ample coleopteran fragments in fair to good condition. Dipteran (flies) and acarinan (mites) remains were also present but unidentified beyond the order level.

Amongst the recovered coleopteran remains, 12 species were differentiated; 5 of which were identified to species level. The saw-toothed grain beetle *Oryzaephilus surinamensis* (L.) was strongly represented in the sample (Minimum Number of Individuals or MNI=38). *O. surinamensis* is considered a secondary pest, typically feeding on grain previously attacked by moulds or primary pests such as *Sitophilus granarius*, but is also known to feed on meal and other ground starchy foods. *O. surinamensis* has been recorded in warehouses, mills, granaries, and brewery silos (Zacher 1927). A single individual of another secondary stored cereal pest was also recovered, the flat grain beetle *Cryptolestes ferrugineus* (Steph.). *C. ferrugineus* would have attacked a similar range of products to the saw-toothed grain beetle (Horion 1960). The staphylinid *Oxytelus sculptus* (Grav.) has been recorded in dung and vegetable refuse (Fowler 1888) as well as in fields, pastures, stables, and on decaying hay (Koch 1989). Although two other staphylinids or rove beetles could not be identified to species, beetles of this family generally inhabit damp environments around compost or rotting organic remains. Both *Cryptophagus scanicus* (L.) and *Lathridius minutus* group (L.) are associated with sweet compost, such as hay, where they are primarily mycetophagous (Lindroth *et al*. 1973; Koch 1989). The identified Coleoptera were largely synanthropic (defined here as species associated with human settlements) and, biogeographically, of European origin.



The Flat Grain Beetle

Context 2158 AA (an arbitrary stratigraphic layer circa 12’3” below the surface)

Sample 1 (treatment of the 0.8 L sample resulted in 25 ml light fraction and 400 ml heavy fraction)

Moist, grey-brown, silty-clay (soaked in Arm and Hammer for two days)

The washover contained fragments of brick, wood (60%), and charcoal (10%). The light fraction yielded a range of Coleoptera as well as Diptera, Hemiptera (true bugs) and Acarina in good to excellent condition. Additionally, floral remains were noted in the flot, including *Anethum* sp. (dill), *Polygonum* sp. (knotgrass), *Juglans* sp. (walnuts), *Vitis* sp. (grapes).

The sample produced a total of 44 coleopteran species (total MNI=85). 44.7 % of the individuals (largely Staphylinidae) were associated with decaying organic matter and litter, particularly vegetation. *Carpelimus obesus* (Kies.) has been noted in disturbed, sandy or muddy areas, especially near rivers and flood plains, where the species inhabits the litter and flood debris (Koch 1989). *Philonthus discoideus* (Grav.), *Oxytelus sculptus*, and *Gyrohypnus fracticornis* (Müll.) are often associated with habitats containing foul compost and manure (Koch 1989, Duff 1993). However, *G. fracticornis* has also been recorded in sweet compost and flood debris (Koch 1989). The sample also contained individuals of the scarab *Ataenius spretulus* (Halde.), which as adults are compost and dung generalists (Cartwright 1974) but as larvae are root-feeders that have gained pest status today in regards to black turfgrass (Ratcliffe and Paulsen 2008).

Right elytron of *Trox scaber* L.

The Hide Beetle *T. scaber* L.

The sample also yielded carrion beetles such as *Trox scaber* (L.), *Catops* sp., and *Omosita colon* (L.). Whereas both *Catops* sp. and *O. colon* are more general carrion associates and are occasionally noted in decaying vegetation (Koch 1989), *T. scaber* is a better indicator species. The scarab has been noted on furs, animal skins, dry bones, horn cores, feathers, and other animal detritus, especially in bird nests (Dillon and Dillon

1972, Koch 1989, Duff 1993). In archaeological contexts, *T. scaber* is considered synanthropic and has been recovered from contexts that were interpreted as stables, houses, and tanneries (cf. Kenward 2009).

Context 2158 AA also contained several species of mould-feeding beetles (e.g. *Mycetea subterranea (*Marsh.), *Cryptophagus scanicus*, *Monotoma picipes* (Hbst.), and *Lathridius minutus* group).These species are often synanthropically associated with mouldy hay and stored product cereals. In addition to hay and stored products, the beetle *Mycetophagus quadriguttas* (Müll.) has also been noted on mould under the bark of deciduous trees (Koch 1989).

33 % of the total individuals recovered are strongly synathropic in temperate and arctic regions. Individual specimens of the grain weevils *Sitophilus granarius* (L.) and *S. oryzae* (L.)*/zeamais* (Motz) were recorded. Both species are primary pests of a range of cereal products including wheat, rye, barley, maize, oats, buckwheat, millet, chickpeas, and even chestnuts, acorns and cornmeal (Hoffman 1954). Additionally, the secondary pests *Oryzaephilus surinamensis* (MNI=18), *Cryptolestes ferrugineus* (MNI=6), and *Palorus* sp. (MNI=1) were also present and would have fed on pre-damaged cereal kernels as well as meal and flour.

Approximately 8% of the individuals in the coleopteran assemblage were comprised of species associated with dead or dying trees and shrubs. Individuals of two unidentified species of Scolytidae (bark and ambrosia beetles) were recovered; supporting the presence of dead or dying trees and shrubs (Bright 1976). Additionally, two individuals of the scolytid *Micracis* sp. (LeConte), which is associated with wood from deciduous trees, were noted (Bright 1976). Another bark beetle, *Pseudopithyophthorus* sp. (Swaine), was represented by a single individual. This species is associated with various hardwoods, especially oak (*Quercus* spp.). Scolytids are typically present in woodland environments where outbreaks occur naturally in mature or overmature forests (Bright 1976). Today, these outbreaks are of economic concern as the scolytids can destroy vast supplies of timber as the beetles bore into the wood (Bright 1976). Bark and ambrosia beetles are often introduced into synanthropic environments along with firewood. The European powderpost beetle *Lyctus ?linearis* (Goeze.) may have been recovered. *L. linearis* is often found in broad-leaved woodland where it develops in deadwood. The species is particularly well-associated with oak but has also been found in beech and ash (Hyman 1992). Synanthropically, the powderpost beetle has also been recorded in timber yards and buildings where it infests the dry, dead wood of structural timbers (Robinson 1991). A single individual of the Colydiidae *Bitoma* sp. (Herbst.) was present in the sample. Colydiids are usually found under bark or in the galleries of wood-boring beetles (Bousquet 1991). *Bitoma* species are primarily predacious of the larvae of other bark and wood-boring Coleoptera. Alexander (1994) recorded species of *Bitoma* under the bark of dead beech and oak, and similarly Koch (1989) noted the genus under the bark on fence posts.

Context 2158 AA yielded a range of Coleoptera associated with both synanthropic and natural contexts. A minimum of 34% of the coleopteran species from the sample have earlier dating archaeoentomological records from European contexts. The common bedbug (cf. *Cimex lectularius* L.), a Hemipteran or true bug species, may have also present in the sample.

Context 2158 AB (an arbitrary stratigraphic layer near lower part of the well)

Sample 2 (treatment of the 1 L sample resulted in 25 ml light fraction and 75 ml heavy fraction)

Very wet, greenish-brown, clayey-silt (soaked in Arm and Hammer for two days)

The washover contained small pieces of wood (30%) and charcoal (10%). In the light fraction, Hymenoptera (sawflies, ants, bees and wasps), Parasitic Hymenoptera, Apoidea (bees), Formicidae (ants), Diptera, Hemiptera, and Acarina were recovered in addition to a range of Coleoptera (34 species; MNI=49) in excellent condition. Amaranthaceae, *Chenopodium* spp. (goosefoots), Coniferae (conifers), *Viola* sp. (violets), and *Nicotiana* sp. (tobacco) were present in both the light and heavy fractions. During processing, bits of yellow paper, hairs, and blue nylon were observed in the washover and the flot; suggesting potential contamination during sampling or processing.

A number of the coleopteran species were associated with decaying organic matter. Amongst the identified staphylinids, *Gyrohypnus fracticornis*, *Oxytelus sculptus*, and *Carpelimus obesus* suggest the presence of decaying vegetable matter. The scarab *Ataenius spretulus* and the leiodid *Catops* sp. have also been noted in compost (Cartwright 1974; Koch 1989). In addition to the decomposer fauna, several mycetophagous species were recovered. The sample yielded two species of the family Ciidae, minute tree-fungus beetles, *Ceracis* sp. (Mellié) and *Octotemnus* sp. (Mellié). Ciidae species are predominantly mycetophagous on fungal hyphae, particularly wood rotting *Basidiomycetes*. Minute tree-fungus beetles have been found under bark, in dead wood, and in bark beetle galleries (Bousquet 1991). The monotomid *Monotoma picipes* has been noted on mouldy decaying vegetation, manure, and sweet compost such as hay and straw (Koch 1989). *Lathridius minutus* group is rarely associated with substrates primarily comprised of foul decomposing organics but is common on fungi in barns, stables, and granaries (Horion 1961). The hairy fungus beetle, *Typhaea stercorea* (L.), has been primarily recorded in synanthropic contexts on mouldy haystack and granary refuse (Hinton 1945).

Additionally, the sample contained several economic species. The clover root borer weevil *Hylastinus obscurus* (Marsh.) has been recorded on wild and cultivated legumes, clovers, beans, and vetch, and today, it is considered a serious pest of clover and alfalfa in the eastern United States (Bright 1976). The presence of the scolytid in the Jamestown contexts at this date is significant as biogeographers consider the clover root borer to be an invasive species introduced from Europe around 1878 (cf. Elton 1958, 54). The tobacco beetle cf. *Lasioderma serricorne* (F.) may have also been present; however, the identification is tentative and in need of confirmation. *L. serricorne* has been recorded in a range of dried vegetable products, particularly tobacco (Buck 1958; Dillon and Dillon

***Elytra of Alphitophagus bifasciatus* Say**

Elytron of cf. *Lasioderma serricorne* F.

1972; Fogliazza and Pagani 1993). A single individual of *Blaps lethifera* (Marsh.) was also recovered. This is one of the largest stored product pests and has been noted in cellars, stables and granaries (Brendell 1975). Its larvae attack a range of stored products of vegetable origin as well as hay and straw. While damage caused by the tenebrionid is usually not significant, the species has achieved pest status as a result of its strong, repulsive odour (Horion 1956). Two individuals of *Alphitophagus bifasciatus* (Say), the two-banded fungus beetle, were identified. *A. bifasciatus* is commonly recovered from mouldy and decaying grain and vegetable products in stables, granaries, and warehouses where both the adults and larvae feed on mould (Brendell 1975). The recovery of the granary weevil *Sitophilus granarius* (MNI=2), *O. surinamensis* (MNI=8), and *C. ferrugineus* (MNI=2) are associated with stored cereals and/or cereal products. While *S. granarius* is capable of damaging whole cereal kernels, *O. surinamensis* and *C. ferrugineus* are only able to infest pre-damaged, mouldy, or processed cereals.

In addition to the coleopteran fauna, two hemipteran individuals were noted. The sample included the remains of what may be *Cimex lectularius* (L.), the common bedbug.

Discussion

The well contexts yielded insect species of archaeological and ecological value. However, aquatic invertebrates were not observed in any of the samples. This absence is notable as archaeoentomological investigations of other archaeological well contexts (e.g. Hall *et al.* 1980; Kenward 2008) have recorded moderate to numerous numbers of *Daphnia* (water fleas), Chironomidae (midge) larvae, Ostracoda, and water beetles; species which were assumed to have been attracted to the surface of the water or breeding in the wells. Moreover, ground beetles (Carabidae) were noticeably scarce suggesting that the well did not act as a pit fall trap. The recovered ground dwelling beetles were primarily staphylinids, which could have entered the contexts with the deposition of organic material. The absence of water fauna along with the paucity of ground beetles suggests that the well may have been covered or sheltered in some fashion. The paucity of pit fall trap fauna and outdoor biota suggests that the well was likely filled in a short span of time. Additionally the majority of the species present in the samples are seemingly associated with the in-filling of the well rather than the immediate well environment.

The presence of wood was supported by a number of species. The wood-related fauna were associated with the presence of deadwood rather than living trees. The powderpost beetle was the only recovered species with a documented association with worked wood; it may have been infesting the structural timbers in the well, adjacent buildings, or fences. As this species has an established archaeoentomological record dating back to the Bronze Age in England (Osborne 1969; 1989), the powderpost beetle would have been introduced to North America by the Europeans and have likely been a familiar pest of their living environment. The samples also contained a range of native wood beetles, particularly the families Ciidae and Scolytidae. The presence of these species hint at the surrounding natural environment; portraying a mature woodland comprised of deciduous trees and hardwoods. Additionally, most tree-associated species have a poor dispersal ability (Kenward 2006; 2008), which implies the presence of barked wood on the site, potentially serving as firewood or fence posts. As *Pseudopithyophthorus* sp. is strongly associated with *Quercus* sp., its recovery from the well samples is a good indicator for the presence of oak on the site.

All three samples contained species associated with indoor environments, implying that domestic waste and floor sweeping were likely discarded in the well. The identified beetle species are also strongly indicative of the presence of stored cereals, and the recovery of both primary and secondary pests of cereals suggests that the grains were unprocessed at the time of deposition. Moreover, the abundance of species associated with rotting or mouldy cereals and vegetation implies that the grains were likely in fairly poor condition. The species comprising the cereal biota, noted here, have an established Mediterranean record dating to the Neolithic and Bronze Age (cf. King 2009; King *et al*. in prep). In previous studies, the recovery of similar faunal groups have been interpreted as potentially representing cereals intended for animal rather than human consumption (cf. Kenward 2009) or indicating stables or barns as tentative contexts for the pre-depositional origin of the remains (Kenward and Hall 1997). However, stable-indicator groups tend to also be comprised of dung fauna, which was poorly represented in the present study despite the presence of foul decomposer species and *Ataenius spretulus* (and certainly not at the levels witnessed at the Bronze Age wells in Wiltsford, Wiltshire, Osborne 1969; 1989). Although the physical presence of dung in the well seems unlikely based on the recovered entomofaunal component, foul decomposers species and *A. spretulus* are fairly migratory and could represent livestock having been kept nearby; this seems to be the most likely explanation for the fauna's presence in the well other than the general presence of fetid, decomposing, organic residues. This may also explain the presence of stored hay fauna which are considered very migratory (Kenward 2008).

However, the stored hay fauna may have also been infesting hay used as flooring, bedding, and thatch and thus could have been deposited in the well alongside domestic waste.

In addition to hay and cereal indicator species, the environmental evidence supports the dumping of other stored and economic products such as tobacco. Meats or other animal products, such as furs, were also likely present in the well fill. Infestations by stored product pests were seemingly common during this period as evidenced by the archaeoentomological accounts from contemporary colonial sites (cf. Bain 1998; Bain *et al*. 2009; Bain and Prévost forthcoming). The range of stored product species recovered suggests that during its in-filling, the well served as a waste dump for a myriad of contaminated perishable commodities.

The well samples also yielded the remains of what may be the common bedbug. *Cimex lectularius* are small ectoparasites that feed on the blood of humans and other warm-blooded animals. The species is known to infest houses, residing in the cracks of walls, under beds, furniture, and behind skirting boards during the day and emerging to feed during the pre-dawn hours (Southwood and Leston 1959). While bedbug bites may cause little to no discomfort, the insects excrete regularly where they are living, often leaving yellowish-black spots on walls (Busvine 1976), and emit an unpleasant odour when disturbed (Eldridge and Edman 2000). Bedbugs have an archaeoentomological record extending back to the site of Tell el-Amarna, Egypt, dating to around 3550 years ago (Panagiotakopulu and Buckland 1999) as well as a strong documentary account from Ancient Greeks (e.g. Aristophanes' *Clouds* 634; *Frogs* 439; Aristotle's *Historia Animalium*) and Romans (e.g. Pliny's *Natural History*). In England, *C. lectularius* have been recovered from Roman (Osborne 1971), Anglo-Scandinavian (Kenward and Allison 1994), and 18th c. (Girling 1984) contexts. In the New World, the remains of bedbugs have been recorded at Abiel Smith School site in Boston (Bain 1997; 2007) as well as the Îlot Hunt (Bain 2001; 2004) and the Intendant's Palace (Bain *et al.* 2009) sites in Québec City. Although the bedbugs may have been irritating bedmates for the Jamestown colonists, there are some accounts of *C. lectularius* being used in healing. Pliny proposes the use of bedbugs in remedies for snake bites as well as being beneficial for weak eyes and ear problems (Smith and Anthon 1847). The use of bedbugs in medicine continued to be practiced in Europe through the 18th century (cf. Guettard's recommendation for their application in hysteria cases; *ibid*).

Conclusion

The insect remains recovered from the Jamestown well are interesting from both biogeographical and socio-ecological perspectives as the samples were dominated by European disturbed land, pest, and economic species. These accidentally introduced species (referred to by Sadler 1991 as stowaways and gatecrashers) may have helped the Euro-American colonists create or negotiate their identity in the North American landscape by contributing to the ecological transformation of their surroundings. The presence of Palaearctic insect pests, while potentially causing structural damage or having a negative impact on the storage of perishable commodities, would have been a familiar nuisance to the colonists rather than forcing them to confront a new enemy. Crosby (2004) proposed that the presence of Palaearctic biota in the New World would have inherently *Europeanized* the landscape, which may have contributed to the survival of the colonies. However, grain and other storage pests cause significant depletion of human food resources (e.g. Tyler and Boxall 1984; McFarlane 1989; Payne 2002), and in the 19th and early 20th century, they were responsible for a very serious loss of food (e.g. Fitch 1879; Kirby and Spence 1859; Munro 1966). Did the presence of these insect species result in increased stress for the colonists, or did the familiar biota contribute to the colony's success?

The archaeoentomological evidence recovered from the well is very significant from a natural historical perspective, as it has provided the earliest dates for the introduction of several European species to North America. Moreover the excellent condition of the specimens harbours potential for the successful application of genetic analyses, which could be used to address issues such as: the rate of species introduction, the date of introduction via thermal age dating of the remains, and the geographic origin of the fauna (cf. King 2009; King *et al*. 2009).

Based on the richness of these samples, further analysis is strongly recommended.

Acknowledgements

Several people made this project happen. The authors would like to thank Véronique Forbes for her help in processing the samples as well as entomologists Jan Klimaszewski and Georges Pelletier of the Réné Martineau Insectarium at the Canadian Forestry Centre. We also wish to extend our appreciation to Julie-Anne Bouchard-Perron for her assistance with the botanical remains. Danny Schmidt and everyone at the APVA Jamestown Recovery Project deserve special mention for the opportunity to collaborate on this project.

References

Alexander, K.N.A. (1994). *An Annotated Checklist of British Lignicolous and Saproxylic Invertebrates.* Cirencester: National Trust Estates Advisors' Office.

Aristophanes (1924). *Clouds* (trans. B.B. Rogers). London: Heinemann Loeb Text Vol. I.

Aristophanes (1924). *Frogs* (trans. B.B. Rogers). London: Heinemann. Loeb Text Vol. II.

Aristotle (1970). *Historia Animalium III* (trans A.L. Peck). Cambridge: Harvard University Press.

Arnett, R.H., Jr., and M.C. Thomas (eds) (2000). *American Beetles, Volume I: Archostemata, Myxophaga, Adephaga, Polyphaga: Staphyliniformia*. Boca Raton, Florida: CRC Press LLC.

Arnett, R.H., Thomas, M.C., Skelley, P.C. and Frank, J.H. (eds) (2002). *American Beetles, Volume II: Polyphaga: Scarabaeoidea through Curculionoidea.* Boca Raton, Florida: CRC Press LLC.

Bain, A. (1997). Analysis of insect remains from the Abiel Smith School site, Boston, Massachusetts. Report submitted to the National Park Service and Museum of Afro American History, Boston.

Bain, A. (1998). A Seventeenth Century Beetle Fauna from Colonial Boston, *Historical Archaeology* **32 (3)**, 38-48.

Bain, A. (2001). Archaeoentomological and archaeoparasitological reconstructions at Îlot Hunt (CeEt-110): New perspectives in Historical Archaeology (1850-1900). *BAR International Series* **973**. British Archaeological Reports, Oxford.

Bain, A. (2004). Irritating Intimates: The Archaeoentomology of Lice, Fleas, and Bedbugs, *Northeast Historical Archaeology* **33**, 81-90

Bain, A. (2007). *Archaeoentomological Analysis of samples from the 2005 African Meeting House Project*, Fiske Center for Archaeological Research, University of Massachusetts Boston

Bain, A. and Prévost, M.-A. (forthcoming). Environmental Archaeology and Landscape Transformation at the 17th-century Ferryland Site, Newfoundland, *Historical Archaeology* **45 (1)**

Bain, A., Bouchard-Perron, J-A., Auger, R., and Simoneau, D. (2009). Bugs, seeds, and weeds at the Intendant's Palace: A study of an evolving landscape. *Post-medieval Archaeology* **43 (1)**, 183-197

Brendell, M.J.D. (1975). *Coleoptera: Tenebrionidae. Handbooks for the identification of British Insects* **10**. Royal Entomological Society of London.

Bright Jr., D.E. (1976). *The insects and arachnids of Canada Part 2: The bark beetles of Canada and Alaska (Coleoptera: Scolytidae).* Ottawa: Minister of Supply and Services Canada.

Bousquet, Y. (1991). Checklist of beetles of Canada and Alaska. Minister of Supply and Services Canada, Ottawa.

Buck, F.D. (1958). The British Anobiidae. *Proceedings of the South London Entomological and Natural History Society* (1958), 51-64.

Busvine, J.R. (1976). Insects, hygiene, and history. London: The Athlone Press of the University of London.

Cartwright, O.L. (1974). Ataenius, Aphotaenius, and Pseudataenius of the United States and Canada (Coleoptera: Scarabaeidae: Aphodiinae). *Smithsonian Contributions to Zoology* **154**.

Crosby, A. (2004). *Ecological imperialism: the biological expansion of Europe, 900-1900.* New York: Cambridge University Press.

Deetz, E., Givens, D., Hudgins, C.C., Mallios, S., May, J., Pecoraro, L., Rock, T., Schmidt, D., and Straude, B. (2008). *2000-2006 Interim report on the APVA excavations at Jamestown, Virginia*. W.M. Kelso and B. Straube (eds.). The Association for the Preservation of Virginia Antiquities and Jamestown Rediscovery.

Dillon, D.S. and Dillon, L.S. (1972). *A Manual of Common Beetles of Eastern North America*. (2 vols.) New York: Dover Publications.

Duff, A. (1993). *Beetles of Somerset: their status and distribution*. Taunton: Somerset Archaeological and Natural History Society.

Eldridge, B.F. and Edman, D. (2000). *Medical entomology*. Dordrecht: Kluwer Academic Publishers.

Elton, C.S. (1958). *The ecology of invasions*. New York: John Wiley and Sons Inc.

Fitch, E.A. (1879). Granary weevils: *Sitophilus granarius* and *S. oryzae*. *The Entomologist* **12**, 41-50.

Fogliazza, D.D. and Pagani, M. (1993). Insect pests in stored foodstuffs in Italy. Part 1: Coleoptera. *Tecnica Molitoria* **44**, 937-951.

Fowler, W.W. (1888). *The Coleoptera of the British Isles*. London: Nathaniel Lloyd.

Girling, M. (1984). Eighteenth century records of human lice (Pthiraptera: Anoplura) and fleas (Siphonaptera: Pulcidae) in the city of London. *Entomologist's Monthly Magazine* **120**, 207-210.

Hall, A.R., Kenward, H.K. and Williams, D. (1980). Environmental evidence from Roman deposits in Skeldergate. *The Archaeology of York* **14 (3)**, 101-56. London: Council for British Archaeology.

Hinton, H.E. (1945). *A Monograph of the Beetles associated with stored products*, I. London: British Museum (N.H.).

Horion, A. (1956). Faunistik der mitteleuropäischen Käfer, Band 5. *Heteromera*. Munich.

Horion, A. (1960). Faunistik der mitteleuropäischen Käfer, Band 7. *Clavicornia* 1, *Teil,* (*Sphaeritidae–Phalacridae)*. Überlingen-Bodensee.

Horion, A. (1961). Faunistik der mitteleuropäischen Käfer, Band 8. *Clavicornia* 2. Überlingen-Bodensee.

Hyman, P.S. (1992). *A review of the scarce and threatened Coleoptera of Great Britain, Part 1* (Revised & updated by M.S.Parsons). UK Joint Nature Conservation Committee, Peterborough.

Kenward, H. (2008). Technical report: Insect remains from a Roman well at Hayton, East Yorkshire *Reports from the Centre for Human Palaeoecology, University of York* **2008/06**.

Kenward, H. (2009). Invertebrates in archaeology in the north of England. *English Heritage Research Department Report Series* **12/2009**, http://research.english_heritage.org.uk/report/?14728

Kenward, H.K. and Allison, E. (1994). Rural origins of the urban insect fauna. In A.R. Hall and H.K. Kenward (eds.), *Urban-rural Connexions: Perspectives from Environmental Archaeology, Symposia of the Association for Environmental Archaeology* **12**. Oxford: Oxbow Books, 55-78.

Kenward, H.K. (2006). The visibility of past trees and woodland: testing the value of insect remains. *Journal of Archaeological Science* **33**, 1368-1380.

Kenward, H.K. and Hall, A.R. (1997). Enhancing bio-archaeological 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., Engleman, C., Robertson, A. and Large, F. (1986). Rapid scanning of urban archaeological deposits for insect remains. *Circaea* **3**, 163-72.

King, G.A. (2009). The alien presence: Palaeoentomological approaches to trade and migration. Unpublished PhD thesis. University of York

King, G.A., Kenward, H., Schmidt, E., and Smith, D. (in prep). Six-legged hitchhikers: An archaeobiogeographical account of the early dispersal of grain beetles.

King, G.A., Gilbert, M.T.P., Wilerslev, E., Collins, M.J., and Kenward, H. (2009). Recovery of DNA from archaeological insect remains: first results, problems and potential. *Journal of Archaeological Science* 36, 1179-1183

Kirby, W., and Spence, W. (1859). *An introduction to entomology or elements of the natural history of insects, etc.* London: Longman, Green, Longman and Roberts.

Koch, K. (1989). *Die Käfer Mitteleuropas. Ökologie, 1*. Goecke & Evers, Krefeld.

Lindroth, C.H., Andersson, H., Bodvarsson, H., and Richter, S.H. (1973). Surtsey, Iceland. The Development of a New Fauna, 1963-1970. *Terrestrial Invertebrates. Entomologica Scandinavia, Suppl.* **5**.

McFarlane, J.A. (1989). Guidelines for pest management research to reduce stored food losses caused by insects and mites. *Overseas Development and Natural Resources Institute Bulletin* **22**. Chatham, Kent, UK: HMSO

Munro, J.W. (1966). *Pests of Stored Products*. London: Hutchinson.

Osborne, P.J. (1969). An insect fauna of Late Bronze Age date from Wilsford, Wiltshire. *Journal of Animal Ecology* **38**, 555-66.

Osborne, P.J. (1989). Insects. In P. Ashbee, M. Bell, and E. Proudfoot (eds), *Wilsford Shaft: excavations 1960-2*, pp. 96-99. HBMC London: HBMC.

Osborne, P.J. (1971). An insect fauna from the Roman site at Alcester, Warwickshire. *Britannia* **2**, 156-165.

Panagiotakopulu, E. and Buckland, P.C. (1999). *Cimex lectularius* L., the common bed bug, from Pharonic Egypt. *Antiquity* **73**, 908-911.

Payne, T.S. (2002). Harvest and storage management of wheat. In B.C. Curtis, S. Rajaram and H. Gómez Macpherson (eds), *Bread wheat Improvement and Production*. *FAO Plant Production and Protection Series 30.* Rome: Food and Agriculture Organization of the United Nations. Accessible at http://www.fao.org/DOCREP/006/Y4011E/y4011e0u.htm#bm30

Pliny (1997). *Natural History* (trans. H. Rackham). Cambridge: Harvard University Press.

Ratcliffe, B.C. and Paulsen, M.J. (2008). The Scarabaeoid beetles of Nebraska. *Bulletin of the University of Nebraska State Museum* **22**.

Robinson, M.A. (1991). The Neolithic and Late Bronze Age insect assemblages. In S. Needham (ed.), *Excavation and salvage at Runnymede Bridge, 1978: the Late Bronze Age waterfront site*. London: British Museum, 277-327.

Sadler, J. (1991). Beetles, boats and biogeography. Insect invaders of the North Atlantic. *Acta Archaeologia* **61**, 199-211.

Smith, W. and Anthon, C. (1847). *A dictionary of Greek and Roman antiquities*. New York: Harper and Brothers.

Southwood, T.R.E. and Leston, D. (1959). *Land and Water Bugs of the British Isles*. London: Warne.

Tyler, P.S. and Boxall, R.A. (1984). Post-harvest loss reduction programmes: a decade of activities: what consequences?. *Tropical Stored Product Information* **23**, 13-28

Zacher, F. (1927). *Die Vorrats-, Speicher- und Materialschadlinge und ihre Bekämpfung*. Berlin.

Table 1: Arthropods Recovered from the Jamestown Colonial Well

Species	JR 2158AA	JR 2158 AB	JR 2158 Z
Arachnida			
Acarina sp.	p	p	p
Insecta			
Hemiptera			
Hemiptera indet	3	2	
cf. *Cimex lectularis* Linné +		2	
Diptera			
Diptera indet	p	p	p
Coleoptera			
Coleoptera indet A	1	1	1
Coleoptera indet B	1		**2**
Carabidae			
Bembidion sp.		1	
Histeridae			
Histeridae indet		1	
Acritus nigricornis Hoff. +	3		
Carcinops pumilo Erich. +	2		
Leiodidae			
Catops sp.	2	1	2
Staphylinidae			
Staphylinidae indet A	2	2	
Staphylinidae indet B	1	1	
Staphylinidae indet C	1	1	
Staphylinidae indet D	2		1
Staphylinidae indet E	2		
Staphylinidae indet F	1		
Micropeplus ?browni	3	1	
Aleocharinae indet A	1	1	1
Aleocharinae indet B	2		
Aleocharinae indet C	1		
Bledius sp.	1		
Carpelimus obesus Kies. +	6	1	
Oxytelus sculptus Grav. +	1	2	1
Paederinae indet	1		
Gyrohypnus fracticornis Müll. +	1	1	
Philonthus sp.	1		
Philonthus discoideus Grav. +	1		
Scarabaeoidea			
Trox scaber Linné +	1		
Ataenius spretulus Halde.	1	2	

Table 1: Arthropods Recovered from the Jamestown Colonial Well (continued)

Elateroidea			
Elateroidea indet A		1	
Elateroidea indet B		1	
Bostrichidae			
Lyctus ?linearis Goeze +	1		
Anobiidae			
Anobiidae indet	1	1	
cf *Lasiodermis serricorne* Fab.		1	
Nitidulidae			
Omosita colon Linné +	1		
Monotomidae			
Monotoma sp.		1	1
Monotoma picipes Hbst. +	3	2	
Silvanidae			
Oryzaephilus surinamensis Linné +	18	8	38
Cucujidae			
Cucujidae indet A	1		
Cucujidae indet B		1	
Cucujidae indet C			2
Laemophloeidae			
Laemophloeidae indet	1		
Cryptolestes ferrugineus Steph. +	6	2	1
Cryptophagidae			
Cryptophagus sp.		1	
Cryptophagus scanicus Linné +	1		1
Endomychidae			
Mycetea subterranean Marsh +	1		
Latridiidae			
Lathridius minutus group Linné	1	2	1
Corticaria/Corticarina sp.	1		
Mycetophagidae			
Mycetophagus quadriguttas Müll. +	1		
Typhaea stercorea Linné +		1	
Ciidae			
Octotemnus sp. Mellié		1	
Ceracis sp. Mellié		1	
Colydiidae			
Bitoma sp. Herbst.	1		
Tenebrionidae			
Tenebroinidae indet		1	
Alphitophagus bifasciatus Say +		2	

Table 1: Arthropods Recovered from the Jamestown Colonial Well (continued)

Palorus sp. +	1		
Blaps lethifera Marsh +		1	
Curculionidae			
Curculionidae indet		1	
Sitophilus sp. +	1		
Sitophilus granarius Linné +	1	2	
Sitophilus oryzae Linné / *zeamais* Motz. +	1		
Scolytidae			
Scolytidae indet A	1	1	
Scolytidae indet B	1		
Hylastinus obscurus Marsh		1	
Micracis sp. LeConte	2		
Pseudopithyophthorus sp. Swaine	1		
Hymenoptera			
Hymenoptera indet		2	
Formicidae			
Formicidae indet		1	
Hymenoptera Parasitica			
Hymenoptera Parasitica indet		1	
Apoidea			
Apoidea indet		1	

+ Indicates an introduced species