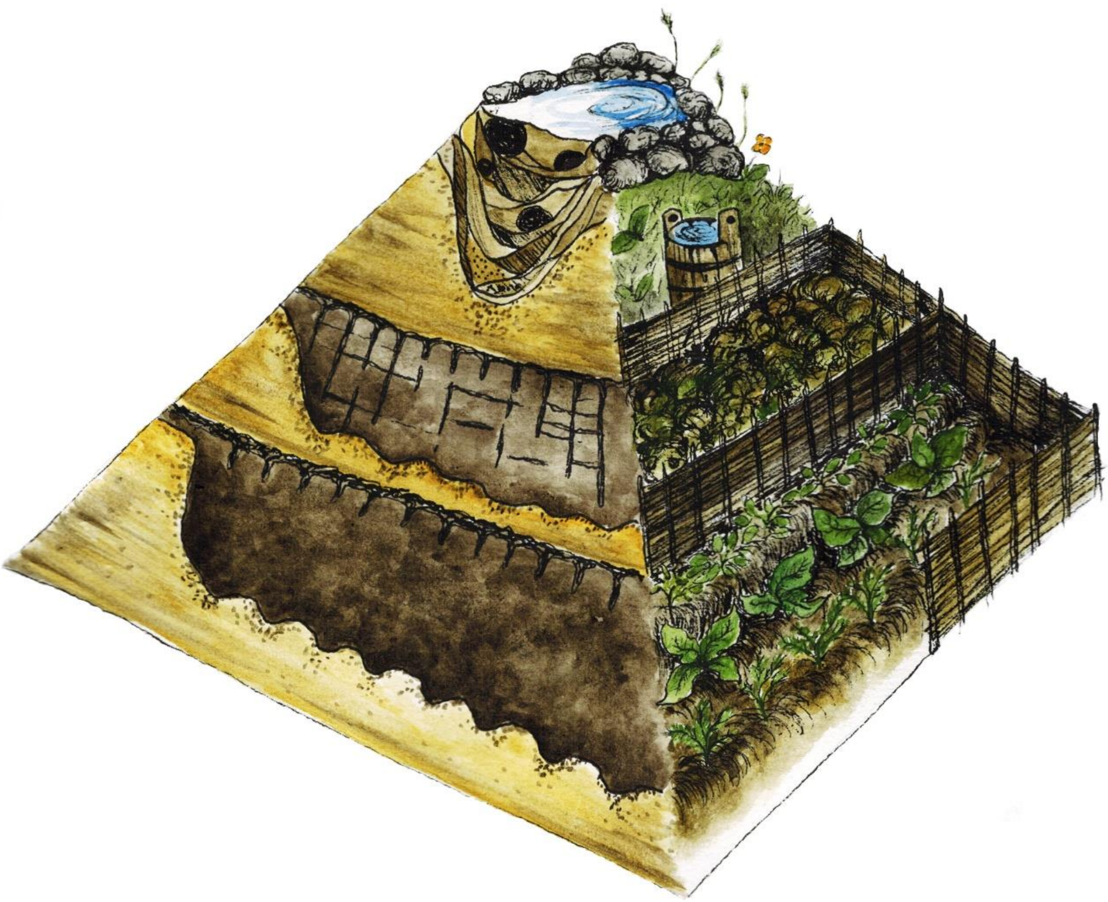
The habitats and inhabitants of fossil garden constructions –

A theoretical study of the dynamic relationships between plants, insects and agroenvironments, and their implications for archaeological interpretation



Hanna Larsson
Magister essay in Environmental archaeology, 15 hp.
Department of Historical, Philosophical and Religious Studies
Umeå University, autumn term 2016
Tutor: Philip Buckland

Umeå 2016

Abstract

The purpose of this paper is to evaluate the possibility of paleoentomology as a proxy in garden archaeology research. Garden contexts can prove difficult to identify and interpret due to the many changes the contexts go through during their activity period. Mixing of materials, harvesting and cultivation of many different plants will affect the environmental data that is retrieved from them and thus our interpretation of horticulture. This essay looks at the contexts and materials involved in the gardening process; irrigation sources, fertilizer, garden plant macrofossils and modern ecological insect and host plant relationships. The goal is to suggest a conceptual indicator group of insect and plant species that could aid in the identification of garden context and the *in situ* growth of relic plants. Paleoentomological information from the relating contexts (middens, composts, wells etc.) and other indicator groups have been included along with the ecological data in order to get a more complex picture over the garden contexts and their varying content. For instance, many of the plants found in garden soils are recorded as host plants to several insect species. This paper argues that investigation of these relationships can aid garden archaeology and further our understanding of herbivorous insects' and associated species' relationships to plant domestication in pre-history.

Keywords: Paleoentomology, archaeobotany, garden archaeology, multi-proxy study, indicator groups, fossil insects and host plants.

Larsson, H. 2016. *The habitats and inhabitants of fossil garden constructions – A theoretical study of the dynamic relationships between plants, insects and agroenvironments, and their implications for archaeological interpretation***.** Umeå

Cover: Illustration by the author of a well, compost and garden – its archaeological profiles and illustrative reconstruction based on information in this paper.

1 Introduction

Gardens have had nearly as many meanings and purposes as they have hade shapes and plants that germinate in them. They are as much a practical necessity as an artistic decoration and symbol for civilization – organized nature. By studying horticulture we gain knowledge of many important aspects of human life such as farming, cultivation, plant domestication, food traditions, import, economy, medical knowledge, health and ritual traditions. There are, however, some difficulties in studying garden contexts and their remains. The soil horizons often offer poor preservation and even if seeds are found in the horticultural soils it can be difficult to prove that these plants were grown *in situ* (on site) and have not been deposited through other human activity, such as fertilization. This paper will suggest another proxy, namely paleoentomology, to be used in garden research in order to aid the identification of garden contexts and indication of relic plants *in situ* growth.

1.1 Purpose, research questions and delimitations

The focus of this paper is to evaluate the possibility of a multi-proxy approach and to suggest a conceptual indicator group of plant and insect species that could help the identification process of garden constructions and the *in situ* growth of relic plants. The idea behind a multi-proxy study is to work with several different sources of information in order to better understand the subject at hand. By using different proxies one can draw conclusions from the overall information gained, and one proxy can complement another if data in one proxy is lost or insufficient (Reitz & Shackley 2012:30). One proxy source, for example one specific beetle species, is only able to describe a limited number of variables, i.e. the ecological condition relating to that particular organism. By including several proxies we receive a more complex picture of the subject studied which illuminates different aspects of the past (Buckland 2007:96).

An indicator group is, as Hall and Kenward describes it (1997) *"a natural grouping of organisms selected because it includes a range of stenotopic species [only able to adapt to a narrow range of environmental conditions] which together encompass a wide spectrum of ecological conditions or human activities relevant to the aims of the study being carried out"* (Hall & Kenward 1997:665). The proxies included in this study's indicator group are archaeobotanical or macrofossil and paleoentomological studies containing fossil insects, especially beetles (Coleoptera). The goal is to establish what plants can be found in historical and prehistoric gardens, what insects species can be connected to these, how the interactions between the contexts influenced the garden composition and how this affects the environmental data that we retrieve from them.

A conceptual indicator group, together with archaeological information, can create an indicator package that will make the garden context more recognizable and aid in the understanding and interpretation of macrofossil finds. The difference between an indicator group and an indicator package is the verity of data. While an indicator group usually contains just a few variables, an indicator package includes all (or most of) the recordable data that together serves as evidence for a past state or activity (Hall & Kenward 1997:665). This study will limit itself to archaeobotany and paleoentomology as proxies and since this is purely a theoretical study no analysis is included. The data in this paper derive from several articles and are therefore not limited to any time period or geographical location. The garden contexts are therefore discussed in general terms since its' specific habitat will depend on a complex set of variables.

The paper will look at the macrofossil content from garden contexts and try to identify the most likely herbivorous beetles that would have been attracted by these food plants. Since most beetles feed on several food plants the ones with the narrowest food web – the feeding network of organisms, (cf. Chapman & Reiss 1999:128f) – and highest representability in the fossil record will be selected as possible indicator species. If only generalists are known to be feeders on a particular plant or if there are only invertebrates that are not likely to survive in the fossil record they will be mentioned but not discussed further. The contexts' changeable nature and how this affects the habitat will also be considered since the interactions between the contexts can drastically change the sustainability of the habitats population. Besides gardens, the other contexts included in this study are middens and compost as a source of fertilizer and wells and watering holes as irrigation sources. By looking at materials from these three types of contexts this paper intends to answer two questions: 1) How would the garden habitat change through the gardening process of fertilizing, irrigation and harvesting and how would the interactions between the contexts affect the environmental data recovered from the context? 2) Can these interactions be used to establish a conceptual indicator group of insect and plant species that would aid archaeology in identifying the complex garden context and the *in situ* growth of plants?

1.2 Previous research, source criticism and problems

The macrofossil data recovered from a garden context would generally be interpreted as the last phase of the context due to poor preservation in the horticultural soils (Heimdahl 2014:5). The data content will therefore depend on the level of interactions between the contexts. This mixture of environmental data between the contexts could also be an important key in the identification process of gardens, which is an important aspect of this paper.

It can prove difficult to establish the origin of the macrofossils found in garden contexts due to mixing of materials between the different contexts. Further, most plants would have been harvested before they could develop or deposit their seeds while other plants leave little to no evidence of their presence due to preservation difficulties, making the garden plant taxa deceivingly small. To complicate the matter further, garden soils do not generally offer good preservation for biological material which limits the plant taxa even further. Another proxy, besides that of macrofossils, could therefore be useful in order to indicate the presence of, and to some extent, the quantity of cultivated plants. Though the poor preservation in garden soils will affect any fossil Coleoptera as well. Whether fossil insects will survive the taphonomical processes and potential damage during excavation and sample preparation will depend on the species morphology, the size and thickness of their sclerites (exoskeleton), population density within the ecosystem and frequency in the fossil record (Buckland 2007:97). Therefore, if fossil beetles are used in order to estimate the frequency of the host plants as well as *in situ* growth one must consider that the taphonomical processes will have limited the paleoentomological data as well as the archaeobotanical data.

Using indicator groups has several advantages. Many times they are used by researches as a time and finance saver – instead of spending a lot of time and resources on a vast and often fragmented material and complex assemblages, a smaller set of data can be chosen to represent the material as a whole. This can, however, pose a problem in terms of representability. If the indicator group only focuses on, for example, one insect family, perhaps due to preservation ability, occurrence or even its temporary popularity in science due to availability of ecological data, the researchers view of the studied subject risks being either biased and narrow or too broad to answer the archaeological questions asked (Hall & Kenward 1997:663-664). These “straight-forward” indicator groups, as Hall and Kenward put it, taken from a large set of bioarchaeological data that, in many cases, can prove difficult to interpret, may result in the expectation that one or a few species can prove to be an easy and accessible explanation of a massive data set (ibid).

As Hall and Kenward state, these problems are not just a paleoentomological phenomenon. In archaeobotany, for example, there is a consensus that it is unnecessary to routinely identify mosses. Rather, all types are classified in the same category (Hall & Kenward 1997:664). Moreover, some archaeobotanists chose to only identify charred plant material (ibid) even though subfossil seeds, fruits and nuts are present. This is most likely due to the fact that charred materials are more easily demonstrated to have been used by people in the past, whereas subfossil materials can be seen as recent contaminants in the archaeological deposits or that their presence in the contexts were not a result of human activity. This convention can cause problems for garden archaeology since a garden rarely burns. Plants *from* the garden that have been harvested and charred during food preparation do of course occur, and some charred plant material can be re-deposited in gardens with the fertilizer. However, these findings do not prove that the plants were grown at the site or that their occurrence in the hearth or fireplace was intended – they could have been a weed collected by mistake along with another crop. Subfossils are therefore vital to the study of garden archaeology since seeds deposited naturally by the plants growing in the garden would be preserved as such and because charring destroys insect remains.

So, as much as specializations or indicator groups can be useful one must be aware of the loss of information that occurs when data are intentionally excluded from these groups. However, in this paper, indicator groups are not used to save time or resources but rather as a context indicator, after which the garden material is to be analysed as a whole. That way we gain new and useful information about historic and prehistoric gardening techniques and traditions. This approach will also contribute with additional biological information that can improve the indicator group as an identifying technique, for the context itself, and for the plants *in situ* growth.

Since this paper is theoretical it is based on a set of articles that present relevant data from a wide range of different sites. The material in the chapter on middens and compost is based on Kenward and Hall (1997) in which the authors have established an indicator group of insects to point towards the presence of stable manure. Unfortunately the raw data remains unpublished, but the indicator group is an excellent example of the data complexity and presents valuable information for this garden indicator group. The species in that indicator group have then been compared with a similar article by Smith (2013) and Kenward (2009) among others. The material discussed in the chapter on wells and watering holes comes from Hellqvist (2013). Though the material has not been used to establish an indicator group it was chosen for this essay due to the material quantity and content relevance. The species in this section were also compared with Kenward (2009). Although aquatic organisms have been used to study the irrigation of gardens and cultivated fields (Buckland *et. al.* 2009;Heimdahl 2014), a paleoentomological investigation of gardens, its insects and their host plants has not (to the author's knowledge) been conducted. The chapter on gardens, their plants and insects is therefore based on a series of archaeobotanical articles, the data from which have been used in order to determine what plants could have been cultivated. The entomological material in this chapter is thus of a modern ecological nature, gathered from the Biological research centre's "Database of insects and their food plants" (Smith. & Roy 2008; http://www.brc.ac.uk/) in order to connect the plants to insects that would prey on them. To establish their presence in the fossil record these insects have been crossed referenced with the Bugs Coleoptera and Ecology Package – BugsCEP (Buckland & Buckland 2006; http://www.bugscep.com/).

Because this is a fairly unresearched area in environmental archaeology one should be careful not to draw too grand conclusions from the information gained regarding the insect and their host plants found in gardens. Even though much is known about insects and their food plants the entire food webs are often not recorded or known. In the database of insects and their food plants, for example, entire plant families, "spp." or "other species" is listed among the food plants relating to one insect species. This causes much uncertainty about the insects food web since plant families often includes hundreds of plants and "spp." or "other species" could include an unlimited number of species. This could make an insect's presence in a garden context even harder to interpret, even if the context surroundings are sampled and analysed alongside the garden materials. It is therefore vital that the user of this method is aware of the ecological complexity in these ecosystems and the many factors in and around the contexts that will alter the data that is retrieved from them. This case is discussed in this paper and the appendices.

Another fact to consider is that the insect-plant relationships are based on modern ecology. Even though most Coleoptera are considered by paleoentomologists to have the same or at least very similar ecological niches in the past as their modern counterparts (Buckland 2007:96-98; Elias 2007:159) these relationships are between beetles and, mostly, *cultivated* plants. Even if the beetles show consistency, humans have interfered with their food sources and there is an uncertainty whether the cultivation of crops affected their pests. It is unclear if the insects embraced their new food sources right away or if they were more likely to prefer their wild relatives. This is, however, a question that paleoentomology and garden archaeology can investigate further. If fossil beetles and their host plants are found together under favourable circumstances dating to the time of the plant's domestication it would give more clarity into the relationships between fossil beetles' reaction to plant domestication.

1.3 Environmental archaeology theory

Environmental archaeology is an interdisciplinary field, relating to both natural science and the humanities with specializations including archaeobotany, soil chemistry, palynology and paleoentomology. It is a discipline that has become increasingly used in archaeological surveys and utilizes several scientific disciplines such as chemistry, biology, geology, ecology and botany, which together with archaeology creates a wide knowledge base for both environmental and human history. The different fields and methods contribute information about sequences of events in past vegetation, environmental and climate change and cultural shifts such as the introduction of new plants, dietary traditions, farming and landscape alterations (Dincauze 2000:327ff; Evans 2003; O'connor & Evans 2005; O'connor 1998; Reitz *et. al* 1996; Reitz & Shackley 2012:1ff). The remains from archaeological sites that are studied in environmental archaeology are referred to as *ecofacts* – raw materials used by, or in other ways associated with, humans. Ecofacts may consist of plant remains, insects and bone but also clay, wood and metals that have been collected and transported to the archaeological site by people in the purpose of, or associated with, use. It is when the raw materials have been transformed into food, tools, weapons or ceramics that archaeologist consider them as *artefacts* (Reitz & Shackley 2012:5).

Ecofacts may be preserved in the archaeological deposit by charring or as subfossils. Subfossils are organic materials, seeds, wood, insects etc. that have been preserved in oxygen-poor conditions, both in dry and waterlogged deposits such as lake or bog sediments but also in wells, ditches or deep in cultural layers. Some organic materials can also be preserved by charring – carbonization. Though it destroys insect remains the process can preserve seeds, grains, wood and more rarely even plant steams, roots and other plant remains. In order for the remains in question to maintain their morphology the charring must occur under the right circumstances in terms of temperature, surrounding medium and the amount of time the remains are exposed to heat. Shape and size can change drastically depending on the materials' resilience and charring can thus obstruct identification (Viklund 1998:30-31).

Oxygen promotes bacteria and microorganisms that break down the plant material. Most often, it is the shells of seeds and nuts that are preserved while the endosperm and other protein-rich plant remains such as root vegetables, peas and beans etc. usually disappears (Romanus &

Haas 2006:17;Viklund 1998:30). Garden soils do not, in general, offer good preservation conditions for organic materials, which is discussed in more detail below. Although deep down in layers of cultivated soils the lack of oxygen can lower the activity of decomposer organisms. In these cases resilient plant parts are preserved (Viklund 1998:30). Charred seeds and other macrofossil remains can be found in gardens if it was destroyed in a fire inside the city or settlement. Burnt material could also have been deposited in the garden soil through fertilization since food waste often was used to enrich the soil (Viklund 2014:18).

Archaeobotanical studies are based on plant remains that have been preserved as subfossils or by charring. Archaeobotanists study wood, seeds, nuts, phytoliths, roots, pollen (thought palynology is considered a field of its own) and other parts of plants from archaeological sites. Archaeobotanical data can provide insight into what plants were used as food, medicine, fodder, fertilizer, fuel, building materials etc., and provide information on environmental changes, introduction of new plants and plant domestication (Reitz *et. al* 1996; Viklund 2014:16). This study will focus on material from garden contexts from which the material is mainly preserved as subfossils.

Paleoentomology is the study of fossil insect assemblages from archaeological and geological deposits. In environmental archaeology there are mainly two fields of study that focus on fossil insects; reconstruction of natural environments adjacent to archaeological sites and reconstruction of anthropogenic environments – man-made structures such as houses and stables where thermophilic insects have established themselves alongside humans and animals. Studies of fossil insects have resulted in greater understanding of the changes in the terrestrial landscape, be it natural or man-made (Elias 2007:153 & 162-163). In paleoentomology it is often fossil beetles (Coleoptera) that are used for studying past environments, be it natural, anthropogenic or, as in this case, agroenvironments – an ecological term used in this paper for environments which are both natural and anthropogenic (cf. Barrett & Odum 2005;405). Other insect remains can be recovered in archaeological deposits, such as fly puparia, though fossil beetles provide researchers with great opportunity due to a range of qualities not offered by many other proxies. For one they have a plentiful fossil record. Their exoskeleton makes them resilient to taphonomical processes and with 1 million known species, they are among the most diverse organisms on earth (Buckland *et. al.* 2014: 5740f; Elias 2007:154).

Many insects are tied to specific host plants or food plants. Finds of such insects can thus provide information about the site's vegetation. Soil type, organic content, grain size of the mineral soil and chemical parameters also affect whether or not the insects thrive. Some insect species are also sensitive to the soils and the water's pH, which can be useful in environmental research where they can be used as sensitive indicators of pollution (Lemdahl 1990: 27-28). Sampling in lakes, bogs, etc. in close proximity to the excavation site can provide significant information about environmental changes in the surrounding landscape (Carrott & Kenward 2001; Elias 2007; Hellqvist 2013:129f; Lemdahl 1990).

Another important field in environmental archaeology and in garden archaeology is soil analysis. Though this paper does not use soil as a proxy it is a vital part for this study and all research regarding agriculture, since the soil (or sediments) is one of the main ecofacts of this particular subject. The formation of soils and the development of soil horizon profiles are studied in order to understand natural and cultural soils, the human impact or chemical and physical integrity of the soil and what that entails (Linderholm 2010:7). Agriculture, waste disposal and other settlement activity are some of the most common anthropogenic changes of soil. It is visible through disturbances in the natural fluxes of the elements in the soil, such as changes in the alignment of chemical compounds, inputs or elevated levels of chemical compounds like phosphorus (P) or phosphate ($PO4^{3-}$) (Linderholm 2007:418). Water, wind, ice, gravity and bioturbation are natural agents of transportation, deposition and other changes which are recorded in the soils and sediments. Though the difference may vary between scientific fields, in archaeology the difference between sediments and soils are distinguished by transported (sediments) or *in situ* (soil) depositions near the surface of the earth that is a medium for plant growth. However, if modified *in situ* from stable sedimentary deposits at the earth surface a sediment may be considered as a soil (Reitz & Sharkley 2012:125-126). The formation processes of soils can be divided into a few variables: climate, organisms, relief, parent material and time, called the clorpt model. Though the human factor can be included in the “organism” variable, it is often regarded as its own factor since it is, at least in part, quantifiable and has relevance for the soil formation (Linderholm 2010:7-8) especially in subjects regarding agroenvironments, which is discussed further below.

2 Human interference and context dispersal

Paleoecologists use modern ecological information in order to understand the relationships between fossil insects and their habitats. This is because while ecologists can study the interactions between organisms and their habitats first hand, paleoecologists’ only source of information is the fossil insects that have been deposited in what once was their habitat, if they have not been re-deposited. This yields a source material that is fragmented by taphonomical processes and has been subjected to dispersal (Buckland 2007:96; Elias 2007:157). Ecological information is therefore vital to paleoecologists. When working with environmental archaeology one relies on the assertion that there is a relationship between the organisms and the habitat in which they are found, and that this relationship was the same as or similar to what it is now. Further, it can tell us about the environmental conditions and human behaviour that affected or created the habitat (Retiz 2012:17-18).

Organisms in an ecosystem are dependent on one another; if one variable (e.g. temperature or humidity) changes in the ecological equation it will affect the community as a whole (ibid). The organisms' body size, tolerance to pH and feeding adaptations are a few examples of traits that evolve either rapidly, or more often over a long period of time. An ecological niche is the specific set of conditions in which an organism with its traits is able to persist and procreate. When organisms maintain their traits and ecological preferences it is called niche conservatism (Wiens *et. al.* 2010:1311) which is vital to the study of paleoecology and paleoentomology. The strongest evidence for beetles' niche conservatism is that their morphology has essentially not changed throughout the Quaternary, which indicates that they have not needed to adapt. There is some disagreement between paleoecologists and other scientific fields regarding this, but the fact that most beetles are highly mobile and therefore able to migrate to a more favourable environment if their habitat were to change would explain this morphological consistency (Buckland 2007:96-98; Elias 2007:159).

The evolutionary tendencies among beetles is an important aspect for the fossil beetle and host plant indicator group since the idea is based on the notion that fossil beetles had the same ecological niche and food webs, the feeding network and relationships between species in an ecological community (cf. Chapman & Reiss 1999:128f), in pre-history as they do today. What complicates the matter is the human interaction in the insects' food source; plant domestication. Studies have been made on wild and cultivated plant species or cultivated varieties of the same crop that seem to suggest that domestication of plants can affect the insect-plant relationships (Macfadyen & Bohan 2010; Bukovinszky *et. al.* 2008). Bukovinszky *et. al.* studied the effects of aphids feeding on wild and cultivated *Brassica* plants and detected a change in body size and density among the aphids. They concluded that the wild *Brassicas* were better host plants for the aphids than the domesticated species and argue that the difference in the plants had an effect on the entire food webs, both on a direct and indirect level of consumption (Bukovinszky *et. al.* 2008:118). To understand the possible effect that plant domestication may have had on to fossil beetles in the past more studies of pest and host plants must be conducted. One example could be the grain weevil *Sitophilus granarius* (Linnaeus, 1758) which have been found in Egyptian tombs beneath the Step Pyramid of Saqqarah together with deposits of barley *(Hordeum* *vulgare)* dating to around 2300 BC (Panagiotakopulu 2001:1238). However, the domestication of barley in the Fertile Crescent is estimated to around 8000 BC (Badr *et. al.* 2000;Zohary 2012:56ff). Older finds of *S. granarius* have been made but whether it was in the same deposit as barley is unclear (Panagiotakopulu 2001:1238), and it is the correlation between the insect pest and its food plant that could indicate the weevils' quick adaptation of the domesticated crop. This area will, off course, require more research and evidence in order for any conclusions to be made. Paleoentomlology and archaeobotany can, however, aid this study by investigating the correlation between domesticated plants and insect pests.

The main difficulty with the interpretation of fossil gardens is their variety and changeable nature. Gardens will appear different depending on cultural period, the choice of crops and geographic location. Comparing ecological data from modern gardens to fossil gardens would not give a representative picture of the latter. Gardens as we know them in our time are large and diverse with a wide range of plant species that have been introduced to, for example northern Europe, much later in history. There is, of course, great variation depending on culture and purpose but what they have in common and what mainly differentiates them from historical and prehistoric gardens is species diversity. Historical monastery gardens might bear some resemblance to our modern gardens, and a modern kitchen garden might bear some resemblance to a prehistoric kitchen garden but the fact is that we know all too little about fossil gardens to

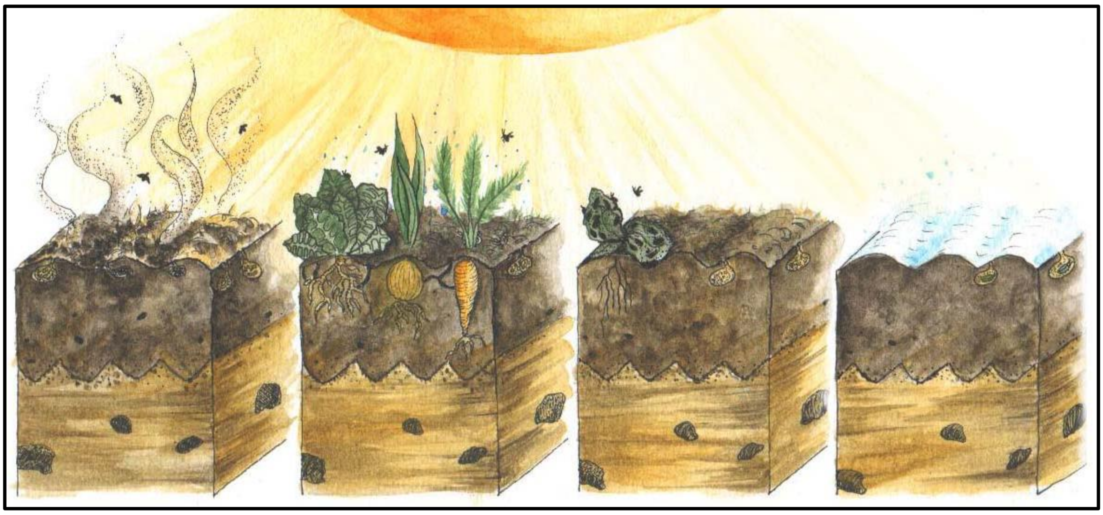


Fig. 1. Four garden phases resembling 1) soil preparation and fertilizing: a heated, fermenting, moist and nutrient rich environment containing fresh, foul and moist decomposing organic matter, decomposer insects and carnivores preying on them. 2) Growing period: sun/shade with increased moisture through irrigation and decreased evaporation. Foul and drier decomposing organic matter, herbivore activity and the predators preying on them. 3) Post harvesting: This will depend highly on season and climate and will either be a heated and dry environment with dried out fertilizer and perhaps withered plant remains and possibly some insects preying on the discarded plants, remains of fertilizer and their carnivores. Or, a wet, cold and foul environment with possibly discarded plants 4) Dormancy: depending on overall climate, a cold and desolate environment with little protection or opportunity for overwintering insects. The insects left would be the few that could overwinter and those that died during previous phases due to "natural causes", predators or inability to migrate. Illustration by the author.

say anything specific about their habitat. However, it is known that horticultural gardens undergo specific stages or phases – from fertilization and sowing to growing, harvesting and dormancy (fig. 1). Regardless of cultural period, crops, or geographical location these phases will alter the environmental material that ends up being deposited in the horticultural soil in a certain way since the phases alter the ecology. The precise composition of this material, in terms of plant and insect species, will of course vary depending on climate, what plants were cultivated, type of fertilizer, the gardens surroundings (other host plants or predators), preferred water source for irrigation, whether or not the insects were alive or dead when deposited and if they were mobile or could thrive in the changeable habitat. Another factor would be if different crops were grown in the garden depending on season – some crops would be grown in spring to early summer and others in summer to fall. If so, phase 1-3 would have been repeated and the environmental material vary even further in between seasons.

This chapter will discuss the different variables that make up the garden context. Three types of structures have been chosen as the main elements in the garden calculation; wells and/or watering holes, middens and/or composts and of course the garden plots themselves. When possible the different contexts and their habitats will be evaluated by their ecological circumstances, how they may vary in their flora and fauna content in their different stages and, when necessary, possible alternatives to these contexts will be discussed if the ecological content in them would alter the archaeological interpretation.

2.1 Wells and watering holes as irrigation sources

Aquatic environments provide great opportunity for environmental archaeology and the study of local environments at a site. The degradation of biological remains in the sediments of lakes, ponds or wells is low due to the oxygen-poor conditions, meaning that subfossil insect and plant remains are often well preserved (Engelmark & Linderholm 2008:61; Reitz & Shackley 2012:52ff).

Freshwater ecosystems can be divided into three main classifications: 1) lentic (calm) standing water such as lakes and ponds, 2) lotic (washed) running water like springs, streams and rivers and 3) wetlands where the water level rises and decreases seasonally or annually (Barret & Odum 2005:424). The nutrients richness of a lentic ecosystem varies and most aquatic species are found in habitats with at least a somewhat high level of nutrient (McCafferty 1998:31). It is in the littoral zone, the narrow shore that extend to the end of the aquatic plants, that generally contains the largest quantity of aquatic species (ibid). Depending on what type of freshwater ecosystem was used as an irrigation source the potential aquatic insect assemblage found in the garden context will differ since the species diversity in the different ecosystems vary in between each other. The size of the water source and whether it was a lentic or lotic freshwater ecosystem, or a man-made agroecosystem like a well or watering hole, will also alter the environmental data represented in the context. This can prove to be as much of a solution as a problem, depending on what structures have been preserved and sampled at the site. If no well or other man-made water source can be identified, the aquatic insects in a garden context (if present) can serve as evidence for what the water source was used for. For example, if insects connected to lotic waters are found in a garden-like structure it is logical to conclude that water was collected from a nearby source of running water in order to irrigate crops.

The problem with man-made freshwater ecosystems is that it can prove difficult to indicate them as the irrigation source by analysing the aquatic insects found in garden soil. Even though the biological material in the wells' sediments are very similar to those of lakes and ponds and generally well preserved, such agroecosystems have a very mixed insect assemblage that may originate from nearby natural water sources and the surrounding environment (Engelmark & Linderholm 2008:61; Kenward 2009:315ff). Another problem with these kinds of contexts is that there may be very little plant and insect life inhabiting them during their activity period, depending on its depth. Well structures vary from deep, sometimes lined structures to sallow puddles. The deep wells do not offer good conditions for aquatic organisms to colonize. Most of the environmental evidence found in deeper wells originate from the wells' closest surroundings and were deposited into the well either during the wells activity period or more commonly as the walls of the well and the surrounding ground layers collapsed into the well due to erosion, marking its abandonment. The shallow wells, however, which can later merge into waterholes may contain a rich and diverse living biota (Engelmark & Linderholm 2008:61; Kenward 2009:319-320).

A well provides significant advantages. Just like a natural water source can be identified as a used component in the settlement if its insects are found in a garden, a well can also provide evidence of a nearby garden context. Since a well would attract and trap insects in its surroundings, insects from an adjacent garden plot can be found in wells. If the well was reinforced with wooden beams it is also possible to date it more precisely. If the garden context and compost pits also have preserved wooden structures such as remnants of posts or a lining the garden, compost and wells' activity period can be compared and the interactions among the components of the ecosystems confirmed or dismissed. To date possible usage of a natural water source would be much more problematic and unreliable.

The aquatic insect assemblages discussed in the following chapter are taken from Hellqvist's article (2013), in which data from fifteen wells from Lövstaholm, Vaxmyra and Kyrsta are analysed. The wells are dated from Neolitic to Early Iron Age, seven of which contained insect remains. The different wells were classified into three groups; 1) funnel-shaped and used as a water source for humans, 2) a well whose function changed over time, from being a water source for humans into a waterhole for grazing animals after becoming partly filled and 3) a water pit for animals (Hellqvist 2013:154-158). Several of the wells had little to no macrofossil content. The preservation conditions in the layers were considered good, the lack of macrofossils was therefore explained by a short period of use and thus a short deposition period (ibid). The different types of well contexts will yield insect species with different ecological niches, which will aid the understanding of how aquatic organisms may vary depending on the configuration of the well or watering hole and thus the habitat of the context.

In late medieval gardening literature advice concerning irrigation was given. Water from dams, lakes, streams or collected rainwater was recommended while well water was advised against, though the reason why is not stated (Heimdahl 2014:8). It may either have had something to do with the believed idea of natural water's purity in contrast to the disease addled water in medieval urban wells, or that well water should not be wasted on garden irrigation. It is difficult to know if this was an idea created in late medieval times or if it had an older history, or if the advice was followed. Identifying water organisms in cultural soils could however be a method to investigate these questions further.

2.2 Middens heaps and compost pits

The components of fertilizer consists of a wide range of different materials originating from many different sources; middens and compost but it could also be kitchen and hearth waste (food, bones, coal and aches) or refuse from cesspits. Mixed together and deposited in pits these context entail a moving of biological remains within a settlement that has consequences for archaeological interpretation. Middens are rarely preserved in their original form, partly because of rapid decay within the midden. There are exceptions, for example on Greenland, where middens have been preserved by the permafrost (Elberling *et. al.* 2011; Panagiotakopulu *et. al.* 2007). Pits, on the other hand are very common on sites from every time period, though they are mostly found on intensive occupational sites. Cesspits are one of the most common features on medieval sites. They could be simple holes dug in the ground or they could be lined with twigs or stones (Kenward 2009:332-333; Smith 2013:526). Either way, the different components should contain or attract similar groupings of insects that would thrive in environments of the components origins (drier habitats like meadows, stored grains, house fauna etc.) and the environments in which they were deposited (moist and foul such as middens, composts and cesspits). A practical way of studying insects in fertilizer is by studying stable manure. It is also a logical conclusion to assume that this material would be put to such use on a settlement where farming and fertilizing techniques were known and applied. Especially in consideration of the quantity of material in question that would have been available at a site were animals were kept. It is also likely that other waste would have been mixed in with the stable manure at the deposition site, be it a midden, compost, cesspit or other refuse pit.

The "background flora and fauna" of the midden or compost (the organisms from the local environment surrounding the constructions) will depend on the overall environment of the settlement and also on where the context is located on that site. Whether it was located in or near a forest, near animal or human housing, a pasture or field will alter what insects were drawn to it and what plants were spread and germinated on it. In addition to the naturally occurring flora and fauna, the components of the midden and compost will also be altered depending on what was deposited in or on them during their activity period and for how long they were left untouched. Compost systems connected to gardens discovered at several late medieval urban sites have been identified. In some cases these were wooden bins located close to the garden context. A mixture of stable manure, latrine waste, kitchen waste and garden waste had been collected in the bins which seem to have functioned as a combination of dung heap and compost. In some cases, a mineral rich soil (sand) had been added into the bins (Heimdahl 2014:6). In late medieval garden-related literature fertilizing is often discussed. Dung from horses and cows, decomposing leaves, straw and hay, "slime" from fish rich waters, decomposing animal carcases, kitchen waste, bark, wood chips, sticks, ach and decomposing wood were all recommended (Heimdahl 2014:7). Several of these materials can be found in cultivated soils. Pig dung, however, was not considered appropriate. It was believed to cause "worms", something that probably related to larvae of different kind that perhaps has something to do with pests on the crops. Alternately, the medieval garden literature often borrowed terms from medicinal literature where the word "worm" was used to describe something unhealthy, so the phrase could be a metaphor for disease (Heimdahl 2014:7-8).

Because kitchen waste was often used as fertilizer and garden waste was often re-deposited on middens heaps or compost pits, samples from such contexts can be similar to those taken from gardens. There are sites that make the difference between these contexts even more unclear. The Neolitic to early Iron Age site of Tofts Ness on the isle of Sanday, Orkney and the

Neolitic to present day site Old Scatness on Shetland were studied in order to investigate how farming methods changed with time. Middens, arable soils and plough marks were found overlaying one another. The analysis of the layers' material showed that they contained the same phosphate levels and particle size distribution and were interpreted as contemporaneous. The evidence suggested that instead of moving soil from the middens into the fields or gardens, the middens were cultivated *in situ*, that is cultivated plots were constructed on top of the middens (Guttmann 2005:232). Such types of midden cultivations may have occurred on several Neolitic sites on the Northern Isles and maybe even in England (Guttman 2005:232ff). It might have been a practical solution to construct cultivated plots in middens instead of transferring soil from middens to fields and gardens.

2.3 Small scale horticultural gardens

As in the case of midden heaps and compost pits, the environment of the garden context will depend on its surroundings. In order to fully understand the habitat change and distinguish the background flora and fauna the gardens surroundings must be established. This can either be done by trying to estimate which organisms in the sample from the garden or other contexts on the settlement with more favourable preservation conditions, belong to the naturally occurring flora and fauna. Samples can also be take "off-site" from places near the settlement which are not believed to have been contaminated by human activity. Comparative sampling or off-site testing are often avoided since analysing more samples means spending more time and resources (Reitz & Shackley 2012:91-92). When trying to connect insects with host plants in gardens, however, it is necessary to know what plants grew in and around the settlement. Since insects and plants are deposited in gardens with fertilizer and irrigation this information is needed in order to estimate whether or not an insect found was attracted to a garden plant and not a similar species that grew close by.

Gardens can be difficult to recognize, but interdisciplinary methods in the fields of archaeobotany, Quaternary science and soil analysis have resulted in the identification of more gardens last decade (Heimdahl 2014:3; Viklund 2014:18). Finding garden constructions at archaeological sites is not a new phenomenon, but it is not until recently that these contexts have been regularly identified and analysed properly. Horticultural gardens should be distinguished from cultivated fields. While cultivated fields were large and located outside or at the edge of the settlement, dedicated to one or just a few crops, gardens were small-scale plots adjacent to houses and included at least some variety of vegetables, spices and maybe even medicinal plants. The latter would also require more work in terms of fertilizing, irrigation and weeding (Heimdahl 2014:3&10).

According to Heimdahl (2014), the garden soil should be considered as an artefact, or perhaps rather an ecofact. Gardens are physically represented by hortic horizons – more or less intact and, at first glance, homogenised horizons about 20-40 cm deep. Their appearance will of course depend on their level of preservation. Well-preserved garden soil can be distinguished from field soils or other similar contexts through its placement, shape and macroscopic content. Several circumstances among these components will determine if a garden can be properly identified and analysed, according to Heimdahl. Any one of these should not, on its own, be considered as evidence of a garden construction. Neither is it possible to say how many of these criteria need to be met in order for the evidence to be sufficient. The context and its content must be analysed together and put up against alternate theories (Heimdahl 2014:5). Even so, remnants of horticulture should consist of small-scale hortic horizons in close proximity to houses. There could be traces of shovels or hacks that appear as crescent shaped depressions in the layer beneath the garden soil. If the old ground layer is preserved the soil will be shown as a charcoal, wood chip and bone enriched layer. At closer examination it usually shows that the soil consist of a mixed material that has not been completely homogenised, with centimetre thick clumps of sand and fertilizer (dung). The stirring of the soil can also be identified when fractions of different soil types are mixed within the horizon and by deposited material deep in the soil that cannot be explained by trampling or overlaying (Heimdahl 2014:3-4). The soil is a mixture of several different components that people have assembled intentionally for very specific reasons. Garden soils can be confused with fillers that are often composed of mixed material, even old garden soil. If the soil is deteriorated it can be difficult to tell apart from other cultural layers or natural brown soils that have been stirred by natural processes. Garden soils are, however, often richer in organic materials and the transition between the garden soil and the surrounding natural soil is more abrupt (Heimdalh 2014:4). Remains of a fence, pot holes and alike, could be present as well as fertilizer in the form of dung, kitchen and latrine waste. Stable manure is often identified due to the presence of meadow plants ingested by the animals, while latrine waste is identifiable by berry seeds and seeds from imported fruit and alike. Kitchen waste usually consists of charred and uncharred bones, cereals and seeds, charcoal and ash (Heimdahl 2014:4-5; Viklund 2014:18). Traces of soil improvement can also occur. The soil can be mixed with sand and other rougher material to improve drainage. Clay can also be mixed with the soil to increase nutrients and to bind moisture. Irrigation can be shown in the form of water organisms, which will be discussed in the following chapter (Buckland *et. al.* 2009; Heimdahl 2014:5; Kenward 2009:71, 85).

Most of the archaeobotanical data is not found where the plants once grew but in houses, storages, wells, places of food preparation and consumption and places of discarding – latrines etc. from which they could be redeposited back in the garden (Heimdahl 2014:5; Viklund 2014:18). The presence of plants and their seeds within the garden context will depend on the preservation properties of the garden soil, though hortic horizons do not, generally, offer great preservation. Another factor that limits the deposition of seeds in the garden context is the fact that most of the plants are harvested before they develop seeds and the produce from gardens are consumed (Heimdahl 2014:5; Viklund 2014:18). The seeds from *in situ* grown plants that survive in the soil, seeds that failed to germinate or seeds that were deposited by the garden plants – perhaps from a few that were considered bad and therefore not harvested or by plants that were cultivated for their seeds are therefore limited. Further, the seeds that are found are generally considered to show the last phase of the garden due to content mixing between the contexts and the poor preservation within the garden context. Many of the seeds found are deposited with the fertilizer. Because of this only cultivated plants that had *not* been handled in the household where the seeds could have been eaten and later deposited in latrines or thrown out with the kitchen waste can be considered to have been grown *in situ* (Heimdahl 2014:5).

In Sweden, most of what we know about garden plants comes from urban cultural layers. Monastery gardens and urban horticulture is fairly well known to people in general. Even though we know quite little about them archaeologically, interest and archaeological excavations have increased in recent years (Andréasson *et. al.* 2014; NTAA). Rural horticulture is a far more un-discovered and somewhat controversial subject. This is, according to Heimdahl, probably due to poor preservation and the notion that rural horticulture has been considered as un-important – that small scale horticulture was a city phenomenon that spread to the countryside much later. This mainly has to do with the lack of historical documentation, possibly because this produce was not taxed (Heimdahl 2014:12). Archaeological excavations of rural gardens are scarce in Sweden, but some evidence have pointed towards the existence of horticultural practice in rural communities, maybe even on a regular basis alongside the traditional agricultural traditions (Heimdahl 2014:12;Viklund 2014:18). The hortic horizons in rural communities should be somewhat different from those in urban environments. The horizons could be much more fragmented and irregular due to moving of the cultivated plots through the years. Other distinctive evidence in the soil like shovel markings, plough lines and remnants of fences could have disappeared in the process. Instead it is finds of fertilizer, hearth ash and kitchen waste that can indicate the demarcation of the garden. These kinds of layers and maybe an irregular stone paving could indicate rural horticulture (Heimdahl 2010:272-274).

3 Results – paleoentomological and archaeobotanical garden archaeology

This chapter will present the insects and plant species that are relevant to the contexts discussed above. The information have been gathered form a series of articles and databases and later compared with one another. Only a part of the plant and insect species are presented below, for a more comprehensive presentation of the material see appendix 1, 2 and 3.

3.1 Insects from wells and watering holes

The insect remains from Lövstaholm, Vaxmyra and Kyrsta were dominated by subfossil remains of aquatic Coleoptera, but there were other finds that illuminate the complexity of the contexts (Hellqvist 2013: 158). From insect remains connected to crops and fields the surrounding environment could be described as an open landscape or arable lands. For example the beetles *Aclypea opaca* (Linnaeus, 1758) and *Chaetocnema concinna* (Marsham, 1802) were found which are considered to be severe pests on plants like beet *(Beta vulgaris).* However, *A. opaca* is also a pest on *Pisum sativum*, *Brassica rapa. spp. rapa* and others. *C. concinna* is connected to several meadow plants such as *Rumex*, *Chenopodium*, *Atriplex*, *Fallopia* and more (Hellqvist 2013:158-159&161; Smith & Roy 2008). The remains of *Phyllotreta vittula* (Redtenbacher 1849) and *Chaetocnema hortensis* (Geoffroy, 1785) were also considered as indicators of fields and cultivated plants since the first is a severe pest on several agricultural plants such as *Hordeum, Avena, Secale, Triticum* and more, and the other is a pest on grasses (Hellqvist 2013:161; Smith & Roy 2008). Collectively, these insects are generally considered pests and a strong indicator for cultivated plants (Hellqvist 2013:158-159). The distance between the well and the fields was not possible to determine since harvest would be brought back to the settlement, and the insects could have travelled with the harvest and later been caught in the well. But the finds are described as definite proof of nearby cultivations (ibid). There were also insects found that indicated the presence of animal grazing, those connected to animal dung and compost. The dung beetle is dependent on fresh dung or dung in various stages of decay, sometimes that of specific animal species (Hellqvist 2013:158-159). One example of a dung beetle found in a well context is *Aphodius foetens* (Fabricius, 1787) which lives on dung from animal stock, especially cow dung, on exposed and sandy ground. Remains of *Aphodius* *granarius* (Linnaeus, 1767) were also recovered. It lives on dung, decaying organic matter and carrion. The larvae live in cow and horse dung (Hellqvist 2013:160; Kenward 2009:168).

The aquatic insects found seemed to indicate the presence of a nearby natural water ecosystem and possibly a lotic one. These finds included diving beetles *Dytiscidae, Agatus* and *Coelambus impressopunctatus* (Schaller, 1783). The first two indicate an aquatic environment. *Dytiscidae* have some connection to floodwater and *Agatus* requires some depth and stagnant water, and the latter thrives in shallow water with a lot of vegetation (Hellqvist 2013:159 & 161; Kenward 2009:129). Another find, *Ochthebius minimus,* (Fabricius, 1792) lives in both lentic and lotic freshwater, also rather shallow with much vegetation, mud and sometimes even brackish waters. *Helophorus granularis* (Linnaeus, 1761) lives in stagnant to slow-running waters or in temporary water collections and the water beetle *Orectochilus villosus* (Müller, 1776) is common in running waters. More finds include the ground beetles *Bembidion varium* (Olivier, 1795) and *Pterostichus nigrita* (Paykull, 1790) that live on wetland plants also indicated an aquatic environment, and the weevil *Notaris acridulus* (Linnaeus, 1758). It has been suggested that there might have been running water or a lake near the settlement since these beetles live on vegetation that surrounds such environments (Hellqvist 2013:159-161; Kenward 2009:219). Furthermore, there were finds of *Donacia,* which can be found near aquatic plants, like water lily. Non-biting midge larvae head capsules *(Chironomids)* were identified and are common finds in archaeological deposits, and are used to study lake typology, water status, climatic reconstruction, water quality and salinity (Hellqvist 2013:160-161; Kenward 2009:56). Egg capsules of water fleas *(Caldocera)* were also found, which have been used in paleoentomological studies for climatic reconstruction, lake acidification, salinity changes etc. These could be important evidence for irrigation since smaller organisms easily could get caught when water was collected in buckets from lakes, streams or wells. Live or dead they could have been swirled up from the bottom and end up wherever the water was deposited – in sumps and drains, or on surfaces such as gardens. They preserve well but seem to need special conditions, for example in fine-grained lake sediments since they occur rarely in other deposits. This could also depend on whether they are overlooked in samples. Larvae and adult remains of caddis fly *(Trichoptera)* were also present which are very unusual in archaeological contexts. The larvae builds protective tubes of sand and plants. Caddis flies can be found in various lentic and lotic freshwater habitats and a large number of microhabitats, in some cases even on wet terrestrial habitats adjacent to water (McCafferty 1998:240). The larvae are considered as indicators of water quality and substratum. Another group to consider is the Bryozoan that has a few fresh water species that are quite often found in natural and occupational sites (Heimdahl 2014:5; Hellqvist 2013:160-161; Kenward 2009:32,59,71,85,263). These organisms can develop quickly in wells and watering holes etc. according to Heimdahl, but they could require special preservation requirements (Heimdahl 2014:5; Kenward 2009:71, 85;appendix 1).

Evidence of irrigation and field manuring has been found at a hay field on the Norse settlement Garðar on Greenland, dated to around 1100 AD (Buckland *et. al.* 2009). Dams and streams were found around the settlement which were suggested to be a part of an irrigation system (Buckland *et. al.* 2009:105-106). The natural insects fauna were dominated by wetland species indicated a wet, mossy grassland environment with permanent pools. The frequency of *Hydroporus morio* (Aubé, 1838) supported this interpretation, reflecting an *in situ* population since it is able to overwinter in shallow waters (Buckland *et. al.* 2009:112). The water beetle *Colymbetes dolabratus* (Paykull, 1798) was also recovered at the site, but needs deeper and permanent waters to survive. Lack of larval scerites indicated that the beetle did not breed in the area. A large amount of Trichoptera larvae and Chironomids larval head capsules supported the interpretation of permanent pools being present on the hay field (ibid). Hay production can prove problematic on Greenland due to a short growing season and summer drought. The paleoentomological evidence pointed to a anthropogenic fen managed by controlled irrigations via dams and streams, a system that has also been found in Norway, England, Iceland and the Swiss Alps (Buckland *et. al.* 2009:114).

The results presented here demonstrates the ability to connect aquatic organisms to different types of water ecosystems, which later can be used as evidence for irrigation of gardens, and from what sources. Further, under favourable conditions man-made water ecosystems could yield evidence that support the presence of a nearby garden if insects from such contexts end up being deposited in the well or watering hole.

3.2 Insects associated with fertilizer

Since stable manure and latrine waste are known components of fertilizer and deposited in similar archaeological contexts there are two articles, in particular, that provide much useful information on the subject of insects associated with fertilizer. The contexts that the articles cover, the data quantity they contain and their discussion about the habitat requirements of the insect species mention proved relevant for the purpose of this essay. In an article by Smith (2013) 49 cesspits from 11 archaeological sites dating to late 11th century AD to late 16th century AD were studied in order to establish an indicator package for the context in question.

The relevant data of this article has been entered into appendix 2 together with the data from Hall and Kenwards article (1997) in which an indicator group of insects and plant macrofossils was established based on data form a large number of archaeological sites. Hall and Kenward divide stable manure into several groups of data that, of course, can vary among sites. For instance, there are usually hay and/or litter remains in stable manure deposits, but different plants, shrubs or leafs could have been used as fodder or litter (Hall & Kenward 1997:666ff). In the case of litter, straw would have been used, but other materials would also have been included. Gorse *(Ulex spp.)* has been suggested as well as bracken, brushwood and even waste products such as leather offcuts, wood shavings and peat or grass turves (Hall & Kenward 1997:667). Litter was used in stables to absorb moisture and depending on the size of the stables and the number of animals kept the amount of litter and hay needed, especially during the cold season, must have been quite substantial. To meet this demand people must have gathered any suitable material that existed in abundance in or around the settlement (Hall & Kenward 1997:666-667). Hay can also consist of a wide range of different plant life from different environments. It can contain wetland species, grassland or meadow species etc. and the plant macrofossil remains can consist of their seeds, flowers, capsules, pods and even pollen (Hall & Kenward 1997:667).

Plant feeders would be attracted to hay or litter. The *Apion, Sitona, Gymnetron* and maybe *Hypera* weevils are often found in hay and can enter the archaeological deposits either via fodder in the stable or after being eaten by grazing animals (Hall & Kenward 1997:667-668; Kenward 2009:182). Another group of insects associated with stored material is mould feeders and their predators, including *Typhaea stercorea* (Linnaeus 1758), *Anthicus formicarius* (Goeze, 1777), *Cryptophagus scutellatus* (Newman, 1834), *Mycetaea hirta* (Marsham, 1802) and *Crataraea suturalis* (Mannerheim, 1831). These are especially important species but there are no species that fully can confirm stored hay, and the species that occur may vary (Hall & Kenward 1997:668; Kenward 2009:50 & 292). Pests on stored grain occur as uncharred grain and weeds from fields are a common component in stable manure since they can enter the deposit along with hay and litter or as feed. Charred cereals can also be found, but are far less common. The beetles *Cryptolestes ferrugineus* (Stephens 1831), *Oryzaephilus surinamensis* (Linnaeus, 1758) and *Sitophilus granarius* are common and *Palorus ratzeburgi* (Wissmann 1848) which is attracted to moist, spoiled grain can also be found (Hall & Kenward 1997:668; Kenward 2009:135). House fauna, that is insects that are associated with storage and stable buildings, may also be present, but will vary between period and structure and can include *Xylodromus concinnus* (Marsham, 1802), *Ptinus fur* (Linnaeus, 1758) and *Tipnus unicolor*

(Piller and Mitterpacher, 1783), *Lathridius minutus* (Linnaeus, 1767) some *Atomaria* and *Cryptophagus* species and maybe even *Aglenus brunneus* (Gyllenhall 1813) (Hall & Kenward 1997:668-669). Decomposer insects associated with moist, open textured, decaying organic matter rich in nutrients are another important component of stable manure. Such insect species may include *Acritus nigricornis* (Hoffmann 1803), *Oxytelus sculptus* (Gravenhorst, 1806), *Lithocharis ochracea* (Gravenhorst 1802), *Leptacinus spp.*, *Anthicus floralis* (Linnaeus, 1758) and *Anthicus formicarius* (Goeze, 1777) and fly puparia from *Musca domestica* (Linnaeus, 1758) and *Stomoxys* (Hall & Kenward 1997:669; Kenward 2009:50,57,232,325; Smith 2013:530-532). Parasites on livestock is another group that can be included in the stable manure deposits. The most common are those from larger domesticated animals, such as the sheep louse *Damalinia ovis* (Schrank), and sheep ked *Melophagus ovinus* (Linnaeus). The pig louse *Haematopinus apri* (Goreau) and horse louse *Damalinia equi* (Denny) can also occur, the first in smaller numbers and the latter more rarely. Some parasitic nematodes can be recovered as well, two common ones being *Trichuris* and *Ascaris* (Hall & Kenward 1997:669; Kenward 2009:22ff,296,347-348) (See appendix 2 for more details).

The insects presented here would be introduced into the deposit within the stable. If the stable is mucked out and dumped outside in middens the material would attract a wide range of plant and insect species. The nitrogen-demanding plants *Chenopodium spp.* and *Atriplex spp.* are likely to colonize the deposits but *Persicaria spp.* and black nightshade *(Solanum nigrum)* may also be found. The latter is also known as “dung-heap plant” (Hall & Kenward 1997:669-670). These annual weeds have a high seed production which can rapidly be deposited in the substrates. If the midden or dung heap remains undisturbed for some time a rich vegetation could develop that includes perennial plants like docks *(Rumex spp.)* and stinging nettle *(Urtica dioica).* The midden or dung heap could attract insects that are associated with these plants and thus indicate an *in situ* growth (Hall & Kenward 1997:970). Hall and Kenward argue that the stable manure indicator group is a distinctive one, but the identification of such a deposit will be uncertain if the number of species are too small and contain species from several other sources. There are also overlaps between the stable manure groups and other indicator groups since the individual components can occur in or even be characteristic of other deposits (Hall & Kenward 1997:970) such as cesspits. Distinguishing between stable manure and pure dung from large herbivores can also be difficult. Their excrement deposits can contain a plant and insect assemblage similar to that of stable manure, but pure dung is unlikely to contain a larger amount of house fauna, mouldering matter, or litter-plants (Hall & Kenward 1997:971).

An interesting example that may show how stable manure manifests in samples from a site, is that of a Neolithic settlement at Weier in North western Switzerland dated to 3800 BC. Environmental samples from the site included manure mixed with preserved leaf fragments which suggested that livestock were foddered with leaves (Nielsen *et. Al.* 2000), (although it could also have been used as litter). Insect remains were recovered from a presumed byre dated to 3600 BC (Nielsen *et. al.* 2000: 209). The results from the insect analysis showed that Diptera puparia, mites and adult Coleoptera were the most common finds in the samples. Lesser dung flies (Sphaeroceriae) most of all *Thoracochaeta zosterae* (Haliday, 1833) dominated among the Diptera in all the layers. Puparia of *Musca domestica* and Sepsidae were also common. Among the mites there were finds of Cryptostigmata *(Oribatida)* and Mesostigmata *(Gamasida, Gamasina* and *Uropodina).* Of the Coleoptera the rove beetle (Staphylindae) were the most common find which included *Oxytelus sculptus* (Gravenhorst, 1806), scavenger beetle (Hydrophilidae) and *Cercyon analis* (Paykull 1798) (Nielsen *et. al.* 2000:210-211 & 213). The Diptera larvae indicated breeding inside the stable and the Gamasida can indicate the presence of dung from domesticate animals, sometimes that from certain animal species.

Since many of the rove beetles are mobile they were interpreted as a part of the background fauna by the authors, belonging to the habitats around the settlements having been attracted by the decaying organic matter in the byre (Nielsen *et. al.* 2000:212). In fact, nearly all species identified are such associated with decaying organic matter and very few "outdoor" species. None of which are associated with dry decomposing organic matter (Nielsen *et. al.* 2000:213-214). The authors interpret this as probable evidence of seasonal mucking of the stable. When the litter and manure was cleared out insects from other habitats on the settlement recolonized the byre. Thus the insect population density fluctuated, being low after the byre had been cleaned out and higher when decaying organic matter had again began to accumulate in the byre. The authors believe the manure to have been moved onto the fields, at least in part. Therefore, habitats for decomposer insects within the settlement could have been scarce (Nielsen *et. al.* 2000:214).

Samples taken from a bog close to the settlement (Nielsen 1989) included material from an ancient field, dated to 2900 – 2800 BC, that had been washed out into the bog where it was preserved. The finds from the bog consisted of fruits and nuts from annual weeds which were interpreted as evidence of permanently tilling of the field. 37 finds of house fly *Musca domestica* puparia were also found in the bog. This, according to Nielsen, is evidence of fertilizing of the field (Nielsen 1989:15). The house fly is a thermophilic species and in colder regions with long winters it generally survives by active reproduction in temperatures over 20 degrees Celsius, in a place that also provides its larvae with food. It can only overwinter in microhabitats that stay above -5 degrees and sustains a temperature above 10 degrees for long enough for the larvae to develop (Nielsen 1989:6 & Nielsen 2000:215). In an outside environment the species is essentially unable to establish a dense population. Therefore, Nielsen argues, that stables or a barn would be a necessity for the establishment of the house fly population at the site. Since house fly puparia have been found in the byres at the site Nielsen believe that the finds in the bog indicates that the field had been fertilized using stable manure from the byres (Neilsen 1989:6). *Muscina stabulans* (Fallen 1817) puparia were also found in the bog. Although it is a species associated with human housing this is not necessary for their breeding purposes. Their breeding habitats are diverse but they have been found together with *M. domestica* in manure heaps. The presence of *M. stabulans* does therefore not contradict the field fertilizing hypothesis, according to Nielsen (Nielsen 1998:7). Though, one could argue that this might indicate that material from human housing were used as fertilizer, as is mentioned below.

A similar example of filed manuring is the hays field at Garðar, which was mentioned above (Buckland *et. al.* 2009). Insect remains, beside the aquatic species, contained strong synanthropic species that derived from an indoor environment and others species from environments similar to that in mouldy hay in stables, byers and barns. The latter species types included the beetles *Tipnus unicolor*, *Omalium excavatum* (Stephens 1834), *Xylodromus concinnus* among others. Several of these may be found outside of their habitat as a result of dispersal, except for *T. unicolor* which is flightless and must have been deposited onto the field by other means (Buckland *et. al.* 2009:112). There were also finds of lice, fleas and flies such as the sheep ked *Melophagus ovinus*, human louse *Pediculus humanus* (Linnaeus, 1758) and human flea *Pulex irritans* (Linnaeus, 1758) which were interpreted by the authors as evidence of secondary floor material removed from human housing to a midden or directly to the field (ibid).

The stable manure insect and plant assemblage is a complex one. However, when considering the specific the requirements of these species it shows quite clearly the possibility to use insects and plants to identify stable manure and fertilizer, on fields or indeed a garden.

3.3 Garden insects and macrofossils

Finds of several cultural plants in Scandinavia and Northern Europe indicate that horticulture existed alongside crop cultivation in fields since, at least, early Iron Age (Heimdahl 2014:8). It is important to recognize horticulture as an independent part of agriculture that most likely played a vital role in crop production. Many prehistoric crops could have been grown in smaller plots while others were grown in larger fields. Peas *(Pisum sativum),* beans *(Vicia faba),* flax *(Linum usitatissimum),* hemp *(Cannabis sativa)* and camelina *(Camelina sativa)* are plants that could have been grown in gardens on the settlement in order to complement the field crops (Heimdahl 2014:10). Finds of plants from the Fabaceae family occur in the archeobatoanical record since the Neolithic and onward. A large find of carbonized peas *(Pisum sativum)* and beans *(Vicia faba)* dating to around year 0 have been found in deposits from Svarteborg (Viklund 2014:23), although they are quite rare in archaeological deposits. Perhaps they were not cultivated in any large scale before the late middle Ages, or perhaps their size prevented them from being lost and thus deposited during food processing (ibid). Their sensitivity to taphonomical processes due to their protein richness and soft coating are probably the foremost reason behind their underrepresentation in the archaeobotanical record (Viklund 1998:30). There are several beetles and flies that feed on peas and beans (see appendix 3 for a more detailed insect and food plant list), *Sitona sulcifrons* (Thunberg 1798) is one of the beetles. It has a few other host plants in the Papilionaceae family, but its' food web is quite limited compared to other pests of these particular plants. It can be found in many varied biotopes on any disturbed ground surface created by animal, geological or human action, which may include ploughed fields, edges of watering holes, farm yards, glacial margins etc. It appears in the fossil record from many sites in England, Ireland, Germany, Russia and Sweden (Buckland & Buckland 2006;Smith. & Roy 2008). Camelina is a host plant to *Ceutorhynchus syrites* (Germar, 1824) and *Ceutorhynchus contractus* (Marsham, 1802). They prefer dry places on disturbed and arable grounds or sandy and dry conditions. The first has a narrow food web that includes several *Brassicas* while the other has a much more uncertain food web. Both appear in the fossil record, though the latter in a much higher frequency (ibid). *Linum usitatissimum* is a food plant to *Aphthona euphorbiae* (Schrank, 1781) which has some presence in the fossil record, but has a wide and varied food web (ibid).

Psylliodes attenuata (Koch 1803) is a pest on *Cannabis sativa* and *Humulus lupulus, Urtica* and an uncertain number of Cannabiaceae species. It prefers warm conditions on disturbed and arable or sandy and dry grounds. It has been found on one site in England (Buckland & Buckland 2006;Smith. & Roy 2008). *Cannabis sativa* and *Humulus lupulus* are plants for which seed production has been inhibited during cultivation and are thus hard to find in archaeological deposits. Female hop plants were cultivated for their cones, used in beer brewing. Fertilization of hops by the male plant would spoil the cones' flavour, therefore the

Fig. 2 *Psylliodes attenuata* with its food plants *Cannabis sativa* and *Hmulus lupulus.* Illustration by the author.

removal of male hop plants was attempted. Finds of hop seeds do occur so this attempt must not have been as successful as desired (Viklund 2014:20). In hemp cultivation only a few male plants were kept for pollination and seed production for cultivation of new plants. The reason for this may have been the different fibre quality in the male and female plants (ibid). Hemp has been cultivated in England since at least 800 AD, perhaps since the Roman Period, mainly for its fibre but also for their oil rich seeds. The evidence for hemp cultivation exists in the form of written sources, place names, map features and fossil evidence in form of pollen. Though hemp pollen is difficult to distinguish from hop pollen the evidence can be complimented by other plant remains and macrofossils. Paleoentomology can give evidence of water pollution from the fibre processing of hemp, called retting, were bundles of hemp are submerged into water for some days where they begin to decompose – making the fibres easily separated (Gearey *et. al.* 2005:317-18). This process occurs when the plant is flowering which means there can be a large amount of pollen deposited in the water, but generally no seeds. If the seeds had developed they were removed prior to the retting but some may be missed. The decay of the plants creates foul waste products that contaminates the water and was thus done away from the settlement (ibid). Highly elevated pollen counts of hemp/hops from sediments at several sites have been discovered, namely Ellerton Priory in North Humberside, Askham Bog in the city of York and Morton Lane, Beverly, North Humberside dating from early to late medieval period. In many cases plant remains and seeds of hemp have been recovered as well, indicating the practice of retting (Gearey *et. al.* 2005:318-21). Unfortunately, trying to use invertebrates to distinguish between hemp and hop pollen would not offer much additional evidence since *P. attenuate* is a pest on both. Though, finds of *P. attenuate* along with hemp or hop seeds or other plant remains could indicate the *in situ* growth under favourable conditions. Finding them at supposed retting sites could support the pollen and macrofossil finds.

Onion *(Allium spp.)* is recorded in historical documents dated to around 300 AD and cabbage *(Brassica oleracea)* have been found archaeobotanically dating to the same period and onward. Even older finds of dill *(Anethum graveolens)*, opium poppy *(Papaver somniferum)* and henbane *(Hyoscyamus niger)* appear in the archaeobotanical record (Heimdahl 2014:8;

Viklund 2014:21-22). The Viking Age sites Hedeby, Staraja Ladoga and Oldenburg have yielded rich finds of spices like parsley *(Petroselinum crispum),* coriander *(Coriandrum sativum)* and medicinal plants including motherwort *(Leonurus cardiaca)* (Heimdahl 2014:8) Some of these have also been found in deposits from the medieval town Nya Lödöse along with catnip *(Nepeta cataria),* henbane *(Hyoscyamus niger), Solanum sp.,* flax *(Linum usitatissimum)* and *Brassica sp.* among others. Some insects were also discovered in the samples including Anthomyidae and *Aphodius sp*. though the context was unclear and the samples were not treated for insect analysis which probably damaged the fragments (Larsson 2012). A large amount of henbane seeds were found in a well in Mörby near a small scale hortic soil which was interpreted as a herb or kitchen garden and seemed to indicate a small scale cultivation at the site (Heimdahl 2009:116). Henbane and opium poppy were cultivated for their seeds which were used, at least in part, for their analgesic properties (Viklund 2014:22). Opium poppy, among other plants in the Papaveraceae family, is a host to *Stenocarus umbrinus* (Gyllenhal, 1837). It prefers warm conditions on disturbed and arable to sandy or dry grounds and has been found on a few sites in England (Buckland & Buckland 2006;Smith & Roy 2008). Though *Psylliodes hyoscyami* (Linnaeus, 1758) is not listed in the fossil record available in BugsCEP, it is a pest on henbane and has a narrow food web. If found it could be used as a valuable indicator for this plant and perhaps the medicinal or ritualistic use of it (Buckland & Buckland 2006;Smith. & Roy 2008). Excavations of Skriðuklaustur on Iceland have yielded well preserved plant macrofossils of several species, including a few medicinal plants. In 1477, some years before the foundation of the monastery a volcanic eruption covered the site in volcanic ash which enabled an exact dating of the plants discovered there, which included onion *(Allium)* borage *(Borago officinalis)* and *Brassica sp.* (Larsson *et. al.* 2012). *Longitarsus anchusae* (Paykull 1799) is connected to borage though it has a long and somewhat uncertain list of food plants and the last is a pest on several plants in the Boraginaceae family, though it does appear in the fossil record (Buckland & Buckland 2006;Smith. & Roy 2008). *Meligethes atratus* (Olivier 1790) is a pest on the *Allium* genus as well as plants in the Ranunculaceae and Rosaceae family. It has been found on one site in England (Buckland & Buckland 2006;Smith & Roy 2008). Though there are hundreds of species in the *Allium* genus and therefore it is of little use in trying to connect an insect pest to establish cultivation without knowing the species of *Allium.*

Seeds from salads, root vegetables and plants in the *Brassica* genus can be quite difficult to find, and when they are some of them can be somewhat hard to tell apart. Most of the cultivated *Brassica* species derive from one wild species *Brassica oleracea* (Viklund 2014:21). The *Brassica* seeds have similar morphology which complicate identification. Turnip *(Brassica* *rapa ssp. rapa)* and the wild filed mustard *(Brassica rapa ssp. campestris)* can prove especially problematic, as can *Brassica rapa ssp. oleifera,* rutabaga *(Brassica napus var. napobrassica)* and oil seed-rape *(Brassica napus ssp. napus)* (ibid). All the cultivated species of *Brassica* are biennial. However most of them are harvested the first year and are therefore somewhat rare finds in archaeological deposits since their seed deposition would be limited. Oils seed-rape or rutabaga have been found in Lund dating to 1100 AD and turnip or *Brassica rapa ssp. oleifera* have been found dating to 1300 AD (ibid). Using invertebrates to distinguish between the *Brassicas* would be problematic, to say the least. There are several beetles and flies that use *Brassicas* as food plants, though they do not discriminate. *Psylliodes chrysocephala* (Linnaeus 1758) and *Ceutorhynchus pleurostigma* (Marsham 1802) are two examples of *Brassica* pests and both of them, as with most of *Brassica* pests, feed on several of the *Brassicas* and other species in the Cruciferae family. They live on disturbed and arable to sandy and dry ground and both appear in the fossil record (Buckland & Buckland 2006;Smith & Roy). The beetles could indicate *in situ* growth if found in garden soil together with seeds from their host.

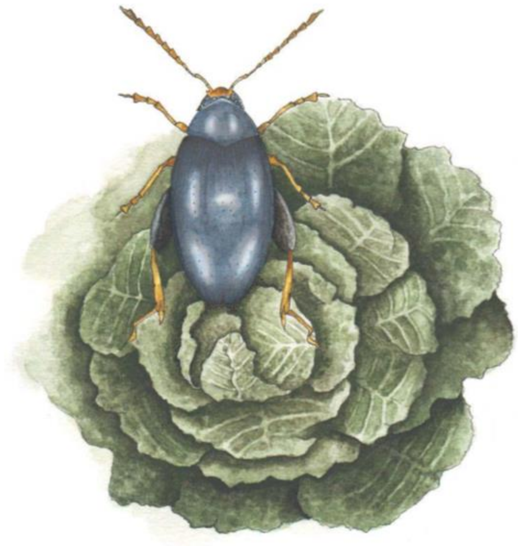


Fig. 3 *Psylliodes chrysocephala* with its food plant *Brassica*. Illustration by the author.

Some native species of carrot *(Daucus carota)* and oregano *(Origanum vulgare)* are also thought to have been cultivated, as have celery *(Apium graveolens)* and cumin *(Carum carvi).* Oregano is host plant to a few Coleoptera species including *Aphthona atratula* (Allard, 1859) and *Longitarsus obliteratus* (Rosenhauer, 1847). They both appear in the fossil record and are associated with several other plants in Labiatae family, the latter on lemon balm *(Melissa officinalis)* and *Thymus vulgaris*. (ibid). Cumin occurs in the wild in Sweden which can problematize the interpretation of the finds if *in situ* growth cannot be established. *Daucus carota* appears quite early in Swedish archaeological deposits. The problem is that it can be difficult to differentiate between the cultivated and the wild species (Heimdahl 2014:8; Viklund 2014:21-22). *Phaedon tumidulus* (Germar, 1824) feeds on a several species in the Umbelliferae family, including some carrot species: *Daucus carota ssp. sativus*, *Daucus carota ssp. gummifer*, *Daucus carota ssp. carota* as well as celery *(Apium graveolens var. dulce),* parsley *(Petroselinum crispum),* fennel *(Foeniculum vulgare)* and parsnip *(Pastinaca sativa).*

Ceutorhynchus terminatus (Herbst, 1795) is another pest on celery, parsley, carrot, cumin and some other species in the Umbelliferae family. They both appear in the fossil record. (Buckland & Buckland 2006;Smith & Roy 2008). The find would not aid the identification of wild or domesticated carrot or a particular plant, but could aid in establishing *in situ* growth of any of these host plants if found in a garden soil.

Some finds can prove difficult to interpret, as mentioned earlier. Because of this, plants such as parsley *(Petroselinum crispum)*, cabbage *(Brassica oleracea)*, marjoram *(Origanum majorana)* and radish *(Raphanus sativus)* have a much higher source value than cumin *(Cuminum cyminum)*, fennel *(Foeniculum vulgare)*, gooseberry *(Ribes uva-crispa)* and coriander *(Coriandrum sativum*) because of the deposition difficulties since they tend to be deposited in latrines and then later in gardens via fertilizer (Heimdahl 2014:5). There are some beetles that are pests of these plants (see appendix 3). Finds of Coleoptera connected to these plants could help prove their *in situ* growth given that seeds from their other food plants are not present.

Other plants are underrepresented in the archaeobotanical record due to pre-depositional crop treatment or post-depositional taphonomical processes, as mentioned above. Examples of the first mentioned factor is onion *(Allium sp.)* an angelica *(Angelica archangelica).* The written sources for onion are very old but archaeobotanical finds are scares. The reason behind this probably has to do with the preferred method of planting onion sets instead of sowing seeds (Viklund 2014:19). The same problem applies to angelica. Finding their seeds in archaeological deposits is uncommon which most likely has to do with limited handling of their seeds during cultivation. The planting of angelica has probably been done with plant shoots since their seeds' germination durability is short. The plant also withers after blooming. The green part of the plant and its roots were used as medicine, food etc. and in order to get the desired part of the plant and their shoots for further planting their flowers would be picked off (ibid). Finds of the weevils *Liophloeus tessulatus* (Müller, 1776) or *Lixus iridis* (Olivier, 1807) could indicate the cultivation of angelica under favourable conditions. They do, however, feed on a few plants in several families including the Umbelliferae family. Both appear in the fossil record and prefer wet enironments (Buckland & Buckland 2006;Smith. & Roy 2008).

3.4 The garden indicator group

The results of this paper have shown that it is possible to connect pest insects to plants known or believed to have been cultivated in historic and prehistoric gardens. The beetles presented as indicator species for garden host plants in this paper are suggestions used as examples for the purpose of this essay (fig 4). However, several of the insects mentioned in this paper could be found in garden contexts since many of them do appear in the fossil record. Further, they are connected to sources known to be mixed in with the garden soil and plants from garden archaeological records. Of course many of the organisms found can derive from other deposits, or a garden may not contain all or other species. Although, in this case the indicator group is not so much dependent on the specific species as it is the assemblage as a whole. In other words, the exact content of the garden indicator group will differ depending on the overall environment of the settlement.

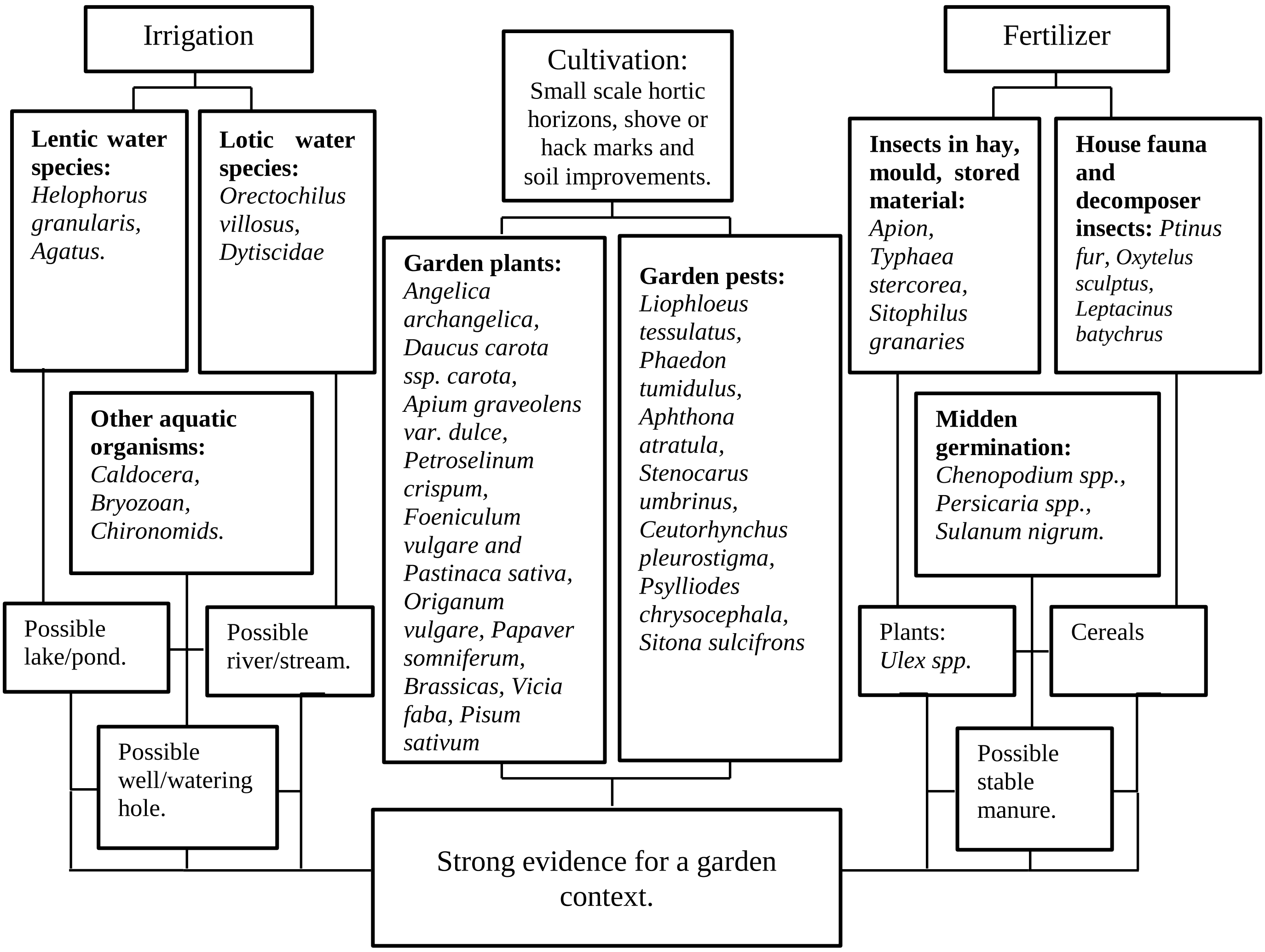


Fig. 4. Some species mentioned in this paper that could be found in and aid in the identification of garden contexts and the *in situ* growth of garden plants if the insect species are found together with seeds or other remains from their host plants.

4 Discussion

The theory developed in this paper demonstrates how fossil insects and beetles can be used as indicators of specific plants *in situ* growth in gardens. Gardens have not, to the authors' knowledge, been investigated paleoentomologically. However, the method presented in this paper will allow garden contexts to be identified and described in future studies. The method relies on the users' awareness and understanding of the dynamic relationships between insects and plants, anthropogenic and natural ecosystems, climate, human interference and context variation that is garden archaeology. It has been suggested that aquatic organisms in garden soils can, and have, given evidence of irrigation (Buckland *et. al.* 2009; Heimdahl 2014:5; Kenward 2009:71, 85), recovering beetles connected to garden plants to be used as evidence for *in situ* growth should be the next step.

When using this method, regard must be given to the contexts' surroundings, the particular food web and environmental niche of the insect species found and possible season of growth – spring, summer or fall. These factors are crucial to the archaeological and ecological interpretation of the environmental data. Plants and weeds in and around the garden could attract insects that end up in the garden fossil record, therefore it is important to sample the surroundings and consider the garden material as a whole. If focus is not given to the seeds of weeds in the garden or the surrounding flora an insect find can be assigned too much importance. What invertebrates could be found in a garden soil will depend on several conditions. The hardiness of the insects is important aspect, as it determines whether it could withstand taphonomical processes it would be exposed to in the context. Whether or not they thrived, if they were able to create a dense population, this will also alter the fossil record. What was used as fertilizer, water source for irrigation and what plants grew in the gardens' surroundings also plays an important role in the final configuration of the environmental data retrieved from the contexts. The choice of crops grown in the garden will depend on what plants would be able to thrive in the settlements environment, what plants were domesticated or introduced during the settlements active time period and what plants were preferred, available and profitable for people to grow. If a specific plant (or a reasonable substitute) grew in abundance in the settlements surroundings it may not have been worth the effort to grow it on site. All of this will also be dependent on the state of the garden at its last phase of use and the preservation properties of the contexts. Therefore, the environmental data from a garden context will contain a wide range of different organisms besides those presented in this paper. This indicator group also shares many similarities with other indicator groups which may lead to misinterpretation, especially if the data set is small or highly fragmented. It is therefore important for this indicator group to be used as a part of an indicator package so that the environmental data can be analysed together with the archaeological evidence at hand. However, it is the relationships between and the mixture of different species from garden contexts that is most important. The archaeologists' awareness of these relationships will have implications for the context identification and interpretation, even though the specific species may vary.

Paleoentomological analysis of garden soil could also yield secondary evidence of plant - insect interactions in the form of predators. A predacious beetle, for example, could indicate the presence of an herbivore which in turn could indicate a plant. However, one must bear in mind that for each step backwards in food web there are several other species of plants and herbivores that could have been the subject of consumption. This is the reason why we differentiate between food webs and food chains (cf. Chapman & Reiss 1999:128f). One species does not directly indicate another but rather suggests several possibilities. *Phaedon tumidulus* for example feeds on a several species in the Umbelliferae family, including several carrot species: *Daucus carota ssp. sativus*, *Daucus carota ssp. gummifer*, *Daucus carota ssp. carota* and celery *(Apium graveolens var. dulce),* parsley *(Petroselinum crispum),* fennel *(Foeniculum vulgare)* and parsnip *(Pastinaca sativa)* plus several other wild species. That is why establishing the flora of the context surroundings is vital. Many cultivated plants do not have any beetles preying on them but rather flies and moths, which have a smaller chance of being found in the archaeological record. Though adult Coleoptera are the most likely to survive the taphonomical degradation it is not uncommon for fly puparia and larval heads etc. to appear in the fossil record. Therefore, it should be possible to use other invertebrates than fossil beetles as indicator species for garden plants.

The different phases in the garden will also alter the environmental data. The seeds that are recovered from garden soils are generally interpreted as the last active season of the garden before its abandonment. The insect remains preform the same function. During phase 1-3 (soil preparation and fertilizing, growing period and post harvesting) there should be some deposition of insects in the garden soil that look different from one another. During phase 1 the garden habitat would be inhabited by insects attracted to dung and other organic material (hay, litter, kitchen waste) in various stages of decay. It would be a warm, moist, open textured, nutrient-rich and foul environment probably attracting several decomposer insects such as *Acritus nigricornis, Oxytelus sculptus, Lithocharis ochracea, Leptacinus spp., Anthicus floralis, A. formicarius* and fly puparia from *Musca domestica* and *Stomoxys*. Other insects associated with dung and foul decaying organic matter could also appear, like *Platystethus anenarius, Cercyon haemorrhoidalis, C. quisquilus, Aphodius spp., and Geotrupes spp.* and insects attracted to decaying plant material or animal carcases (flies such as Sphaerocerids (Sphaeroceridae) and Sargus spp., (Stratiomydae)). Rove beetles that breed in warm and fermenting compost heaps or similar environment could also be present, such as *Pseudomedon obscurellus, Leptacinus batychrus and Leptanicus pusillus* (see appendix 2). What insects end up in the fossil record will depend on whether the insects were alive or dead when deposited with the fertilizer and which colonized the garden after the deposition of fertilizer. If alive their presence would depend on whether or not they would continue to thrive when the habitat changed.

During phase 2 there would be an addition of herbivorous insects feeding on the plants growing in the garden. The decomposing organic matter would have partly dried or altered from fresh/foul to foul/dry. Mould feeders and their predators such as *Typhaea stercorea, Anthicus formicarius, Cryptophagus scutellatus, Mycetaea hirta* and *Crataraea suturalis* would appear in the context. The plants would create shelter in form of shade and leeward. It is during this phase that the plant pests would appear in the garden context. Several of the plant pests presented in this paper can be found in many different biotopes (see appendix 3). Some of them prefer disturbed or arable to sandy and dry ground, such as *Sitona sulcifrons, Psylliodes chrysocephala* and *Ceutorhynchus pleurostigma* while *Liophloeus tessulatus* prefer shade and wetland habitats. Others, such as *Phaedon tumidulus* and *Aphthona atratula* are connected to meadowlands, the latter preferring dry conditions. While the species share some similar ecological preferences they also have their own niches that might affect their ability to thrive in the garden context. The level of moisture would increase due to irrigation and decreasing evaporation. Depending on the climate and season the garden habitat might thus be favourable for *L. tessulatus.* Though, if the climate is dry and warm the garden might instead be more suitable for species such as *Stenocarus umbrinus* which prefer warm conditions on disturbed, arable and/or sandy and dry grounds. Therefore, the garden fauna will differ depending on climate and season and might even shift during the phase if the habitat changes from dry to humid due to weather or other disturbances within the habitat. Finds of different herbivorous beetles might therefore indicate growing season and climate as well as *in situ* growth of cultivated plants, under favourable conditions. Throughout phase 1 and 2 aquatic organisms would enter the deposits through irrigation, and what kind of organisms would depend on the water source. For instance, *Helophorus granularis* has a connection to lentic waters whereas *Orectochilus villosus* are find in lotic habitats (see appendix 1). Finds of certain aquatic organisms in garden contexts could therefore not only indicate the presence of a garden but also where the water was collected from, and thus how the settlements or city's water resources were used.

At phase 3 when the plants have been harvested the garden habitat would have been transformed into somewhat of a wasteland. Depending on the overall climate and season it could either be wet and cold or dry and sunny, contain much less nutrients and with no real shelter or food resource. Some plant refuse might have been left behind, such as plants that were too infested by vermin or in other ways did not live up to the consumption standard. The parasites of such plants may be left and the plants might have lived long enough to produce and deposit seeds but the habitat would not likely attract any additional insects from this moment on. Perhaps the habitat could attract some insects preying on the discarded plants, remains of fertilizer and predators of these insects. If the season and/or climate offered dry conditions *M. domestica* and *Stomoxys calcitrans* and similar house fauna might thrive in the context during this phase since the presence of them in the cesspits was interpreted as a shift to a drier environment which favoured the development of the flies. Whether or not any insects would be able to survive in the habitat during its final phase would depend on the insect species that ended up there. In northern climates, it would be a cold and desolate environment with little to no protection for hibernating insects. The insects left would be the few that could overwinter and those that died during previous phases. What insects end up being deposited depends on several factors; whether they were alive or dead when deposited, if they could thrive in the garden despite the changes – if not whether or not they were mobile and could relocate, or if they simply died in the garden by predation or other causes. The human interference will drastically alter the habitat several times during the year, not only by adding material such as fertilizer and moisture but also through various garden activity, trampling, sowing, weeding, harvesting and so on will interfere and destroy nests in the soil and on the plants. This will affect the population density, the insects' ability to thrive and hibernate. Some insects might adapt to this better than others, it will depend on the species breeding and hibernation routine and at what time of year their offspring develop and hatch. Selection of crops also have an important role, not only because certain plants attract certain insects, but also because the crops could be seasonal. Some crops could have been grown in spring to early summer and others from summer to fall, in this way phase 1-3 could be repeated and thus the environmental data differ depending on season.

Whether cultivation of plants also would affect herbivorous beetles to an extent that would have an effect on the fossil beetle assemblage in a potential garden is uncertain. This is an important question to consider if this indicator group would be applied in garden archaeological research. It would be wise to consider the species found and selected and whether or not they have shown morphological consistency or if they have proven prone to change. Fossil plant and beetle studies in a garden context could also be of use to investigate this question. If a certain beetle is frequently found in the same deposits as its domesticated food plant dating to around the time of the plants known domestication, it could be argued that the beetle quickly embraced its new food source.

The sources in this paper regarding garden plant pests have consisted of modern ecological information from somewhat limited origins. Though databases uses a wide range of sources there is a great need for more, multidisciplinary and accessible databases that will enable this kind of research since relevant publications can be difficult to come by. This subject requires more research and before paleoentomology can be evaluated properly as a proxy in garden archaeological the method must be tested in order to see how it would hold up in practical work. Relevant and accessible databases that cross-reference ecology, climate data, archaeological sites, fossil insects and macrofossils would be an important step in order to encourage and enable similar research. What this paper has shown, however, is that paleoentomology may offer great opportunity for garden archaeology and should thus be considered a part in the garden indicator package in future research.

5 Conclusion

The results of this paper has pointed to the possibility of using fossil beetles as indicator proxies for the *in situ* growth of relic plants. There are, however, many questions yet to be answered and difficulties to consider. For instance, the ecological complexity that this method entail and how these ecological conditions gets altered by human interference, and what that means for the archaeological interpretation. Beetles have several other plants in their food webs, both cultivated and wild species. This does not mean that they cannot be used as indicators, only that extra caution must be taken in regards to other plants in and around the context. If a beetle feeds on several species in one plant genus they cannot easily be used to establish the *in situ* growth of one specific plant in that genus, nor to distinguish between plant seeds with similar morphology. Many of these beetles seem to thrive in environments similar to that of a garden, at least in the growing phase (2) when plants offer food, the ground is nutrient rich and there is both warmth, shade and shelter. Though it is possible that different species will be attracted to the garden habitat if the local climate of the habitats shifts, even during one phase. Wetland species might be attracted to the garden during more humid periods and species that prefer dry and warm conditions might enter the context during drought. The garden's habitat and what species will be attracted to it and thrive in it will therefore depend on the overall environment of the site and the conditions of the garden. However, since there is some diversity among the insects mentioned in this paper, many of which can be found in a variety of biotopes it is likely that some of these beetles could be found in varied garden habitats. By the information presented in this paper one can conclude that the environmental data would vary depending on the site and on changes during the garden phases due to climate, season and human interference. The exact content in terms of insects and plants species, both host plants, their pests and species from other deposits, will depend on too many variables and is thus not feasible to comprehend at a theoretical level such as this. What these variables are and how they might alter the environmental data are however intelligible. Therefore, the garden indicator group could be adapted as an analytic tool within a wider indicator package to aid the identification of garden contexts and plants *in situ* growth, given that cautionary measures are taken in terms of the surrounding environment in relation to the species food webs and ecological niches.

6 Sammanfattning

Syftet med denna uppsats har varit att utvärdera möjligheten att använda paleoentomologi som en proxy i trädgårdsarkeologisk forskning. Fossila trädgårdar kan vara svåra att identifiera och tolka på grund av de många förändringar som kontexterna genomgår under sin aktivitetsperiod. Blandning av material, skörd och odling av många olika växter under olika säsonger kommer att påverka de miljöarkeologiska data som hämtas från dem och därmed vår tolkning av trädgårdsodling. Denna uppsats har undersökt sammanhanget och de material som ingår i trädgårdsprocessen. Bevattningskällor, gödsel, trädgårdsmakrofossil och moderna ekologiska insekts- och värdväxtförhållanden har analyserats i syfte att föreslå en ”indicator group” av insekts- och växtarter som kan tillämpas vid identifiering av trädgårdenskontexter och *in situ* odling av kulturväxter. Uppsatsen har visat att många av de växter som vi vet har odlats under förhistorien och under historisk tid är värdväxter till flera insekter och i många fall skalbaggsarter. Flera utav dessa har återfunnits i det arkeologiska materialet, men många saknas. Vad detta beror på är svårt att besvara, de kan antingen vara svåra att identifiera, för små eller för sköra för att bevaras eller så har inte ”rätt kontexter” (det vill säga trädgårdskontexter eller liknande habitat där dessa insekter normalt vistas) analyserats paleoentomologiskt. Att flera av dem emellertid har återfunnits i arkeologiska kontexter öppnar upp för paleoentomologi som metod inom trädgårdsarkeologin. Det är dock viktigt att ta hänsyn till arternas specifika ekologiska nischer samt trädgårdens omgivning då det dels är många olika variabler som kan leda till att en insekts deponeras i en kontext, och dels då denna grupp av insekt- och växtarter bär stora likheter med andra. Det är således avgörande att analysera de miljöarkeologiska data (inne och utanför kontexten) tillsammans med den arkeologiska för att slutsatser skall kunna göras utifrån insekterna och deras värdväxter.

References

Andréasson, A., Gräslund Berg, E., Heimdahl, J., Jakobsson, A., Larsson, I., Persson. E. (red) 2014. *Källor till trädgårdsodlingens historia. Fyra tvärvetenskapliga seminarier 2010–2013 arrangerade av Nordiskt Nätverk för Trädgårdens Arkeologi och Arkeobotanik (NTAA).* Sveriges lantbruksuniversitet. Fakulteten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap, Rapport: 2014:25, Alnarp

Badr, A., Müller,K., Schäfer-Pregl, R., El Rabey, H., Effgen,S., Ibrahim, H. H., Pozzi,C., Rohde, W., and Salamini, F. 2000. On the Origin and Domestication History of Barley (Hordeum vulgare). *Molecular Biology and Evolution* 17, p. 499-510

Buckland,P. C., Edwards, K. J., Panagiotakopulu, E., and Schofield, J. E., 2009. *Palaeoecological and historical evidence for manuring and irrigation at Garðar (Igaliku), Norse Eastern Settlement, Greenland.* The Holocene 19,1 2009 p. 105–116

Buckland, P.I. & Buckland, P.C. 2006. *BugsCEP Coleopteran Ecology Package. IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2006-116. NOAA/NCDC Paleoclimatology Program, Boulder CO, USA.*
Available at: http://www.ncdc.noaa.gov/paleo/insect.html or http://www.bugscep.com (Accessed November 2016)

Buckland, P.I. 2007. *The Development and Implementation of Software for Palaeoenvironmental and Palaeoclimatological Research: The Bugs Coleopteran Ecology Package (BugsCEP).* PhD thesis, Environmental Archaeology Lab. Department of Archaeology & Sámi Studies. Archaeology and Environment 23, University of Umeå, Sweden.

Buckland, P.I., Buckland, P.C., Olsson, F., 2014. Paleoentomology: insects and other arthropods in environmental archaeology. In: Smith, C., Lanteri, C., Reid, J., Smith, J., Krauss, T.M. (Eds.), *The Encyclopedia of Global Archaeology*. Springer.

Bukovinszky, T., vanVeen, F.J.F., Jongema,Y., & Dicke, M. 2008. Direct and indirect effects of resource quality on food web structure. *Science*, 319, p. 804–807.

Carrott, J. & Kenward, H. 2001. Species Associations Among Insect Remains from Urban Archaeological Deposits and their Significance in Reconstructing the Past Human Environment. *Journal of Archaeological Science* (28) p. 887–905. York

Chapman, J. L., & Reiss, M. J. 1999. *Ecology: principles and applications*. 2. ed. Cambridge

Dincauze, D. F. 2000. *Environmental archaeology: principles and practice*. Cambridge

Elberling, B., Matthiesen, H., Jørgensen, C.J., Hansen, B.U., Grønnow, B., Meldgaard, M., Andreasen, C., Khan, S.A., 2011. Paleo-Eskimo kitchen midden preservation in permafrost under future climate conditions at Qajaa, West Greenland. *Journal of Archaeological Science* 38, p. 1331-1339.

Elias, S. A. 2007. Overview of Fossil Beetles. *Encyclopedia of Quaternary Science*. Vol. 1 p. 153-163. Amsterdam

Engelmark, R. & Linderholm, J. 2008. *Miljöarkeologi. Människa och landskap – en komplicerad dynamik.* Malmö

Evans, J. G. 2003. *Environmental archaeology and the social order.* London

Gearey, B. R., Hall, A. R., Kenward, H. K., Bunting, M. J., Lillie, M. C. and Carrott, J. 2005. Recent palaeoenvironmental evidence for the processing of hemp (Cannabis sativa L.) in eastern England during the medieval period. *Medieval Archaeology*, 49, p. 317-322

Guttmann, E. B. A. 2005. Midden cultivation in prehistoric Britain: arable crops in gardens. *World Archaeology*, 37:2, 224-239

Hall, A. & Kenward, H. 1997. Enhancing bioarchaeological interpretation using indicator groups: stable manure as a paradigm. *Journal of Archaeological science*. 24, p. 663-673. York

Haye, T., Kenis, M., 2004 Biology of Lilioceris ssp. (Coleoptera: Chrysomelidae) and their parasitoids in Europe. *Biological Control* 29: 399-408.

Heimdahl, J. 2009. Bolmörts roll i magi och medicin under den svenska förhistorien och medeltiden. *Fornvännen.* (104), s. 112-128. Stockholm

Heimdahl, J. 2010. Barbariska trädgårdsmästare: nya perspektiv på hortikulturen i Sverige fram till 1200-talets slut. *Fornvännen,* (105), p. 256-280. Stockholm

Heimdahl, J. 2014. När grönskans prakt till mull och stoft förtvinat. Forna tiders trädgårdar i Sverige studerade genom kvartärgeologi och arkeobotanik 1999 – 2012 *In: Källor till trädgårdsodlingens historia: fyra tvärvetenskapliga seminarier 2010–2013 arrangerade av Nordiskt Nätverk för Trädgårdens Arkeologi och Arkeobotanik (NTAA).* Sveriges lantbruksuniversitet. Fakulteten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap. Rapport 2014:25 p. 3-15. Alnarp.

Hellqvist, M. 2013. The well in the settlement: a water source for humans and livestock, studied through insect remains from Southeast Sweden. *In: Barely Surviving or More than Enough?: The environmental archaeology of subsistence, specialisation and surplus food production* p. 151-173. Leiden

Hill, Dennis S. 1997. *The economic importance of insects.* 1. ed. London

Kenward, H. 2009. Northern regional review of environmental archaeology invertebrates in archaeology in the North of England. *Environmental studies report*. English Heritage, Research Department Report Series no. 12-2009

Larsson, Hanna (2012) Nya Lödöse SU Gö 218, Gamlestaden i Göteborgs kommun, V Götalands län. Arkeobotaniska analyser, MAL-rapport 2012-017, Umeå: Umeå universitet.

Larsson, I. Åsen, P. A. Kristjánsdottír, S & Lundquist, K (red.) 2012. *Medeltida klostergrunder på Island - vegetation och flora, kultur och reliktväxter, samtida växtnamn* rapport från ett forskningsprojekt 2009-2011. Alnarp

Lemdahl, G. 1990. Insektsanalys och arkeologiska tillämpningar. *Bebyggelsehistorisk tidskrift* (19) p. 23-31.

Linderholm, J., 2007. *Soil chemical surveying: a path to a deeper understanding of prehistoric sites and societies in Sweden*. Geoarchaeology 22 (4), p. 417–438

Linderholm, J., 2010 *The soil as a source material in archaeology. Theoretical considerations and pragmatic applications*. Archaeology and Environment 25. Umeå University, Umeå

McCafferty, P. W. 1998. *Aquatic Entomology: The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives.* Sudbury

Macfadyen, S., Bohan, A.C., 2010. Crop domestication and the disruption of species interactions. *Basic and Applied Ecology* 11, p. 116–125.

Nielsen, O. B., 1989. House fly puparia (Musca domestica L.) from a neolithic field in Thayngen-Weier, Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 62, 5–8.

Nielsen, O. B., Mahler, V., Rasmussen P. 2000. An Arthropod Assemblage and the Ecological Conditions in a Byre at the Neolithic Settlement of Weier, Switzerland. *Journal of Archaeological Science* 27, 209–218

Nordiskt nätverk för Trädgårdens Arkeologi och Arkeobotanik (NTAA)
Available from: www.archaeogarden.se (2015-10-20)

O'connor. T. P. 1998. Environmental archaeology: a matter of definition. In: *Environmental archaeology 2*. p. 1-6. Oxford

O'connor, T. & Evans J. G. 2005. *Environmental archaeology: principles and methods.* Sparkford

Odum, E. & Barrett, G. W. 2005. *Fundamentals of ecology*. 5. ed. Belmont

Panagiotakopulu, E., 2001. New Records for Ancient Pests: Archaeoentomology in Egypt. *Journal of Archaeological Science.* 28, p. 1235–1246

Panagiotakopulu, E., P. Skidmore & P. Buckland. 2007. Fossil insect evidence for the end of the Western Settlement in Norse Greenland. *Naturwissenschaften* 94, 4. p. 300-306.

Reitz, E. J. & Shackley, M. 2012. *Environmental Archaeology*. Boston

Reitz, E. J., Newsom, L. A. & Scudder, S. J. 1996. Issues in environmental archaeology. *Case studies in environmental archaeology*. New York

Romanus, H. & Haas, J. (red.) 2006. *Från tro till vetande?: trädgårdsarkeologi vid Nydala kloster* : seminaar report 1, Nydala may 3rd 2004. Jönköping

Smith, R. & Roy, D.B. 2008. Revealing the foundations of biodiversity: The Database of British Insects and their Foodplants. *British Wildlife*, October.
Available from: http://www.brc.ac.uk/ (Accessed: December 2015)

Smith, D. 2013. Defining an indicator package to allow identification of 'cesspits' in the archaeological record. *Journal of Archaeological Science*, 40: p. 526-543.

Viklund, K., 1998 *Cereals, weeds, and crop processing in Iron Age Sweden.* Archaeology and Environment 14, Department of Archaeology, University of Umeå. Umeå.

Viklund, K., 2014. Arkeobotanik och trädgårdshistoria. *In: Källor till trädgårdsodlingens historia: fyra tvärvetenskapliga seminarier 2010–2013 arrangerade av Nordiskt Nätverk för Trädgårdens Arkeologi och Arkeobotanik (NTAA).* Sveriges lantbruksuniversitet. Fakulteten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap. Rapport 2014:25 p. 16-30. Alnarp.

Wiens, J.J., Ackerly, D.D., Allen, A. P., Anacker, B. L., Buckley, L.B., Cornell, H. V., Damschen, E. I., Davies, T. J., Grytnes, J. A., Harrison, S. P., Hawkins, B. A., Holt, R. D., McCain C. M., & Stephens, P. R., 2010 Niche conservatism as an emerging principle in ecology and conservation biology. *Ecology Letters* (13) p. 1310–1324.

Zohary, D., Hopf, M., & Weiss, E., 2012. *Domestication of plants in the Old World: the origin and spread of domesticated plants in south-west Asia, Europe, and the Mediterranean Basin.* 4th ed. Oxford

Appendix

Appendix 1, well insects and aquatic organisms found in wells or watering holes, taken from Hellquist 2013 and Buckland *et. al.* 2009 and compared with Kenward 2009.

Insects and aquatic organisms	**Habitat**	**Context implication**	**References**
Aclypea opaca (Linnaeus, 1758)	Severe pest on *Beta vulgaris, Pisum sativum, Brassica rapa. spp. rapa* and more.	considered as indicators of fields and cultivated plants	(Hellqvist 2013:158-159&161;Smith & Roy 2008).
Chaetocnema concinna (Marsham, 1802)	Severe pest on *Beta vulgaris,* meadow plants such as *Rumex, Chenopodium, Atriplex, Fallopia* and more.		
Phyllotreta vittula (Redtenbacher 1849)	Pest on cultivated plants such as *Hordeum, Avena, Secale, Triticum* and more.		
Chaetocnema hortensis (Geoffroy, 1785)	Pest on grasses.		
Aphodius foetens (Fabricius, 1787)	Lives on dung from animals, especially cow dung, on exposed and sandy ground.	Might be evidence of nearby fields with grazing livestock?	(Hellqvist 2013:160; Kenward 2009:168).
Aphodius granarius (Linnaeus, 1767)	Lives on dung, decaying organic matter and carrion. The larvae live in cow and horse dung.		
Dytiscidae	Has some connection to floodwater.	Could have entered/been attracted to the well during a phase with high water levels*.	(Hellqvist 2013:159 & 161; Kenward 2009:129).
Agatus	Requires some depth and stagnant water.		
Coelambus impressopunctatus (Schaller, 1783)	Thrives in shallow water with a lot of vegetation.	Could have entered/been attracted to the well during a phase with low water levels/the wells abandonment*.	
Ochthebius minimus, (Fabricius, 1792)	Lives in both lentic and lotic freshwater, shallow witch much vegetation, mud and sometimes even brackish waters.		(Hellqvist 2013:159-161; Kenward 2009:219).
Helophorus granularis (Linnaeus, 1761)	Lives in stagnant to slow-running waters or in temporary water collections.		
Orectochilus villosus (Müller, 1776)	Common in running waters.	Suggests that there might have been running water or a lake near the settlement.	
Bembidion varium (Olivier, 1795)	Lives on wetland plants.		
Pterostichus nigrita (Paykull, 1790)			
Notaris acridulus (Linnaeus, 1758)	Lives on vegetation that surrounding such environments		
Donacia	Lives near aquatic plants.		(Buckland *et. al.* 2009:112;Hellqvist 2013:160-161; Kenward 2009:56)
Chironomids larvae head capsules	Needs deeper and permanent waters to survive.	Common finds in archaeological deposits. Used to study lake typology, salinity, environmental reconstruction, water status and quality etc. Can indicate permanent pools.	

Caldocera egg capsules	Seem to need special conditions, for example in fine-grained lake sediments.	Can easily swirl up from the bottom when water is collected and thus provide evidence of irrigation. Used to study lake acidification, environmental reconstruction, salinity changes etc.	(Heimdahl 2014:5; Hellqvist 2013:160-161; Kenward 2009:32,59,71,85,263; McCafferty 1998:240).
Trichoptera	Lives in lentic and lotic freshwater, in microhabitats and sometimes on wet terrestrial habitats adjacent to water.	Uncommon in archaeological deposits. Considered as indicators of water quality and substratum.	
Bryozoan	Has some fresh water species.	Often found in natural and occupational sites.	
Hydroporus morio (Aubé, 1838)	Able to overwinter in shallow waters.	Indicating a wet, mossy grassland environment with permanent pools.	(Buckland *et. al*. 2009:112).
Colymbetes dolabratus (Paykull, 1798)	Needs deeper and permanent waters to survive.	Lack of larval scerites indicated that the beetle did not breed in the area.	
Trichoptera larvae	As above.	Supported the interpretation of permanent pools being present on the hay field.	

Appendix 2, stable manure indicator insects taken mainly from from Hall & Kenward (1997) but also Buckland *et. al.* (2009), Nielsen (1998 & 2000) Smith (2013) and compared with Kenward (2009). Description in "way of deposition/interpretation" is either described in these articles or this authors own interpretation.

Insects **plant feeders**	**Habitat/stable manure component and associated plants**	**Way of deposition/interpretation**	**References**
Gymnetron	Hay and litter – wetland, grassland and meadow species.	Via fodder or accidental consumption by grazing animals.	(Hall & Kenward 1997:667-668; Kenward 2009:182; Smith 2013:531-532)
Hypera (?)			
Apion	Hay, litter, waste, pasture and grasslands. Unable to breed in human housing	Via fodder or accidental consumption by grazing animals. Also appeared in cesspit.	
Sitona	Hay, litter, other. Unable to breed in human housing		
Insects **mould feeders and predators**			
Typhaea stercorea (Linnaeus 1758)	Stored materials/hay	With collected hay during harvest or attracted to site? (own reflection)	(Hall & Kenward 1997:668; Kenward 2009:50 & 292;Smith 2013:531-532, 534).
Anthicus formicarius (Goeze, 1777)			
Cryptophagus scutellatus (Newman, 1834)			
Crataraea suturalis (Mannerheim, 1831)			
Mycetaea hirta (Marsham, 1802)	Stored materials/hay. Also appeared in cesspit, drier organic materials and house fauna	collected with harvest or attracted to site, accidental consumption?	

Insects **grain pests**			
Cryptolestes ferrugineus (Stephens 1831)	stored grain	collected with harvest or attracted to site?	(Hall & Kenward 1997:668; Kenward 2009:135;Smith 2013:531-532).
Oryzaephilus surinamensis (Linnaeus, 1758)		collected with harvest or attracted to site? Also appeared in cesspit – accidental consumption?	
Sitophilus granaries (Linnaeus, 1758)			
Palorus ratzeburgi (Wissmann 1848)	moist/spoiled grain	attracted to site?	
Insects **house fauna**			
Omalium excavatum (Stephens 1834)	storage and stable buildings, also mouldy hay in stables, byers and barns.	Floor material may be deposited either on middens or directly onto fields/gardens. Many of these might be found outside their habitat, except for *T. unicolor* which is flightless and must have been deposited if found outside its' natural habitat.	(Buckland *et. al.* 2009;Hall & Kenward 1997:668-669; Kenward 2009:144, 164, 208, 282, 308-309;Smith 2013:530-532,534).
Tipnus unicolor (Piller and Mitterpacher, 1783)			
Lathridius minutus (Linnaeus, 1767)			
Aglenus brunneus (Gyllenhall 1813)?			
Lathridius minutus (Linnaeus, 1767)	storage and stable buildings and maybe semi-natural habitats, such as hay stacks.		
Ptinus fur (Linnaeus, 1758)	common in archaeological deposits and cesspits, drier organic matter and part of house fauna.		
Xylodromus concinnus (Marsham, 1802)			
Cryptophagus (some species)			
Atomaria (some species)	storage and stable buildings, drier organic matter and may occur with charred grains.		
Muscina stabulans (Fallen 1817)	species associated with human housing		(Nielsen 1998:7)
Decomposer insects			
Oxytelus sculptus (Gravenhorst, 1806)	moist, open textured, decaying organic matter rich in nutrients.	May be deposited with fertilizer taken from a midden or similar habitat, or directly attracted to the site.	(Hall & Kenward 1997:669; Kenward 2009:50,57,232,325; Nielsen 1989:6 & Nielsen 2000:215;Smith 2013:530-533).
Lithocharis ochracea (Gravenhorst 1802)			
Leptacinus spp.,			
Anthicus floralis (Linnaeus, 1758)			
Anthicus formicarius (Goeze, 1777)			
Musca domestica (Linnaeus, 1758) puparia	thermophilic species.	found in the cesspit material, interpreted as a shift to a drier habitat.	
Stomoxys calcitrans (Linnaeus, 1758)			
Acritus nigricornis (Hoffmann 1803)	decaying organic matter, but not linked to either dry or foul materials.	May be deposited with fertilizer taken from a midden or similar habitat, or directly attracted to the site. Found in the cesspit material	

Platystethus arenarius (Geoffroy 1785)	associated with dung and foul decaying organic matter.	May be deposited with fertilizer taken from a midden or similar habitat, or directly attracted to the site. Discovered at the Weier byre.	(Nielsen *et. al*. 2000:214-215).
Cercyon haemorrhoidalis (Fabricius, 1775)			
Cercyon quisquilius (Linnaeus, 1761)			
Aphodius spp.			
Geotrupes spp.			
Sphaerocerids (Sphaeroceridae)	connected to decaying plant material and/or animal dung.		
Sargus spp., (Stratiomydae)			
Pseudomedon obscurellus (Erichson, 1840)	breed in warm and fermenting compost heaps or similar environment.		
Leptacinus batychrus (Gyllenhal, 1827)			
Leptacinus pusillus (Stephens 1833)			
Nehemitropia lividipennis (Mannerheim, 1830)			
Atholus bimaculatus (Linnaeus 1758)			

Appendix 3, garden insects and host-plants. Contains the insects found to be pests on plants found at mentioned archaeological sites. Habitat descriptions from BugsCEP (Buckland & Buckland 2006):
Sandy/dry: Typifies beach, dunes and aeolian landscapes, or ploughed fields on more sandy soils.
Disturbed/arable: Any disturbed ground surface, be it animal, geological or human action. May include ploughed fields, edges of watering holes, farm yards, glacial margins etc.
Wetland/marches: Water tolerant but not living specifically in water. May include mud and bank species, as well as those moss and reed dwellers that prefer permanently wet environments.
Meadowland: Natural grassland or similar open landscapes.
Woods and trees: Species tied to either actual wood or trees, or the forest/woodland environment. Generally shade tolerant.
Heathland and moorland: may also indicate the under-storey of a Boreal forest.
Generally synanpthropic: in association with humans, either when outside of their "natural" geographical range, or in all known records.
Hydrophilous: shade intolerant species, shingle beaches and other exposed wet environments.
Appearance in fossil record: data from BugsCEP. If "none" is listed it means no such records exists in the database, if nothing is stated it means the insect itself does not appear in BugsCEP. As many insect species have several names or name synonyms they are not always called by the same name in the sources. When this is the case, that synonym is mentioned below their name.

<table>
<tr><th>Insects</th><th>Habitat</th><th>Food web complexity</th><th>Relic hostplants</th><th>Fossil record appearance</th><th>References</th></tr>
<tr><td>Tychius quinquepunctatus (Linnaeus 1758)</td><td>Can be found in many varied biotopes, but prefers dry places. Sandy/dry or disturbed/arable</td><td rowspan="2">Feeds on leaves of a narrow range of often closely related species. Some in the Papilionaceae family, otherwise quite limited.</td><td rowspan="2">Vicia faba, Pisum sativum</td><td>Rare, 2 sites in Germany</td><td rowspan="5">(Buckland & Buckland 2006;Hellqvist 2013:158-159&161; Smith. & Roy 2008).</td></tr>
<tr><td>Sitona sulcifron1s (Thunberg 1798)</td><td>Can be found in many varied biotopes. Disturbed/arable</td><td>Many sites from England also Ireland, Germany, Russia and Sweden.</td></tr>
<tr><td>Chaetocnema concinna (Marsham, 1802)</td><td>Occurs everywhere in wetland and/or marches.</td><td>Feeds on leaves and plant materials from several meadow plants such as Rumex, Chenopodium, Atriplex, Fallopia and more</td><td>Beta vulgaris</td><td>Many sites from the British Isles but also Denmark and Sweden.</td></tr>
<tr><td>Aclypea opaca (Linnaeus, 1758) or Biltophaga opaca in Bugs.</td><td>Stenotopic, lives in fields and on disturbed/arable ground.</td><td>Feeds on a wide and uncertain variety of various plants or animal species</td><td>Beta vulgaris, Pisum sativum, Brassica rapa. spp.</td><td>A few sites in England.</td></tr>
<tr><td>Phyllotreta vittula (Redtenbacher 1849)</td><td>In many various biotopes.</td><td>Feeds on leaves on a wide and uncertain variety of various plants or animal species.</td><td>Hordeum, Avena, Secale and Triticum</td><td>Many sites in England.</td></tr>
<tr><td>Ceutorhynchus syrites (Germar, 1824)</td><td>Prefer dry places on disturbed/arable or sandy/dry ground.</td><td>Feeds on leaves of a narrow range of often closely related species. Several brassicas</td><td rowspan="2">Camelina</td><td>2 sited in England and Germany.</td><td rowspan="3">(Buckland & Buckland 2006;Smith. & Roy 2008)</td></tr>
<tr><td>Ceutorhynchus contractus (Marsham, 1802)</td><td>Occurs everywhere on disturbed/arable and/or sandy/dry ground. Salt tolerant, often costal or salt march tied or where mineral precipitation is prominent.</td><td>Feeds on leaves on a wide range of food plants.</td><td>Many sites on the British Isles, also Iceland and Faroes Island.</td></tr>
<tr><td>Longitarsus parvulus (Paykull, 1799)</td><td>Meadowland</td><td></td><td>Linum usitatissimum</td><td>None.</td></tr>
</table>

Aphthona euphorbiae (Schrank, 1781)	In many varied biotopes. Prefer dry places. Meadowland and/or disturbed/arable or sandy/dry ground.	Pests on many species from a wide range of plant families.		4 sites in England.	
Psila rosae (Fabricius, 1794)		Wide range of food plants.	*Anethum graveolens*		
Meligethes atratus (Olivier 1790)	On flowers and in trees. In many varied biotopes. Meadowland.	Eats pollen and plant materials from several plants in the Ranunculaceae and Rosaceae family	*Allium* genus	1 in England.	
Lilioceris lilii (Scopoli, 1763)	On herbs and flowers. May cause damage to parks and gardens. Typical nut non-obligate synanthrope. Disturbed/arable ground and woods and trees.	Feeds on leaves on a narrow range of often closely related species, mostly in the Liliaceae family.	*Allium.*	None	(Buckland & Buckland 2006;Haye & Kenis 2004)
Psylliodes chrysocephala (Linnaeus 1758)	In many varied biotopes. Tolerant to saline habitats. Disturbed/arable and/or sandy/dry grounds.	Feed on leaves of several of the *Brassicas* and others in the Cruciferae family.	*Brassica*	3 in England.	(Buckland & Buckland 2006; Smith. & Roy 2008)
Ceutorhynchus pleurostigma (Marsham 1802) as *C. assimillis* in Bugs.	On herbs and litter. In many varied biotopes. Disturbed/arable and/or sandy/dry grounds.			A few in England, Wales and Scotland.	
Stenocarus umbrinus (Gyllenhal, 1837)	On herbs. Prefer warm conditions on disturbed/arable and/or sandy/dry grounds.	Feeds on roots and leaves on a narrow range of often closely related species, Papaveraceae family and more.	*Papaver somniferum*	A few in England.	
Epitrix atropae (Foudras 1860)	Woods and trees.	Feeds on roots and leaves on some plants in the Solanaceae family.	*Hyoscyamus niger, Atropa belladonna*	2 sites in England	
Psylliodes hyoscyami (Linnaeus, 1758)	On herbs in sandy/dry grounds.	Feeds on leaves. Specifies on a narrow food web. No one else listed.	*Hyoscyamus niger, Atropa belladonna, Solanum dulcamara*	None.	
Aphthona atratula (Allard, 1859) as *A. euphorbiae* in Bugs.	On herbs in many varied biotopes. Prefer dry places. Meadowland.	Feeds on leaves on a narrow range of often closely related species, a few plants in the Labiatae family and others.	*Origanum vulgare*	4 in England.	
Hypera pastinacae (Rossi, 1790)	On herbs. Prefer warm conditions on disturbed/arable and/or sandy/dry grounds.	Feeds on leaves on a narrow range of often closely related species. No one else listed.	*Pastinaca sativa* and *Daucus carota*, wild and cultivated.	None.	
Phaedon tumidulus (Germar, 1824)	Meadowland.	Several species in the Umbelliferae family.	*Daucus carota ssp. sativus, Daucus carota ssp. gummifer, Daucus carota ssp. carota, Apium graveolens var. dulce, Petroselinum crispum, Foeniculum vulgare and Pastinaca sativa.*	Many sites in France, Wales, Ireland and England.	
Ceutorhynchus terminatus (Herbst, 1795) as *Calosirus terminates* in Bugs.	On herbs in many varied biotopes on disturbed/arable and/or sandy/dry grounds.	Feeds on leaves on a narrow range of often closely related species, Some in the Umbelliferae family.	*Apium graveolens var. dulce,* Petroselinum *crispum, Daucus carota* and *Carum carvi.*	3 in England.	(Buckland & Buckland 2006; Smith. & Roy 2008)

Stegobium paniceum (Linnaeus, 1758)	Strongly often obligate synanthrope. Generally synanpthropic.	Feeds on plant materials of a vast and unknown food web. Pest on stored grain/products.	Seeds of *Coriandrum sativum*	Many sites in England and also Egypt, France, Ireland, Canary Island, Israel and Greece.	(Buckland & Buckland 2006; Hill 1997:118; Smith. & Roy 2008).
Eupteryx aurata (Linnaeus 1758)	On herbs and flowers. Prefer dry places on disturbed/arable and/or sandy/dry grounds.	Feeds on plant materials and pollen from several other food plants from several plant families.	*Leonurus cardiaca*	None.	(Buckland & Buckland 2006; Smith. & Roy 2008).
Meligethes incanus (Sturm 1845)	On herbs and flowers. Prefer dry places in meadowland.	Feeds on plant materials and pollen from plants in the *Echium* genus.	*Nepeta cataria, Nepeta mussinii*	None.	
Mantura chrysanthemi (Koch 1803)	On herbs. Prefer dry places. Tolerate saline habitats.	Feeds on leaves of a narrow range of often closely related species, *Rumex acetosa* and *Rumex acetosella*	*Beta vulgaris, Chrysanthemum leucanthemu*	None.	
Longitarsus obliteratus (Rosenhauer 1847)	On herbs. Prefer dry and warm conditions in meadowland and/or heathland and moorland.	Feeds on leaves of a narrow range of often closely related species, a few plants in the Labiatae family.	*Origanum vulgare, Melissa officinalis and Thymus vulgaris*	2 sites in England.	
Chrysolina banksi (Fabricius, 1775)	On herbs on disturbed/arable ground.	Uncertain number of food plants.	*Melissa officinalis*	6 sites in France and England.	
Longitarsus anchusae (Paykull 1799)	Meadowland.	A vast and uncertain food-web including many plants in the Boraginaceae family.	*Borago officinalis*	2 sites in England.	
Ceutorhynchus geographicus (Goeze 1777)					
Ceutorhynchus asperifoliarum (Gyllenhal, 1813)		A few plants in the Boraginaceae family.			
Phyllotreta vittata (Fabricius 1801)	On herbs in many varied biotopes.	Feeds on leaves of some species in the Cruciferae family.	*Raphanus sativus, Brassica oleracea* and *Brassica rapa ssp. rapa.*	Many sites in England, Sweden, Wales and Russia.	
Chrysolina fastuosa (Scopoli, 1763)	On herbs in many varied biotopes. Tolerant to saline habitats. Heathland and moorland.	Feeds on leaves of a few species in the Labiatae family.	*Ribes uva-crispa*	Many sites in England and Scotland, also Denmark.	
Liophloeus tessulatus (Müller, 1776)	On herbs in many varied biotopes. Prefer shade. Wetland/marshes.	Feeds on leaves and roots of a few plants in several families including the Umbelliferae family.	*Angelica archangelica*	A few in Wales and England.	
Lixus iridis (Olivier, 1807)	Open, wet environments. Hydrophilous.	A few plants mainly from the Umbelliferae family.	*Angelica archangelica, Pastinaca sativa*	3 sites in France and England.	
Psylliodes attenuata (Koch 1803)	On herbs. Prefer warm conditions on disturbed/arable and/or sandy/dry grounds.	Feeds on leaves of *Urtica* and an uncertain number of Cannabiaceae species.	*Cannabis sativa and Humulus lupulus*	1 site in England.	
Helicoverpa armigera (Hübner, 1809)		A vast and uncertain food-web.	*Cannabis sativa, Hyoscyamus niger* and *Pisum sativum*		