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On The Significance of Insect Remains and Traces in Archaeological Interpretation

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Abstract

Archaeological insect remains and their iconological traces are often given less attention than their vertebrate and mollusc counterparts. Whether this is due to accidental or intentional neglect on the part of the researcher, entomological insights can nevertheless be valuable additions to the interpretation of past events. Insects and related arthropods were undoubtedly as ubiquitous and economically important inhuman prehistory as they are today. Insect remains can illuminate taphonomic issues, as well as inform mortuary practices, diet and subsistence, and pale environmental conditions, to name a few. Many innovative entomological techniques have been employed to archaeological questions and deserve mention. However, the goal of this paper is not to provide a comprehensive history or exhaustive review of all the literature concerning archaeological entomology. This paper hopes to showcase the value and possible applications of insect remains in clarifying the archaeological record with the end goal of making entomological analyses standard practice in the field and lab.

keywords: Entomology; Paleoenvironment; Iconology; Diet and subsistence; Taphonomy; Archaeological method; Zooarchaeology

Introduction

Zoo archaeology as a discipline has seen rapid growth in recent decades, but subspecialty has been arguably focused on vertebrate and malacological remains. This is undoubtedly due to issues of preservation; bones and shells are more likely to survive in the archaeological record versus those of soft-bodied or otherwise miniscule organisms. Underrepresentation of the diverse range of animals that certainly co-existed with humans in the past may also be the result of collection biases on the part of the excavator. The under emphasis of other taxa must be remedied if a fuller record of the roles of animals in prehistory is to be achieved. In this respect, insect fauna provide valuable insight into human activity in antiquity. Insects are globally ubiquitous, both today and likewise in the distant past. Whether as part of pre-depositional activities or post-depositional processes, insects are present in almost all archaeological sites even if not always recognized by excavators [1-3]. Much like how endoskeletal elements in vertebrates are preferentially preserved because of their hard mineral structure, exoskeletal elements in most insects allow relatively good preservation due to their chitinous (made of a long-chain polymer hardened by calcium carbonate) composition [4-7]. Unlike vertebrate bones, the external structures of insects are preserved and display the outward characteristics and morphology of the animal. This is particularly useful for identification of species, age, and sex when the inter and intraspecific morphological variation and degree of fragmentation permit such detail. Archaeoentomology is largely concerned with preserved or mummified insect material from archaeological sites, or traces of insect occupation that may have been preserved in the absence of actual remains (i.e., iconological approaches such as burrows, tracks and nests). Although also of great interest, material culture associated with insects such as art or artefacts involved in their harvesting, processing, storage and trade are not thoroughly discussed here. Readers interested in this latter aspect may refer to Sutton [2] for an ethnographic and material cultural literature review of insect use in antiquity. This paper is primarily concerned with the use of insect remains as biological proxies in answering archaeological questions.

Before specific applications of insect remains are tackled in more detail, a review of basic insect classification and taxonomy is presented, as well as a necessary note on researcher biases. Furthermore, notable successes in the analysis of ancient insect remains are discussed, of which only a fraction are highlighted. These successes are especially evident in illuminating issues of taphonomy and funerary practice, diet and subsistence, and the reconstruction of pale environments. This is followed by recommendations for the improvement of both in-field and laboratory archaeoentomological recovery and analysis. The goal of this paper is not to provide a comprehensive history or review of all the literature concerning archaeological entomology, but it hopes to provide inspiration to readers on the value and possible applications of insect remains in clarifying the archaeological record.

Classification and Taxonomy

According to Linnean classification, phylum Arthropoda not only includes insects in the subphylum Hexapoda, but also a wide variety of other organisms. Other subphyla of Arthropoda include Chelicerata (spiders, scorpions, and mites), Myriapoda (millipedes and centipedes), and Crustacea (mostly aquatic crabs, lobsters, barnacles, and shrimp, with the notable exception of terrestrial woodlice). Members of Hexapoda, with their consolidated thoraxes and six legs, encompass insects as well as smaller groups of wingless arthropods (previously considered insects). There are over 30 orders of insects containing millions of species. The most species orders, and hence the most commonly encountered, are Diptera (flies), Coleoptera (beetles), Hymenoptera (bees, wasps, and ants), and Lepidoptera (butterflies and moths).Other common insect orders include Hemiptera (true bugs), Orthoptera (crickets and grasshoppers), Blattodea (cockroaches and termites), and Thysanura (silverfish and firebrats). Siphonaptera (fleas), Phthiraptera (lice), and family Cimicidae (Order: Hemiptera; bedbugs) are common ectoparasites of humans and related domesticated animals. Many of these insects have strong impacts on modern human life as pests, vectors of disease, and sources of food. It would be reasonable to assume that their importance today has carried on from their importance in the distant past.

Colloquially, the term ‘bug’ refers to most arthropods excluding aquatic crustaceans, and terrestrial and horseshoe crabs. The informal use covers insects, arachnids, myriapods, and woodlice, among others. Formally, the term refers to the insect order Hemiptera or true bugs, generally characterized by sucking or piercing mouthparts and forewings with both membranous and hardened portions. In actuality, ladybugs are beetles belonging to Coleopteran, love bugs are flies belonging to Diptera, potato bugs are ants belonging to Hymenoptera, and pill bugs are terrestrial crustaceans that are outside of the insect class altogether. Here, the more appropriate term insect, rather than bug, is used when referring to the taxonomic class. Although a strict definition of entomology is the study of insects, wider inclusion of other arthropod lineages such as arachnids and myriapods is common due to the historical laxity in what was deemed an insect.

Given a reasonably preserved specimen, identification to at least the level of order should be easily achieved even by a neophyte analyst with introductory taxonomic training. In most cases, those with moderate to advanced experience are able to at least identify common insect families and up to the genus level, and in some cases the species. Typically, visual inspection with the aid of a magnifier is sufficient for family and potentially genus identifications. At these classification stages, a plethora of ecological and behavioural data can already be extrapolated. Visual inspection becomes increasingly difficult when dealing with egg, larval, and pupal stages, or when dealing with highly fragmented or poorly preserved remains. In such cases, PCR amplification of ancient DNA fragments have also been used, and can often arrive at the resolution of the species level [8-11], albeit not always successful [12].

A Bias Against Insects

Anthropologists trained in Western academic climates may possess a bias towards insects [2]. In many developed countries, insects are considered pests and vermin. Indeed, successful businesses have made their living off of the extermination of these animals. They are typically associated with uncleanliness and disease, and can invoke fear and disgust in many individuals. Ironically, despite this aversion, most Westernized people savour closely related arthropods such as lobsters, crabs and shrimp for their meat, and insect products such as silk (silkworm cocoons) and honey (bee vomits) [2].

The utility of archaeological entomology was recognized early on [13-17], yet insects are rarely the focus of any standard zooarchaeological investigation, even though they likely played significant roles in human societies [2,3]. Archaeologists excavating at a site or sorting through material in a lab are largely unaware of the presence of insects in their respective assemblages [3]. This may be attributed to several reasons, some of which include a Western bias towards insects, the small visible size of remains especially when fragmented, a concentration on other modes of subsistence besides the harvesting of insects, and an overemphasis of large gain animals such as larger mammals [2]. Most archaeologists also attribute the presence of insects as intrusive bioturbatory agents [2,18]. Although highly probable, ignoring the possibility of their direct exploitation by humans or indirect role as environmental and taphonomic indicators during the time of deposition [19] will rob from a more guided interpretation. Fortunately, the role of insect faunal analysis is gaining intensity with the steady recognition of their utility.

Taphonomy and Funerary Practice

Forensic entomologists have long recognized the utility of insects in death investigations [20-23]. The predictable succession and ecological specialization of carrion species can act as proxies for the time, season and place of a person’s death. The careful extraction of insect remains from burial sediments can inform specific aspects of the burial process and environmental conditions at the time of internment [24-26]. Such care has even been applied to the collection of puparia and cuticle fragments within the personal effects of a soldier from the First World War [24]. Moreover, five insect orders have also been recognized as bone modifiers: Isoptera (termites), Coleoptera (beetles), Diptera (flies), Hymenoptera (solitary wasps and wild bees), and Lepidoptera (moths) [18,25-30]. These groups are the most likely to destroy bone, whether for use as burrows or as food

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resources. This knowledge is transferrable to archaeological contexts. Not only does the recognition of insect impact at a site shed light on funerary practice, entomotaphonomic damage can also be included in the differential diagnosis of paleopathological assessments.

At the Moche complex of Huaca de la Luna, Peru, Huchet et al. [18] identified evidence of taphonomic human bone modification from osteophagous termites. In this case, the termites were likely initially attracted to the coffin (comprised of cellulose) and secondarily consumed the bones. Their presence at a site may infer once existing wooden or plant fiber artefacts that are no longer present. Furthermore, termites prefer dark environments, respond to moisture, and are highly sensitive to desiccation [31]. Given the arid desert environment of the Peruvian north coast, it is likely the infestation occurred after burial. Another burial from the same site has been helpful in elaborating mortuary ritual. Huchet & Greenberg [32] demonstrate that delayed interments were practiced among the Moche at Huaca de la Luna. The presence of specific fly puparia precludes open exposure or temporary interment in an unfilled grave of the individual for a period of at least 3 to 4 weeks after death [32]. The presence of trogid beetle remains, coupled with missing leg bones of the interred individual, suggests the tomb was reopened after some time, as these beetles generally visit surface carrion at the dry decay stage to feed on skin and ligaments [33].

A similar situation was described by Huchet et al. [6] in a Middle Bronze Age Southern Levant burial with the identification of several dermestid beetle larvae borings in fragmentary human remains. Dermestid larvae create these cavities to protect themselves from cannibalism and predation during metamorphosis into adult beetles. Although chambers are not necessary for metamorphosis, high selection pressure from cannibalism likely drives these burrows. Huchet et al. [6] claim that larvae also do not typically bore into bones, and chambers are often built away from food sources, but evidence for this from laboratory settings is largely anecdotal, and some findings are contentious [34]. These chambers may indicate a scarcity of food and nesting substrates for the larvae at the time of pupation [35]. The southern Levant tomb was clearly secondary, as the bones contained multiple individuals that were scattered and piled up in disarray. This practice is already well known for the region, but primary treatment of corpses is ambiguous [6]. In this matter, dermestid larvae point toward initial infestation of unburied corpses at least in this instance, as these species prefer surface remains. An alternate hypothesis is that dermestid colonization occurred during re-openings of the grave that granted access to desiccated food and nesting substrate. This implies grave re-opening was done before complete skeletonization occurred.

Diet and Subsistence

In Western societies, insects are not conventionally sought after for food. However, the consumption of insects was widespread in prehistory and still remains a vital resource in many groups today [36,37]. Principal evidence of human entomophagy comes from coprolite data from various sites around the world [38]. Certainly, numerous ethnographic accounts detail the importance of insects as food [39-43]. Insect meat generally contains considerable sources of proteins, vitamins, minerals and essential amino acids [44,45]. Sutton [2] demonstrates the variety of ways in which insects are consumed:

a. As a regular, and often substantial, portion of diet,

b. As last resort foods in periods of famine,

c. As medicine,

d. As ritual elements,

e. As novelty items,

f. By accident.

An important benefit from the study of insects is their connection to domestication and agriculture. The evolution of domesticated plants and animals under human supervision spurred co-evolutionary mechanisms in insects and parasitoids [46]. Closely associated plant/animal-insect interactions can inform what types of plants and animals were used by humans at a site even with only the presence of their insect counterparts. The identification of agriculturally associated insect pests can also potentially be used to track agricultural expansion in Europe [47]. Insects are also found in stored agricultural products [48,49]. Panagiotakopulu's [50] identification of several insect pests from Egyptian food offerings presents some of the earliest evidences of pests and stored products. The destruction of crops due to pests may have also left significant detrimental effects on past populations [2] accompanied with technological countermeasures from humans such as ancient pesticides [51,52].

Insect remains have also been used to infer ancient food ways. Chomko & Gilbert [53] were able to establish a seasonal timeline of food preparation at a Late Prehistoric site in Wyoming based on detailed knowledge of carrion succession. Namely, an estimated chronology of food preparation, consumption, neglect, and discard was achieved through the analysis of differing insect assemblages in varying stages of the life cycle. Through this evidence, the authors concluded discontinuous occupation at the site within a relatively narrow time span [53].

Reconstructing Paleoenvironments

Entomofauna from archaeological sites are revealing of past environments, especially in terms of human living conditions. Specific insect assemblages can indicate the effects of human occupations such as the identification of cesspits for waste disposal [54], the environmental quality of floodplain and luminal settlements [55], and tracking climate change [56]. Understanding the ecological adaptations of insect communities can shed light on paleoenvironmental contexts, for instance of

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human occupation, anthropogenically altered landscapes, and the introduction of invasive species. Behavioural traits of species and their abundance in certain contexts allow interpretation of specific habitat requirements that support the ecology of such species [57,58].

Assemblages of archaeological insects from an Anglo-Scandinavian urban site reveal several different microenvironments based on their respective fauna [59]. One assemblage, identified as house-dwelling fauna, contain species typically associated with dry plant litter and stored products, as well as wood borers and human parasites such as flees and lice [59]. Insects associated with sheep's wool were also identified, suggesting wool cleaning was done within households [59]. Another assemblage is highly correlated with decaying matter, and was likely attracted to the site's wastes [59]. Some species preferred very wet environments, and were associated with drainage systems at the site, while others inhabited animal manure [59].

The Intendant's Palace in Quebec City, a historical 17th century site, saw entomofaunal assemblage transitions telling of a multipurpose complex with administrative, defensive, residential and political functions [60]. European granary weevils, rove beetles and handsome fungus beetles suggest greater refuse disposal in urban sectors and less dumping within the palace's domestic spaces [60]. Imported flora and fauna that supplied the emerging colony were stored in the King's Stores warehouse, which harboured unintended invasive species that flourished in what had to be poorly kept conditions based on the types of insects found [60]. Differential insect assemblage compositions between rooms at the palace point to differential maintenance of the rooms. In particular, two rooms were both used for grain storage, but insect fauna suggests one of the rooms was kept in damper and mouldier conditions [60].

King [61] has extended stable-isotope technology to insect remains in order to reconstruct past paleoeconomies at the West Stow site in England. Because distinct regional isotopic signatures are stored in insect chitin through diet much like in vertebrate bone, local and non-local origins of insects can be inferred [61]. His analysis of carbon, nitrogen and deuterium isotope levels in several hexapods that were likely co-transported with raw materials demonstrates thatch material used at the site was non-local in origin while wood timbers were from nearby sources.

Smith & Howard [62] were able to isolate changing fluvial deposition events based on ratios of ecologically grouped Coleoptera fauna (e.g. aquatic, waterside, grassland, woodland and moorland). They identified two distinct sets of fauna, each associated with high-energy and low-energy fluvial conditions [62]. This demonstration of paleoenvironmental reconstruction has potential importance when compounded with human activities at the site. Amazingly, Chironomids (a family of Diptera known as midges) have been used to study the quality of aquatic ecosystems as they are accurate indicators water temperature, acidity, oxygen regimes, nutrient status, and metal pollution [63-66]. This technique has been applied to archaeological contexts, and Chironomid documentation has granted long-term longitudinal analysis of anthropogenic climate change and the effects of luminal and floodplain settlements [67-69]. Similarly, Kenward [56] was able to infer fluctuations and rises in temperature from archaeological sites to modern times over two millennia using Hemipteran and Coleopteran assemblages.

Recommendations and Conclusion

As has just been demonstrated, the addition of archaeoentomological approaches to excavation and laboratory procedures greatly enhances the interpretative ability of archaeologists. Here, only aspects of taphonomy, funerary practice, diet, subsistence and environmental reconstruction are highlighted. However, the versatility of entomofauna extends to cover issues of disease and parasitology [70-75], site formation [76-78], material culture [79,80], religion and ritual [81], ethnoarchaeology, carbon dating [82,83] and others. But first, in order to utilize these benefits archaeologists must be able to recognize and interpret the archaeoentomological record.

Current field methods must be tailored to include the capture of fragmentary insect material. This can be achieved by using smaller screens, collecting soil samples in combination with floatation techniques, and teaching field crew members how to recognize remains. More efficient and practical methods of recording should also be evaluated [84,85]. Their role as bioturbators must also be recognized, as some insect colonies (e.g. ants) can reach relatively large sizes and move considerable amounts of earth [76-78]. Experimental data collected from contemporary observations on the formation of insect assemblages can greatly inform archaeological depositional processes [86,87]. Indeed, more research is warranted in this respect.

In laboratory settings, the identification of insect remains can be facilitated by understanding local ethnographic insect use, and by familiarizing oneself with contemporary extant species that may have existed in the past, much like what is done in vertebrate zooarchaeology. Comparative collections and regional identification keys should also be employed. Conventional collection methods, usually borrowed from paleobotany such as flotation techniques, should be evaluated in terms of their efficacy with insect material [88]. Molecular-genetic and isotopic techniques should also be explored King [10,61,89].

Obviously, for these research needs to be met archaeologists must first appreciate the value of insects not only as ecofacts or accidental intrusions, but also as active participants in the lives of humans both past and present. Once this is accomplished, and field and laboratory methods are improved, the archaeoentomological record will likely gain similar momentum as that of its vertebrate and malacological counterparts [90-99] (Table 1).

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Table 1: Some examples of uses of insect remains and traces in archaeological investigations.

Uses	References
Taphonomy	Watson & Abbey [25]; Britt et al. [26]; Blackwell et al. [27]; Huchet et al. [6,18]; Dirrigl & Perrotti [29]; Zanetti et al. [30]; Morrow et al. [19]
Site formation processes Funerary and mortuary practices	McBrearty [75]; Robins & Robins [76]; Araujo [77] Nystrom et al. 2005; Fugassa et al. [92]; Huchet &Greenberg [32]; Huchet [93]; Morrow et al. [99]; Vanin & Huchet [23]
Diet and subsistence	
Diet composition	Madsen & Kirkman [98]; Reinhard & Bryant [37]; Tommaseo-Ponzetta [35]
Food storage and pestology	Buckland [46]; Benrey et al. [45] Panagiotakopulu & Buckland [47]; Panagiotakopulu et al. [50]; Bain [89]; Panagiotakopulu [48,70]
Food ways	Crane [78]; Chomko & Gilbert [52]; Kritsky [97]
Diet and subsistence	
Diet composition	
Tracking dom	
Paleoenvironmental reconstruction	
Environmental impacts, climate change, and pollution	Kenward [55,94]; Belshau [53]; Brooks & Birks [66]; Ruiz et al. [54]; Taylor et al. [67]; Cao et al. [68]
Ecological conditions	Buckland & Coope [47]; Nielsen et al. [56]; Smith & Howard [61]; Kenward & Carrott [57]; Forbes et al. [86]
Distinguishing microenvironments	Carrott & Kenward [58]; Bain et al. [59]
Diseases and parasitological	Nelson [69]; Panagiotakopulu [70]; Mumcuoglu et al. [71]; Bain [72]; Forbes et al. [73]; Huchet et al. [6]
Radiocarbon dating Migration, movements and invasive species	Hodgins et al. [81]; Tripp et al. [82]; Bain [89]; King [60]

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