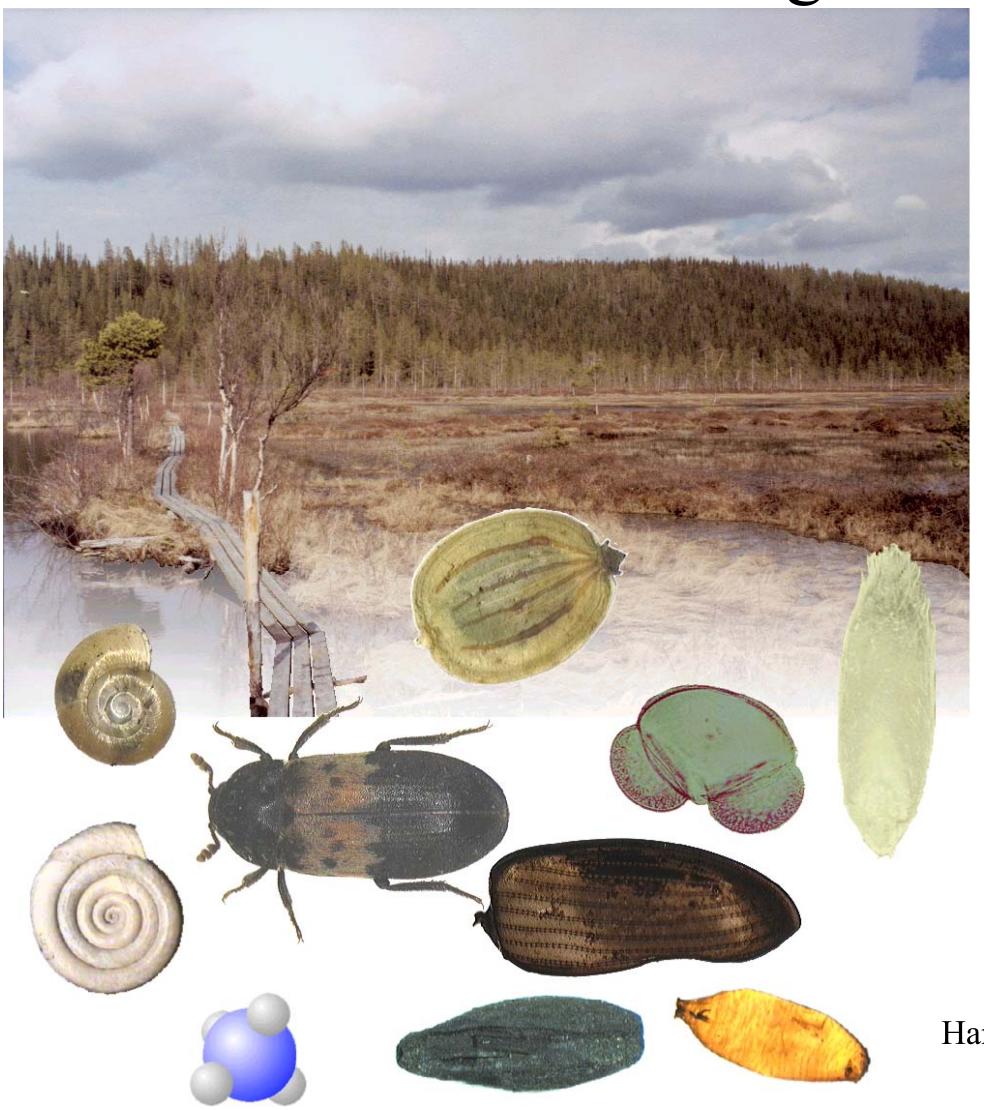
Institutionen för arkeologi
och samiska studier, Umeå universitet

An Introduction to Palaeoentomology in Archaeology and The BUGS Database Management System



CD-uppsats i arkeologi
Phil Buckland
Vt 2000
Handledare: Noel Broadbent
Roger Engelmark

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General Introduction

Within archaeology there are numerous techniques for the analysis and interpretation of organic deposits which may lie in and around a site. Probably the most widely known of these are palynology, plant macrofossil and insect analysis, and the analysis of geochemical/physical properties of sediments. This paper will introduce the technique of insect analysis, although a full review is not necessary due to the number of existing publications (see Ashworth *et. al.* (1997) for the most up to date compilation of papers including Buckland *et. al.* "QBIB - A Bibliography of Quaternary Entomology"). A Swedish introduction to palaeoentomology in archaeology can be found in Lemdahl (1990), and similarly in Hellqvist (1989).

Most research methods have been treated to some form or other of computerisation. Tilia (Grimm, 1991), for example is a widely used program for storing and drawing up pollen data. Fossil insect analysis has similarly gone electronic with the computer program BUGS, the discussion of which is the main scope of this paper. This author was one of, and currently is the only author of the present version of the BUGS program, the data for which is collated by Paul Buckland of Sheffield University (UK). BUGS is a database management system which enables researchers to greatly accelerate their initial investigations into fossil and modern insect assemblages. An earlier overview of BUGS can be found in Buckland *et al.* (1997). This paper will examine issues in environmental archaeology, palaeoecology, and ecology, from the perspective of the BUGS system. The target audience is, primarily, more or less computer literate environmentally aware archaeologists, a rare but rapidly growing breed. It is divided into three parts, followed by a general conclusion, as follows:

Part 1 discusses palaeoentomology, its concepts and methodologies.

Part 2 gives an overview of the BUGS computer program (A concise developmental history can be found in Appendix I).

Part 3 case studies of palaeoentomological research, including discussion of the use of, or potential for use of the BUGS program.

Two appendices are included to provide information which some readers might find useful:

I. A brief developmental history of the BUGS program, showing how it evolved from a simple database to a complex analytical tool.

II. A small list of web resources for palaeoentomologists, the web being the most powerful information gathering medium that has ever existed.

Notes on Reading

For the sake of clarity a few style conventions have bee adopted:

[Bibliography]	The names of buttons on the computer screen will be enclosed in square brackets
MIDDEN	Words or phrases that are to be typed into the computer program are in CAPITAL LETTERS.

BUGS is the result of work by numerous individuals and, to avoid breaking the flow of the text, their contact addresses are provided in the acknowledgements towards the end of the paper. Likewise any software is appropriately attributed and referenced at the end of the paper.

PART 1: Palaeoentomology in Archaeology

Introduction

Palaeoentomology is the study of ancient environments through the analysis of fossil insect parts preserved within various sediments. It generally goes under the banner of **Environmental Archaeology**, or **Quaternary Science**, the main difference between the disciplines being in the types of sediments with which they usually deal. In general, environmental archaeology tends to be orientated towards more directly anthropogenic sediments, that is those most obviously influenced by human beings. The sphere of human influence is large though, and sediments many kilometres from sites of occupation/activity (which are the traditional focus of archaeologists) can produce important evidence. Insects are particularly sensitive to environmental changes, and react rapidly. They are therefore, when discovered in ancient deposits, excellent tools in the interpretation of the history of humanity and its interactions with the Earth. Part 1 of this paper describes the main concepts and methodologies employed in conducting palaeoentomological research.

1.1 Concepts of Palaeoentomology

1.1.1 Niches, Colonisation and Migration

The fundamental concept of palaeoentomology is that the ecological niche[*] preferred by any species has remained a constant throughout recent prehistory. Underpinning this is the theory of species constancy, that under repeated conditions of change, insect communities will migrate rather than adapt through evolution (Coope, 1978). There are exceptions, such as isolated island or mountain populations, where migration is rare and speciation dominates, and there are areas where little research has been undertaken, such as tropical rainforests (Elias, 1994). However, extensive palaeontological research has confirmed that some insects seem to have been morphologically constant, and stable with regards to their requirements, for up to 30 million years (*op. cit.*). Although such long-term stability is still somewhat debatable (despite the evidence), the timespans

[*] *Ecological Niche* = "...the physical space occupied by an organism..." and "...its functional role in the community ..." and the range of conditions it prefers for existence.

Habitat = more generally, "...the place where it lives, or where one would go to find it." (Odum, 1971, p.234).

involved in archaeology and recent Quaternary geology are less likely to be controversial, and we can rely on our assumptions for at least the Late Quaternary.

Migration is achieved by largely annual cycles of activity, opportunism, random dispersal and death that are part of normal insect life. Those individuals that continue to try to live outside their ecological niche will (somewhat by definition) die; whereas those which have flown, walked or been transported into a more hospitable area will survive. The species moves permanently (or as long as conditions are unfit for recolonisation) from less to more suitable environments as this cycle repeats. The rate of migration will depend on factors such as the dispersal habits of the species and the rate of environmental change and local geomorphology. With winged insects this can be quite rapid, and the bare ground preferring, and wide roaming carabids can be the first of the higher animals to colonise freshly exposed ground, such as moraines; these may be preceded by groups, like the chironomids, which rely upon dispersal in the ‘aerial plankton’.

Such rapid colonisation is an extremely important advantage for palaeoentomology as a research tool, as our results reflect rapid environmental and climatic change events at close to the actual speed of occurrence. Insects increasingly have been used in climatic reconstructions, the methodology of which will be discussed in Section 1.2.5.2.

1.1.2 Various Types of Insect and Their Uses

Thylum Arthropoda, class Insecta is the most abundant group of animals on the Earth, and accounts for 75% of the species presently known (Elias, 1994). These species are grouped by way of their morphology and activities into numerous groups - the taxonomy following the pattern: Order; Family; Genus; Species (Subspecies), with individual species having a unique Linnaean scientific name. Several of these groups (including mites, which are not insects) are used in palaeoentomology, a summary list of which is shown in Table 1.

The Coleoptera are by far the most commonly used group, although many investigators will not ignore the remains of other groups when found in their samples. With practice many Coleoptera are identifiable to the species level from disarticulated fossil parts. Fig.1. illustrates the parts of beetles that are most commonly used in palaeo-investigations.

Group	Main uses in palaeoentomology	Useful references
Non-biting midge larvae (Diptera: Chironomidae)	Generally found in laminated lake sediments, so especially useful where detailed chronologies are desired. Water chemistry (nutrients)/temperature/flow regime. Sediment loading/type -e.g. deforestation, soil erosion, etc. Climatic change.	Brooks (1997) Sadler & Jones (1997)
Fly (Diptera) larvae	State of decay - or foulness - of well preserved deposits such as middens. Presence of animal matter, flesh etc. Temperature regime, within the original deposits and the surrounding environment in which the adults live. Presence of other species, e.g. upon which they parasitise.	Skidmore (1996)
Caddisfly (Trichoptera) larvae	As Chironomidae to an extent where water quality is concerned, but more commonly used to find out about flow regimes, trophic status, bed characteristics etc. in streams and rivers. E.g. some species only attach themselves to large rocks in flowing water.	Solem & Gullefors (1996) Williams (1988)
Beetles (Coleoptera) (The main group under discussion in this paper)	Similarly useful as Diptera but the adults are more often found preserved, and are much easier to identify as fossils. Many species that are specific to very narrow niches - e.g. grain storage; pine trees; or parasitic on/cohabit with other species.	Ashworth *et al.* (1997)
Mites (Acari)	Presence of animal excrement. Identification of the use of certain species of plant, e.g. *Sphagnum.* Background environmental signals.	Schelvis (1997)
Fleas (Siphonaptra)	Presence of their host organisms. Some indication of the cleanliness/health of the host. Their context could be related to cleaning/processing practices.	Buckland & Sadler (1989)
Lice (Anoplura,/Mellophaga))	Presence of their host organisms, or at least the fleece/skin. E.g. the presence of sheep lice could indicate wool processing – sheep have head, foot, and wool lice. Some indication of the cleanliness/health of the host.	Buckland & Perry (1989)

Table 1. Major insect groups used within archaeological palaeoentomology.

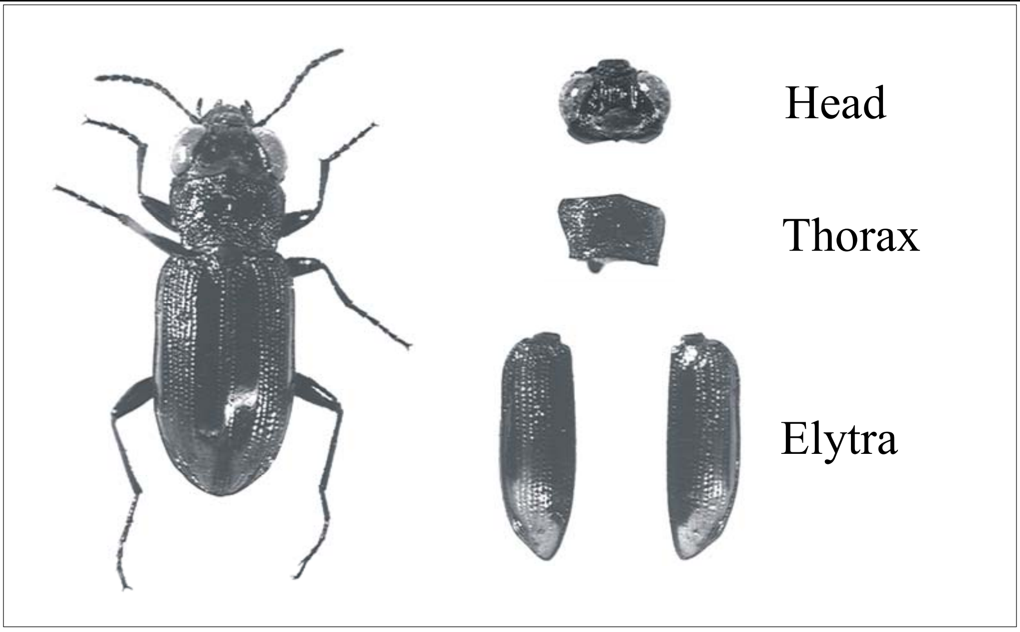

Fig.1. Insect parts most commonly found in archaeological deposits. Others may be found, but, apart from the genitalia, tend to be less identifiable (see Elias (1994) for a more detailed diagram covering identification features).

1.1.3 Extraction of Archaeological Information

The process by which we extract archaeological information from the fossil assemblages is somewhat similar to the way traditional archaeologists use anthropological analogies. Rather than superimposing the activities of existing "primitive peoples" over the evidence in the archaeological record, we superimpose the habits of modern insects, and their communities, over the fossil record. The source for our analogies are ecologists and biologists, who have described species assemblages and their ecology in the modern world. Fig.2. explains, in a simplified overview, how palaeoentomology fits into archaeological research.

There are many contentious issues involved in the use of anthropological analogies, such as assumptions of evolutionary stagnation; the influence of the observer on the subjects; accuracy and usefulness of various observations; interpretative difficulties - both language and conceptual. Likewise palaeoentomology does not escape some theoretical and methodological difficulties involved with the transposition of the present into the past.

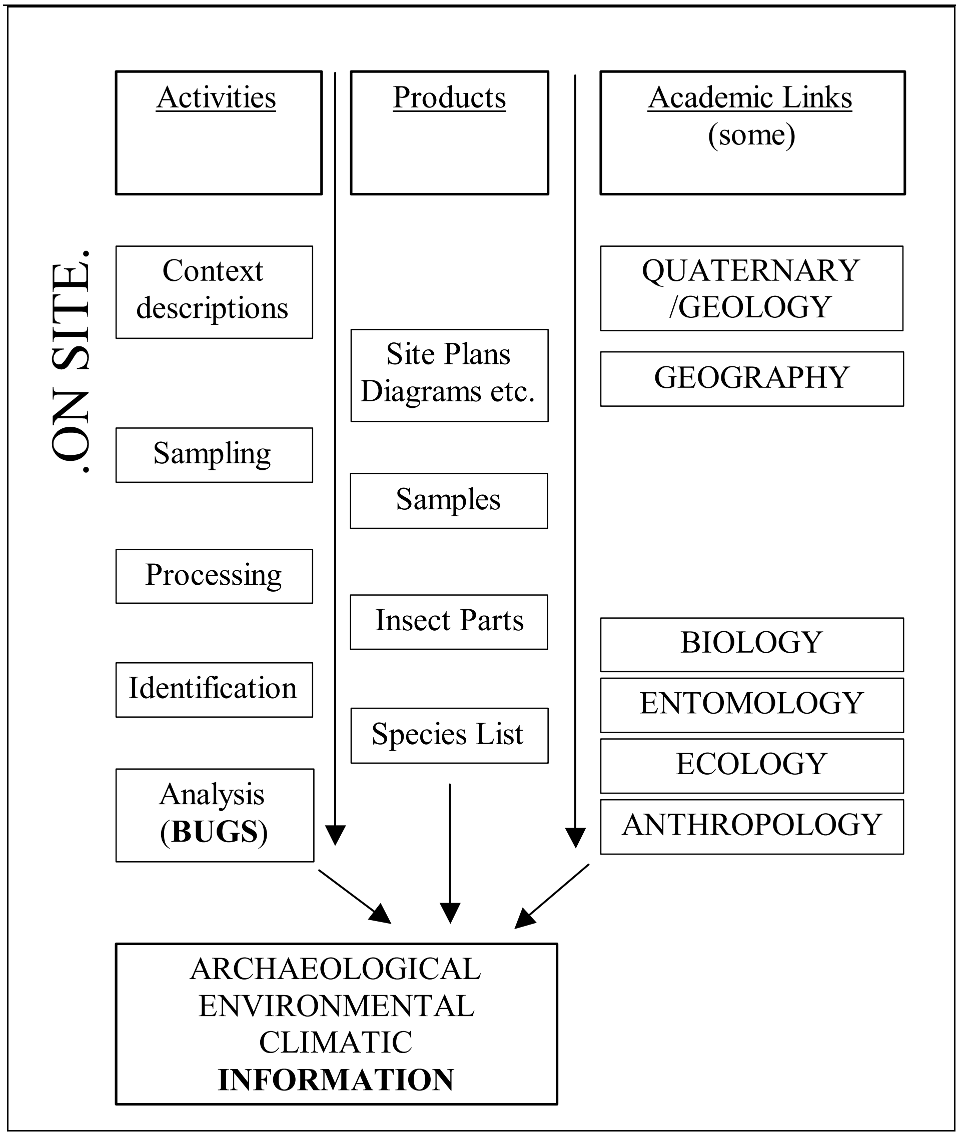

Fig.2. How Insects fit in to archaeological research.

Perhaps the most fundamental problem with archaeology is that it can only really look at small points in space. Formerly these points were sites of human occupation but the surrounding environment is now also commonly investigated - either with or without a definite contemporary occupation site nearby. These points in space tend to contain within themselves very complex pictures of time - there may be many horizons, and often reworked or disturbed. Modern ecology on the other hand deals mainly with continuous areas of space over linear periods of time. Because of this they can build up quite comprehensive models of species dynamics through extensive sampling programs (see Krebs, 1999). Even the most comprehensive palaeoenvironmental sampling project could not match such data sets, at least not with the same degree of confidence, and certainly the cost in terms of labour would be much larger. So in the name of economic compromise palaeoenvironmental data sets are smaller, time averaged, and more stippled versions of the modern equivalents. The range of statistical techniques available are also more limited (see 1.2.5).

1.1.4 Insects in Archaeological Deposits

Where they are Found

The exoskeletons of insects are made from a material called chitin, which is almost chemically inert and extremely durable. Because of this insect remains can survive for millennia if the conditions are favourable. There are two situations which give the best preservation and a large array of in between situations under which insect remains can be preserved to a lesser extent.

1. Permanent waterlogging	Most of the sites investigated contain wet deposits of some kind. The best are peat bogs and organic lake/river clays, where the decay rate is slow due to low biological action. Wet soils and clays which have not been subject to much hydrological fluctuation are also good. Frozen sediments, such as the permafrost of Arctic sites are excellent, as seen in the specimens from the Norse farm site of GUS in Greenland (Arneborg & Gulløv, 1998, and Section 3.1, p. 40).
2. Permanent drying	Dehydration reduces the biological activity which causes decay. Desert sites can produce excellent specimens, although little work has been done on them to date. Recent work in Egypt has produced synanthropous faunas associated with the food brought in to feed workers in the Roman quarries at Mons Claudianus in the Eastern Desert of Egypt (Panagiotakopulu & van der Veen, 1997).

What they Mean - Ecology and Archaeology

Archaeological deposits are so variable in their nature that it is difficult to provide a general explanation of where the insects in a context come from. What follows is therefore a simplified overview followed by a few examples to help clarify some details.

After sorting out the bits of insects from the sediment (see section 1.2) we are left with what is known as an *insect death assemblage*. Most assemblages contain components both native and external to the represented living population, just as the overall sediment itself will contain autochthonous and allochthonous material. An holistic view would see the insects as inseparable components of the sediment – they constituted part of the living matter of the environment which deposited it, and now form part of the sediments composition. Within this both the insects that lived in the immediate environment and casual visitors are represented to varying extents.

Autochthonous insects, with respect to the sample assemblage, are those that lived within the immediate environment of the deposit. For example, if the deposit represents a kitchen floor layer from a Norse farm then the insect would have lived in the floor layer during human occupation. An allochthonous insect would be one that normally lived in another environment, outside the building for example, and just happened to be passing through when it died. Insects that are commonly found in many samples on a site, or in a particular location, are sometimes referred to as the ‘background fauna’ (Kenward, 1976). In many cases it is possible to identify two groups of species that could be classified so. Firstly there are those mostly synanthropic species, which thrive in a wide variety of anthropogenic environments. *Xylodromus concinnus* is a good example, and is almost always found in deposits from within Norse houses (e.g. Arneborg & Gulløv, 1998, pp74-80). Secondly there are those species which live in the environment around the site and are particularly mobile, having a tendency to permeate all deposits.

Fig.3. illustrates some of the possible sources for insects in a Norse farm, the lines showing dynamic links rather than directional fluxes (- humans generally influence their environment as much as it influences them). The job of the palaeoentomologist is to separate out these components. With our knowledge of modern insect habitats we can then go on to recreate both the immediate environment, and to an extent (by way of the incidental species found) the environment outside it. There are, however, numerous special circumstances. For example, the finding of a lone grain weevil (*Sitophilus granarius*) in Norse Icelandic farm is an indication that grain was probably in the house at some point. Grain weevils do not survive in Iceland outside of the actual grain stores, so the species is most definitely an anthropogenically imported component rather than a casual wanderer (Buckland *et. al.* 1992). The fact that only one individual was found suggests that grain was not stored in any large quantity there, as the species can breed prolifically given a sufficient food supply. There are many other species that occupy such a narrow niche that they must be considered with special care, since their specificity can provide extremely useful information.

It is a fundamental factor in our analyses that we look at the dead composition of an insect fauna at snapshots in time represented by the total age of the encasing deposit or sample interval. This "instant" could represent a period from seconds to years, depending on the sedimentation processes, subsequent reworking, and the eventual sampling strategy. Therefore the sample could include many faunal fluctuations which had a smaller time dimension than the total - we would see an averaging of this period in the results[*], although through multivariate statistics it might be possible to visualise the different communities. If we wish to estimate absolute populations, for example, to compare pest problems in the past with the present day – then statistical methods based on modern ecological research are our main source of inspiration. The assumptions involved are immense, and there is a constant danger in the 'Catch-22' of model development – if we use our results to infer environmental conditions, and then these conditions to make inferences about the populations themselves (a common problem in grey/black box modelling where the exact processes are unknown or too complex to describe fully (see Hardisty *et al.* 1993)).

At this point the importance of multidisciplinary studies must be emphasised. If various methods are used simultaneously, each having their own pros and cons, our theories and models will be stronger.

A Short Note on 'Ecofacts'

Some archaeologists like to term identifiable organic entities in archaeological deposits as "ecofacts", to form a conceptual link with the term "artifacts". Such use, however, has come under criticism from other archaeologists in that it downplays the human influence in the creation of the deposit (see Viklund, 1998). On the other hand others believe that the use of such terms downplays the importance of natural processes in the accumulation of sediments. It is, of course, purely a question of perspective, and such discussions should not become so overarching as to hinder research (as many discussions at a "theoretical" level do – see Yoffee & Sherrat (1993) if you wish to go deeper).

[*] This is where careful sampling plays an important role, as will be discussed later in section 1.2.2.

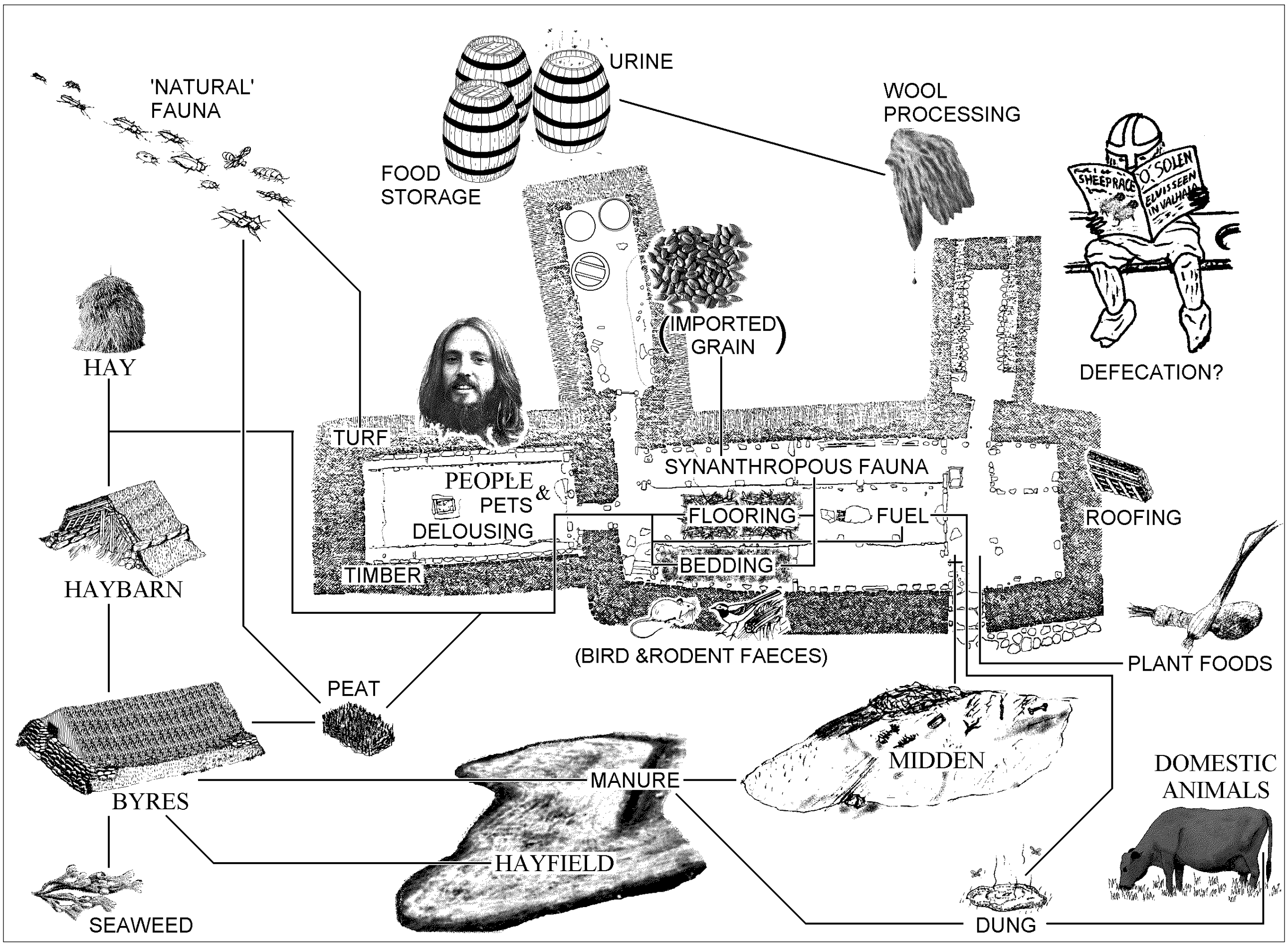

Fig.3. Some sources and possible interpretations of fossil insects in a Norse farm. Redrawn with data from Buckland *et al.* (1993).

1.2 Methodology - from Sampling to Analysis

1.2.1 A Brief History of Palaeoentomology

The man generally regarded as the father of the science is Prof. Russell Coope, who established the validity and refined the methodology of palaeoentomology, along with various co-workers, in particular Peter Osborne and Fred Shotten (Ashworth *et. al.* 1997)*. Since then the basic processing technique has remained more or less the same, but analysis methods have developed considerably. Essential to the growth of the methodology was the corroboration of the theory that species found in Quaternary deposits could be found to exist today, albeit in geographically different locations. This suggested that the evolution of insects was slower than previously believed, and that they

* Previous work by Carl Lindroth (e.g. Lindroth, 1948) should also be noted.

tended to migrate rather than evolve*. The idea that they could be used to demarcate late Quaternary type horizons, as zone fossils in geology, was thus overturned (see, e.g. Matthews 1977; Böcher 1995). In turn, this led to the superimposing of modern ecological data over the fossil assemblages and the use of insects in palaeoenvironmental reconstructions. Early work on fossil insects established that climatic change at the end of the last glaciation was rapid, in contrast to the pollen evidence, which was interpreted as suggesting gradual change (e.g. Coope, 1975). More recently the Greenland ice core data have reinforced the insect evidence by means of analyses of seasonal laminations (Alley *et. al.* (1993), for a discussion on snow accumulation and the Greenland icecores). Fig.6. (p.22) compares the Coleopteran Mutual Climatic Range (MCR - see section 1.2.5.2) data with the Greenland Ice Core (GISP2) curve.

Insects are now widely acknowledged as valuable environmental indicators and should be routinely involved in conservation research (Buckland, 1993), in terms of their sensitivity to changes in climate and habitat.

> "...insect numbers are extremely sensitive to environmental change, so that problems in conservation are often first seen in insects." (Dempster, 1989)

This was as much true for the past as it is for the present day.

1.2.2 Sampling Strategies

There is a variety of sampling strategies published for the sampling of organic materials from a site (e.g. Evans, 1978, p81-; Buckland 1976; and Elias, 1994). Generally speaking archaeologists will want to know more about the immediate site than the surrounding area, although this depends on the situation. The variety of site types and situations is enormous, and so sampling should ideally be arranged in terms of the questions that are being asked - problem orientated.

Section 3.2 describes a stratigraphically controlled sampling system as used on a Norse Farm midden in Greenland. Such strategies are most commonly used where the excavation follows rather simple trench based paths, and the layers are readily visible in the profiles. It is advantageous if all

* Evolution is achieved where genetic inconsistencies within a species, which favour the prevailing conditions, are retained, and eventually dominate with subsequent generations - those best adapted stand a better chance of surviving and breeding. Migration occurs when the movement of species into neighbouring areas, where the conditions are more favourable for their survival, continues over subsequent generations. Individuals either prefer to move out of less favourable areas, or fail to survive there.

the samples can be taken from a profile in one go, normally towards the end of the excavation, but not before the sediments dry out too much.

In most excavations however the digging tends to be lead by the desire to expose and explain contexts created more or less wholly by human actions. In these cases sampling is more likely to take on a more sporadic context orientated approach. Samples are taken when new contexts are discovered, and as new layers are exposed within features, for example as successively older floor layers are removed from a room, or if a vessel is found intact. If an entire floor is to be exposed it could be useful to take several samples, from different areas of the floor for the purpose of comparison, and examination of possible activity areas within the room, as was done at GUS in Greenland (Arneborg & Gulløv, 1998).

In addition to the methodological sampling outlined above there will be occasions where samples can be taken more opportunistically. Table 2 details some situations where insect samples would prove useful. Note that it is always advantageous to look at plant macrofossils and other groups from the same deposits.

When considering the sediments themselves we must remember that, just as with the insect, there are autochthanous components - those that were created at the deposition point; and allochthanous components - created elsewhere, transported into the area, and then deposited, or eroded and redeposited. The genesis of the sediments is often part of the primary goal of investigations.

It is often difficult to establish rates of accumulation in the field, and so samples must be taken with this in mind. Finer sampling resolutions are most desirable scientifically (remember the phrase "You can always lump up, but never lump down"), but often impractical in terms of time and money.

Deposit/situation	**What insects could tell us (a non-exhaustive list)**
Sediment from around bones	The state of the carcass when deposited - e.g. much meat left; bone marrow intact; semi-decayed. Whether the carcass was deposited in a warm/indoor environment or outside. Whether the animals fur was on it when deposited.
Moss within a house	If the moss was used as 'toilet paper'. Whether the moss was harvested wet or dry/ in summer or winter.
Barrel contents	Some idea of what was in it - e.g. animal/vegetable products; urine/milk. Whether it was left standing for a long time.
Under a barrel impression.	Some idea of what was in it.
Peat	Whether the peat was dried outside; or drained before it was cut. What it was used for, e.g. flooring; fuel.
Lake sediments	Lake chemistry and bathimetry. Much information about the surrounding landscape (terrestrial species are often found in lake sediments, just as terrestrial deposits will contain aquatic species if water is nearby). Landscape change.
Palaeochannels	Flow regimes. Surrounding environment. (Lakes and rivers tend to act like large pitfall traps), and possible human influence such as burning or clearance.
Byre fodder tray	When the fodder was collected. What the fodder's constituent parts were and where it came from.
Byre floor	Health state of the animals, particularly in terms of parasites. Whether humans spent much time in the byre with their animals (presence of human parasites). What animals were housed there (and maybe for what parts of the year). How frequently the floor was cleaned (in Norse farms byres are often raised rather than cleaned out, this insulates the floor and provides us with excellent deposits for analysis).
Turf wall bricks	Season during which the turf was cut. Whether the turf was cut from specially grown fields (i.e. cultivated turf).
Wells	Local environments – wells tend to act like giant pitfall traps. Note that good stratigraphic analysis is essential due to the problems associated with infilling and collapse.

Table 2. Some deposits from which insects could provide valuable archaeological information. Note that plant macro fossils could produce quicker or better results in some of the situations, such as those where seasonality is involved. It is, of course, most advantageous to use several methods simultaneously.

(This is just a short list, an extension of which could fill tens of pages).

1.2.3 Processing

1.2.3.1 Standard

Samples are carefully dissagregated with water over a 300µ sieve, to wash out the clay-silt component. Clayey or highly humified sediments can be left to soak (for weeks, if necessary) in a weak hydroxide solution (<5%) to aid disaggregation. The remainder is then mixed with a little paraffin (Swedish: lys fotogen) and cold water in a spouted bucket, and allowed to settle for 15 minutes. After this time the heavier plant material should sink, and the chitinous insect parts float - as the paraffin preferentially bonds to their surface. As much of the floating component as possible is carefully pored off into a 300µ sieve. The flotation process is repeated two more times and the floats washed with detergent and then stored in ethanol. A binocular microscope (x6 to x20) is used to sort the float under ethanol, which has a lower surface tension and allows for longer preservation than water. Insect parts are usually picked out from the plant matter with forceps and placed into ethanol in a glass phial. Seeds can be recovered at this stage too, although paraffin flotation causes some bias.

The float residue, the sinking component, can be washed with detergent and used for additional processing as necessary. It should be noted, however, that the use of paraffin could influence radiocarbon dates if taken from a processed sample. It is advisable to take a subsample beforehand to be used in dating.

1.2.3.2 Variations

To recover charred seeds and molluscs as well as insects.

After processing the sample as standard the residue can be gently dried - say a few hours in a ventilated oven at 50°C. Then a standard water flotation technique (such as passing the overflow from a stirred bucket through a sieve) can be used to float the remains. Air trapped within the shells and seed bodies should cause them to rise with the water turbulence.

Note that for small samples (<1 litre) with a large fine component (which will be washed away) it may be quicker to sort the entire sample after cleaning, rather than refloat.

Thickly matted fibrous peat

In these cases almost everything can float, but a hybrid washing technique seems to help. Use a coarse (>1cm) sieve over the 300µ and frequently empty the contents of each into separate buckets. Floating the cleaned buckets separately produces floats that are easier to sort because the size of the plant matter is more homogeneous. This is a particularly useful technique when the sample seems to double in size when it starts to dissaggregate.

Statisticians may be a little concerned that this is adding another possible error contributor, or unknown bias to the processing due to differential separation of particle sizes. Rigorous testing (by the author) in the lab (at Sheffield) has as yet not revealed any bias. It is, however, essential to thoroughly describe one's processing technique (whatever it may be) so that future researchers are aware if a bias is discovered subsequently.

Processing in the Field

The main reason for field processing is to reduce the bulk of the samples. This cuts shipping costs and storage space requirements, leaving more funds for the actual research. Essentially, if buckets, sieves, and a water source (a hosepipe is ideal, but a lake or river will suffice) are available then it can be done (Fig.4.).

Paraffin floatation should *not* be performed in the field because of the pollution caused by waste water.

Fig.4. A somewhat *ad hock* field processing setup at Nesstofa, Iceland.

However, field processing is not recommended for three further reasons:

1) The probability of intrusions/contamination is great, such as live insects, or fossils from the excavation.

2) The ‘controlled’ environment of the lab is absent, and there may be more possible sources of variation in the processing technique than are realised, and results may be biased by this.

3) Processing time could be used for taking more samples.

1.2.4 Identification

When identifying a modern specimen the researcher refers to a “Key”, that is a book which leads one, through a series of question stages (couplets) to the name of the species being examined. Most use a system of binary opposites to form the couplets - i.e. if the insect has feature A then go to question 2; if not then go to question 18. The extract below is the first couplet from Lindroth’s (1985) key to the adult Carabidae:

1	Entire elytron uniformly pubescent, or at least with one row of setae or bristles along entire length of each (or every second) interval.	2
-	Elytron glaborous, except for marginal setae and often setiferous “dorsal” punctures on intervals 2-3, or with only outer intervals pubescent.	18

Lindroth (1985) p.24

When it comes to fossil insects there are three major problems due to the nature of preservation and recovery:

1. The insects are *very* seldom recovered whole (see Fig.1.). (Exceptions do occur, for example in splitting peat laminae, or in frozen arctic deposits - see the GUS example in Section 3.1).

2. In general only the larger parts, heads, thoraces and elytra, are recovered by processing, antennae, legs and abdominal segments become disarticulated and are either not recovered or are unidentifiable.

3. Detailed features such as setae (hairs) are often lost with time (although the pits that anchored them are always present).

Because of these factors, especially the first, it is rarely possible to use keys to identify fossil insects. The most commonly used parts are the head, thorax, and elytra, as shown in Fig.1. The identification of these parts, therefore, is done mainly by comparing the fossil parts with modern specimens. The efficiency with which this is done depends on the researcher, and is a function of personal knowledge and visual skills, which lead one towards intelligent guesses (although many would prefer to use the word 'assumptions'). A major factor though, as with any such science, is the size and proximity of reference collections.

It is not always possible to identify the insect to species level, but even the genus is often enough to tell us many things about the nature of the environment recorded in the deposit.

1.2.4.1 Species list

The product of identification is usually a "count sheet", that is a list of the species found with a tally for the number of each of the parts accounted for (Fig.5.). These figures are converted into a Minimum Number of Individuals (MNI) per species, and it is these figures that are used in the interpretation. The BUGS database allows for the storing of these count sheets (Section 2.2.3).

SPECIES LIST	N.	R.O.	H.	Th.	L.E.	R.e.	Misc	COMMENTS
Carabus granulatus				1	2			
Aclypea opaca					1			
Cryptopleurum minutum					1			
Megasternum obscurum				2	~~6~~7	8		= boletophagum
Pterosticus versicolor						1		
Cercyon spp.					1	3		
Aphodius granarius					1			
A. sphacelatus			1					
A. spp				[illegible]	[illegible]	[illegible]		

Fig.5. Count sheet, space for site details and some summary info if usually provided above the counts table.

1.2.5 Analysis and Interpretation

1.2.5.1 In General

As has already been described (Section 1.1) the main part of the analysis procedure is producing a synthesis of the environments represented by the fauna found in the samples. This should be used in conjunction with the archaeological and other data to provide the most probable explanation(s). Beyond the basic qualitative interpretations there are numerous numerical and statistical techniques which can be employed.

1.2.5.2 Climatic Change and Mutual Climatic Range Analysis (MCR)

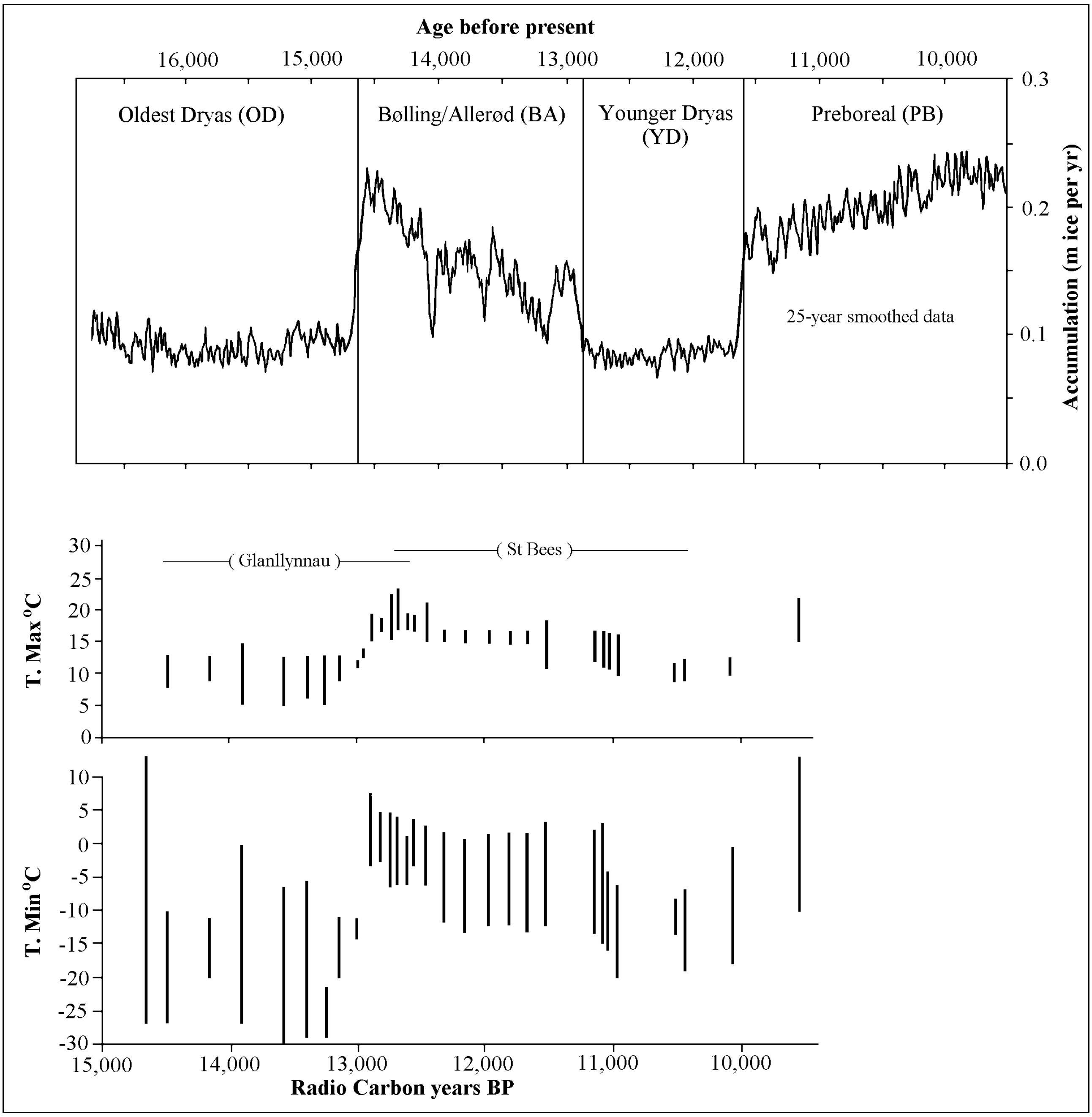

Fig.6. The fossil beetle evidence (MCR) for climatic change in Lateglacial Britain compared with data from the Greenland Ice Core (GISP2). Data from Alley & Meese (1993) and Walker *et. al.* (1993).

Soon after the birth of palaeoentomology it was realised that fossil insects provided an excellent record of climatic changes (see e.g. Coope, 1965). Many species are more dependent on the temperature regime than the vegetational. By constructing a list of these species over time from sequential sampling projects researchers were able to reassess important transitions in climatic history. It was discovered that many of these changes were a lot more rapid than was previously believed - a result of a an extreme uniformitarianist hangover and plant based chronologies (plants follow climatic changes much more slowly than do many insects). Fig.6. helps to illustrate this point by comparing part of the MCR insect record for the UK with the GISP2 Greenland Ice Core data (also see Coope & Lemdahl 1995, and Lowe & Walker 1997, the latter of which contains a more detailed comparison of datasets).

The calculations involved are reasonably simple, if the ecological data exists (e.g. Atkinson *et al.* 1986). Every insect can live in a regime between a maximum (TMAX, the temperature of the warmest month) and minimum temperature (TMIN), which is known as the temperature range (TRANGE, which is regarded as an index of continentality, in that the interior of large land-masses tend to have greater seasonal temperature variations) (Atkinson *et al.,* 1987). These values (and their error margins) are calculated from modern habitat and geographical data (several researchers are currently involved in constructing databases of this data, see Lowe & Walker, 1997). By looking at the overlapping values for all species in a fossil assemblage we can extract the most probable thermal range for the environment represented by the deposit. This is, of course, best done by a computer, and graphical outputs can be produced to illustrate the results in the form of contour graphs or something similar to the diagrams used to display probabilities in mathematics (Fig.7.). The method slightly overestimates TMIN for cold climates, and underestimates mild winters, but a (linear regression) calibration can be applied to remove these biases (see Atkinson *et al.* 1987).

Similar methods have been applied to pollen for some years, beginning in the 1940's with Iversen's work (Iversen, 1944). There are a variety of computer simulations of vegetational successions available over the net, the North American Pollen Database being particularly extensive (see http://www.ngdc.noaa.gov/paleo/pollen.html).

BUGS and MCR

The intention is to include TMIN and TMAX values for species within the BUGS database. This is not currently a primary concern though, as there are other researchers who are working on, and have been using existing programs that calculate MCR's (see Lowe & Walker, 1997, for example). Eventually basic MCR calculating capabilities will be introduced, although the graphing functions are likely to be somewhat limited by the programming language used. However, it is anticipated that most users would prefer to port over the results into more powerful graphing packages.

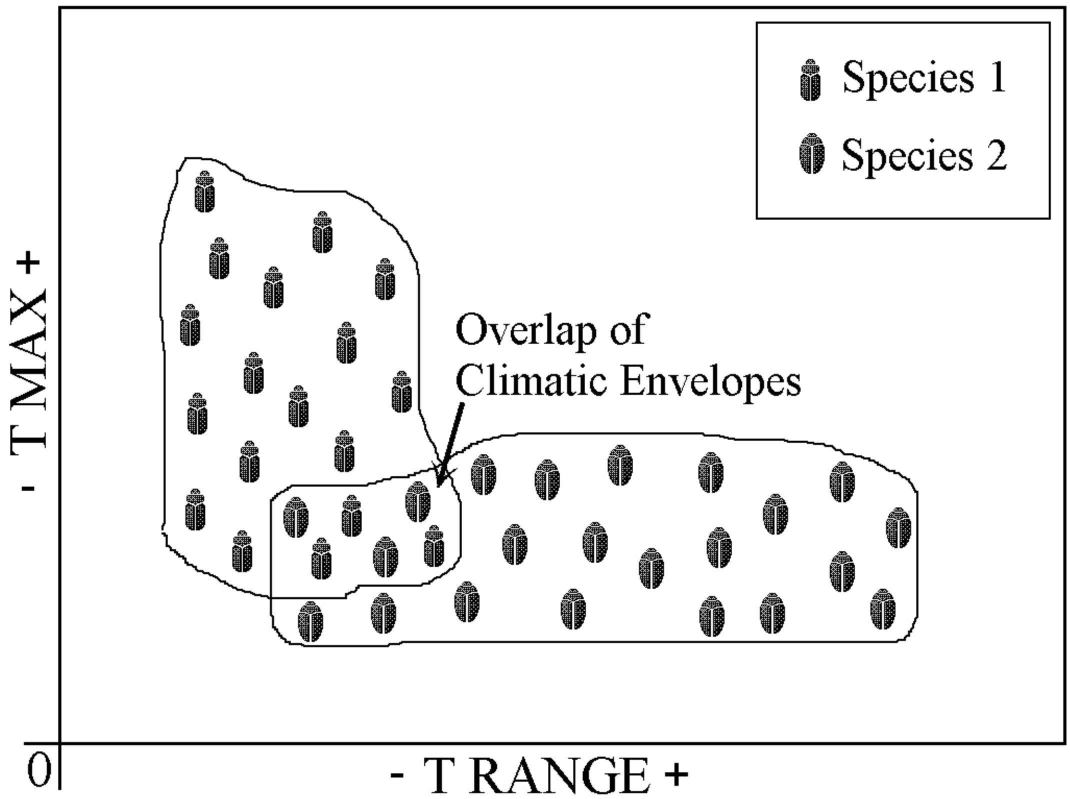

Fig.7. The Mutual Climatic Range for two species. The smaller the overlap, the more precisely the palaeoclimatic regime can be deduced. TMIN can be calculated from the intercept of the gradient line from the median and extreme values of the overlap. Adapted from Atkinson *et al.* (1986).

1.2.5.3 Comparing Samples - Coefficients of Similarity and β-Diversity

The measure of change, difference and similarity between communities is known as β-Diversity, within ecology. *Coefficients of similarity (or comparison)* are probably the most established and commonly used statistical technique in the analysis the fossil beetle assemblages. These allow the intercomparison of the species lists from each sample with each and every other one. The results can be displayed in a variety of ways, but the simplest is as a trellis diagram, or matrix of the results, as shown in Fig.8.

Similarity Indices in a trellist diagram.
Showing two communities (A-F) and (G-L)

	A	B	C	D	E	F	G	H	J	K	L
A	X										
B	0.72	X									
C	0.68	0.74	X								
D	0.52	0.64	0.90	X							
E	0.48	0.57	0.72	0.95	X						
F	0.54	0.50	0.58	0.61	0.86	X					
G	0.20	0.27	0.35	0.40	0.31	0.26	X				
H	0.35	0.32	0.26	0.28	0.18	0.15	0.72	X			
J	0.45	0.21	0.37	0.41	0.35	0.48	0.63	0.96	X		
K	0.15	0.27	0.12	0.19	0.26	0.18	0.59	0.75	0.91	X	
L	0.05	0.12	0.24	0.27	0.35	0.29	0.57	0.62	0.68	0.86	X

Key: 0.50 to 0.70 0.70 to 0.90 0.90 to 1

Fig.8. Example of a trellis diagram for displaying the results of sample comparisons using a coefficient of similarity. The samples can be ordered so as to group together the highest values, and then differential shading can be used to visualise comunities - two in this case. From Southwood (1978).

The four most commonly known equations, and are shown in Table 3. All equations compare two samples, a and b, at a time, and the calculations are repeated until each sample has been compared with every other.

The first three give equal weight to all species, but the fourth more accurately reflects the similarity in individuals by assessing the relative proportions of the species involved. It is, however, affected by super-abundant species, rare species adding little to the value of the coefficient. With our sample sets it can be dangerous to over emphasise the value of casuals and possible contaminations, so this in fact works to our advantage. Rare species should be assessed on their ecological merits, that is their dependence on very specific habitats or host items (such as plant species, animals). In some cases there is a fuzzy border between quantification and qualification, which is often called semi-quantification (e.g. Cong & Ashworth, 1997).

The principal use of these coefficients in our studies is to tell which samples might represent similar environments. The calculations are a little tedious, but can be performed reasonably quickly in a spreadsheet. The BUGS program will soon include a function for these calculations, which will be an immense help.

Jaccard	C_J=j/(a+b-j)
Sørensen or Czekanowski	C_S=2j/(a+b)
Kulezynski	C_K=½C_S
Modified Sørensen*	**C_N=2j*N*/(a*N*+b*N*)**
Where	
j =	Number of species common between samples a and b.
a & b =	Total numbers of species in sample a, and samples b.
a*N* =	Total number of individuals in sample a.
b*N* =	Total number of individuals in sample b.
j*N* =	The sum of the lower values where species are common to both samples.

Table 3. Equations for Coefficients of Comparison, as used in ecology and palaeoentomology. All equations produce a value between 0 and 1, 1 being total similarity. (Southwood, 1978).

1.2.5.4 Additional Statistics

Some of the statistical techniques used by ecologists rely on the assumption that the entire population of the environment is represented in the samples, and can thus calculate with respect to absent, as well as present species. This is something that we tend to avoid in palaeoentomology because of the added variables of preservation and processing. Palaeoentomology can be called a proxy-environmental source, that is, we use the method to estimate environmental variables such as temperature, decay, humidity etc. In ecology these variables are often measurable directly, and therefore we tend more towards descriptive statistics than predictive methods.

Environmental variables can govern the diversity of a population in very specific ways, and ecologists often use statistics to ordinate these variables. For example, the abundance of particular food sources is one of such; air temperature would have affected the abundance of Helomyzid flies in Norse Greenlandic houses; the amount of decay affects which species of xylophagous beetles

* This is in fact the complement (1-*B*) of the Bray & Curtis measure of dissimilarity (Krebbs, 1999)

will live in a tree. Multivariate statistics could be useful in explaining some of these variations, although there is always the danger of circularity of reasoning in the re-incorporation of proxy-data into models. Correspondence analysis, cluster analysis and other techniques could prove useful and some authors have investigated these with respect to climate and local conditions (e.g. Perry 1982; Cong & Ashworth 1997; Kenward 1997). There is not space to discuss these methods here, but it should be said that there is room for much development.

1.4 Conclusion to Part 1 - The Future of Palaeoentomology?

Palaeoentomology is a growing discipline, and it will continue to grow as more and more archaeologists discover how much information it can give to their site interpretations. Very little work has been done in Sweden to date, other than that by Geofrey Lemdahl (e.g. Lemdahl, 1988; Lemdahl, 1997; Gaillard & Lemdahl, 1994) and Magnus Hellqvist (see Hellqvist, 1999, for a comprehensive reference list) at the Department of Quaternary Geology in Lund, so there is much scope for development. The incorporation of work on fossil insects into some projects being undertaken by the Environmental Archaeology Lab. Umeå, combined with the lab's existing portfolio, is an important step towards their wider use.

As far as statistical methods are concerned it is clear that there are areas where we are lacking, in particular in the ecological analysis of environments described by samples. Ecological coding systems (such as that of Koch, 1989a & b; 1990), with a little alteration for synanthropic situations, could prove very useful in combination with relational databases (e.g. Hall & Kenward, 1990). This could also help maintain important links with biology and ecologists. Correspondence analysis and ordination methods require much thought, especially with our 'semi-quantitative data' (Cong & Ashworth, 1997), but could prove useful in illustrating ecological groupings within a fauna. This in turn could possibly be used to develop an advanced method for the interpretation and display of faunal data.

With the expansion of the MCR method (e.g. Coope *et al.* 1998) and its wider (but careful – see Hellqvist, 1999) use in archaeology as well as quaternary geology , palaeoentomology has a chance of becoming a major voice in the halls of interdisciplinary research. The latter is, perhaps, where the major obstacle lies – to educate people into looking outside what they see as their immediate discipline for methods, interpretations, and cooperation. Archaeologists are beginning to do this, and we will hopefully see the growth of truly interdisciplinary work that is of mutual benefit to all those concerned.

PART 2: BUGS Palaeoentomology/Entomology Teaching and Research Aid

This part will discuss the computer program BUGS, an aid to palaeoentomological research and teaching, with respect to its history and present and potential uses.

2.1 Introduction

BUGS is a program designed to assist those interpreting fossil insect assemblages. That is, extracting ecological and environmental information from the remains of insects found in buried deposits, such as those which form archaeological contexts, or organic rich Quaternary sediments. The program holds a database of ecological information for over 5300 species, mainly Coleoptera (beetles), plus a few others that are of particular archaeological interest, such as the human flea (*Pulex irritans)* and the sheep louse (*Damalinia ovis*).

The primary interface is designed for looking up information on a particular species. The screen shows modern ecology and distribution information for the selected species (Fig.9.). Buttons link to other parts of the program, and a menu bar provides standard features such as copy and paste, searching, and reporting. The manual describes these features in detail, and this chapter will deal only with the uses of BUGS, rather than its specific functionality. Most of the standard features of a database are accessible, along with some custom functions which make it particularly useful to its target audience.

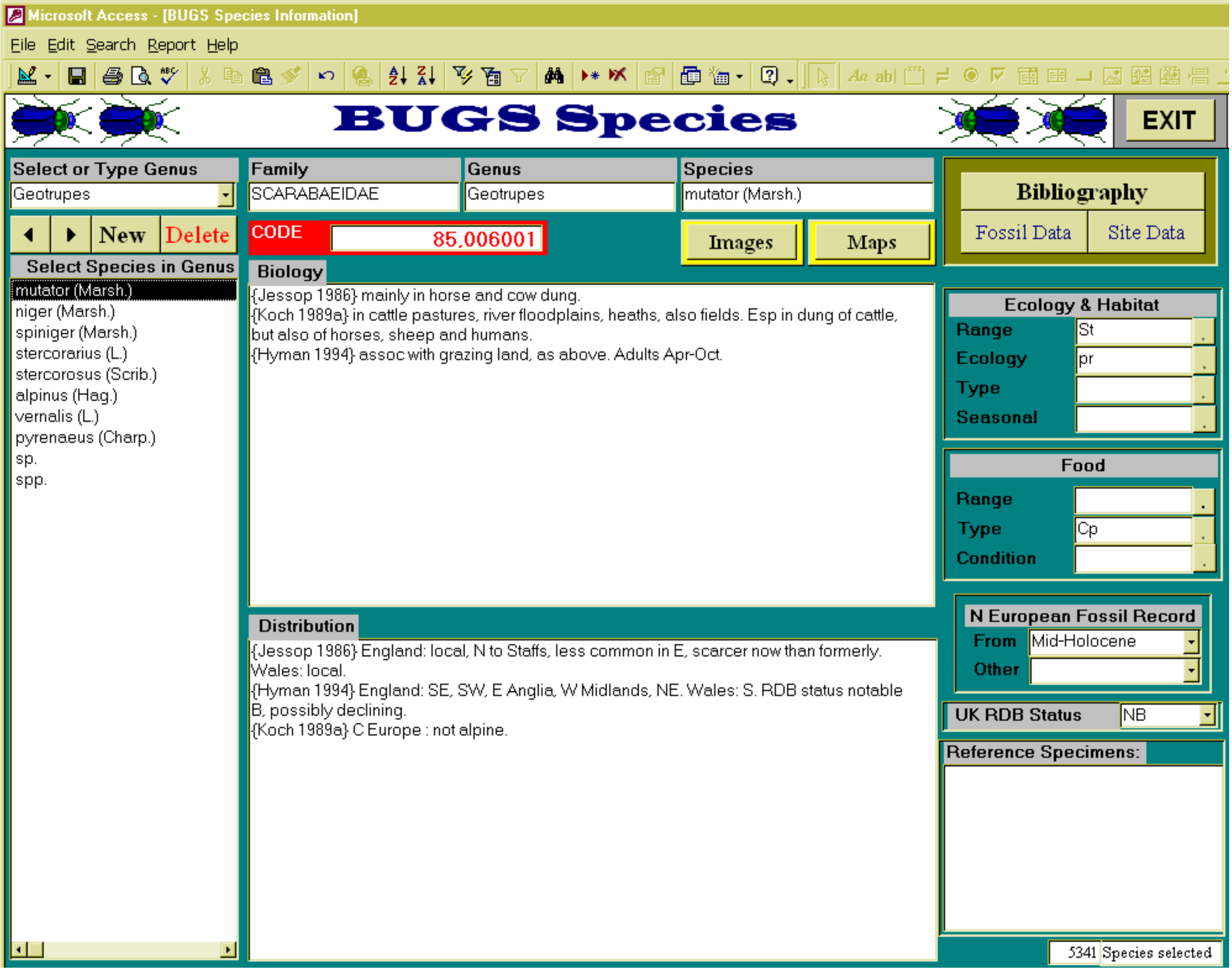

Fig.9. BUGS main screen showing the basic information for any one particular species.

The distribution version of BUGS runs in Microsoft Windows (3.1 or later) either within MS Access (the database management system), or as a runtime installation without Access. For complete functionality the spreadsheet program MS Excel is also necessary, although BUGS can function as a database without it. The program was designed to run on a 486 laptop computer using VGA resolution (640x480 pixels), and the aim was to stick to the this ideal. However, due to a lack of backward compatibility in Access versions this was not possible, and the latest version of BUGS needs Access 2000 and a screen capable of displaying 1024x800 pixels (Fig.9.).

2.2 What BUGS Does

This section describes, with examples, the various functions of the program. (Please refer to the manual or website for instruction on how to actually do it - Section 1.3.1).

2.2.1 Looking up information on a particular species.

For each of the five and a half thousand species in the database several pieces of information are stored:

Ecology and habitat	extracted from numerous texts which are referenced within the program (see Bibliography, section 2.2.5). Information relating to where and how the insect lives, how it behaves, and what it likes to eat.
Distribution	Descriptions of the known modern extent of the species, again extracted from texts.
Fossil Sites	Where the species has been found fossil in archaeological and Quaternary science investigations.
Koch's Ecology Codes	From "Die Käfer Mitteleuropas", Koch (1989a & b; 1990), with a few additions. Combinations of two letter codes, which describe the ecology of the species.
Earliest and North European Record	Shows the oldest known fossil record, and the oldest North European Lateglacial or Holocene record.
Red Data Book Status	A country specific index of rarity for the species. Data for UK and Sweden is currently stored.
* Pictures	Space is provided, hard disk space permitting, for 3 images of each species. For example, a line drawing, a photo, and illustrations to help with identification. A notes field is attached to each of these.
* Maps	Presently two maps can be stored for each species, such as a modern and a fossil map for the users particular area of interest. (The author is working on a complete mapping interface which will be available in the next few of years).

[*] Very few pictures and maps are included due to the time and boredom involved in such tasks. Images will be added with time, but no maps. The present simple, and doubtfully useful system will be replaced in time with something more akin to GIS (Geographical Information Systems), most probably using ESRI's ArcView software.

2.2.2 Finding species that do certain things or live in certain places

BUGS provides the facility to search the database for the occurrence of words within the ecology and distribution fields. Although quite a simple system it can be extremely useful. For example:

1. Archaeology — The case may arise where one is faced with an assemblage of fossil beetle parts extracted from a context which is believed to represent a hay store. BUGS could be searched for mentions of HAY or STORE or BARN within the ecology text (which will give 310 species). This would give a useful list of species with which to compare parts.
2. Ecology — Upon bringing a pitfall trap assemblage from a forest into the lab one could search for species whose ecology descriptions include the words FOREST or WOOD or TREE (this gives 1803 species!). In addition one could ask BUGS only to return those species whose distribution text includes the words SWEDEN or NORWAY (which brings it down to 335 species, but see the note below on the choice of words). This would produce a list of species which quite probably would include many of the ones captured. It is subject to local variations, of course, but the list would give useful pointers as to where to start identifying the species. This is particularly useful with large genera such as *Amara*, or within the staphylinid family where many species with different habits can look quite similar.

In addition to the text searching facility it is possible to look for species with specific RDB (Red Data Book) Codes, the index of rarity. One could retrieve a list of all species extinct in the UK, which are common in Sweden. This is useful information to bear in mind when collecting specimens for exchange. In the above ecology example we could use this feature to see which of the forest species are now extinct in the UK (remembering not to look just for those species in SWEDEN or NORWAY - which is 24 species).

Due to the nature of the ecology and distribution data, search words should be carefully chosen. The information is extracted from the references *as is* - that is to say *unmodified by the compilers*. The reason being to avoid any possibility of unintentional reinterpretation, which can happen when one person summarises somebody else’s words, particularly if their research interests differ. So an inevitable consequence of this is that a standard database search for the word CHEESE would retrieve those records that also included the text DOES NOT LIKE CHEESE, for example (6 species, incase you were wondering). To cater for the occurrence of such phrases would take a laborious bit of programming, and would slow down the search routine considerably. We think it better to leave it to the awareness and rationality of the users (!), and state the motto "Never trust a computer!", and certainly do not depend on them totally for the right information.

2.2.3 Create, store and edit a count sheet and basic information for a site

The palaeoentomological analysis of a site leaves us with a list of the species which were found in each sample. Frequency counts for the different parts (see Fig.1) of each species (such as 4 heads, 3 left elytra...) are converted into "minimum numbers of individuals" (MNI), which is a calculation based on the identifiable fragments and the minimum number of whole individuals these could represent (a method that inherently underestimates, but provides the safest bet - see methodology Section 1.2). The MNI data is usually presented as a "count sheet", that is a list of species names against their frequency of occurrence of individuals in each sample (Fig.5. & Fig.10.). BUGS allows the storage of these as MS Excel spreadsheet files, a format, which is commonly used and can be read by those who do not run BUGS itself. Storage of the files in this way allows for easy editing, production of graphs and data analysis to the full functionality of Excel, a program with far greater analytical possibilities than Access where spreadsheet data is involved.

Species are added to the list by a simple mouse click selection process, and the list is automatically sorted into taxonomic order before saving.

A limited amount of other information on the site can be stored in the database. This is purely to provide adequate reference to the location and structure of the site (Fig.10.), it is not the intention of BUGS to be any kind of general site database, as that is, to quote Douglas Adams, "Somebody Else's Problem". Clicking on the [Bibliography] button will display the primary references should one wish to read up on any site.

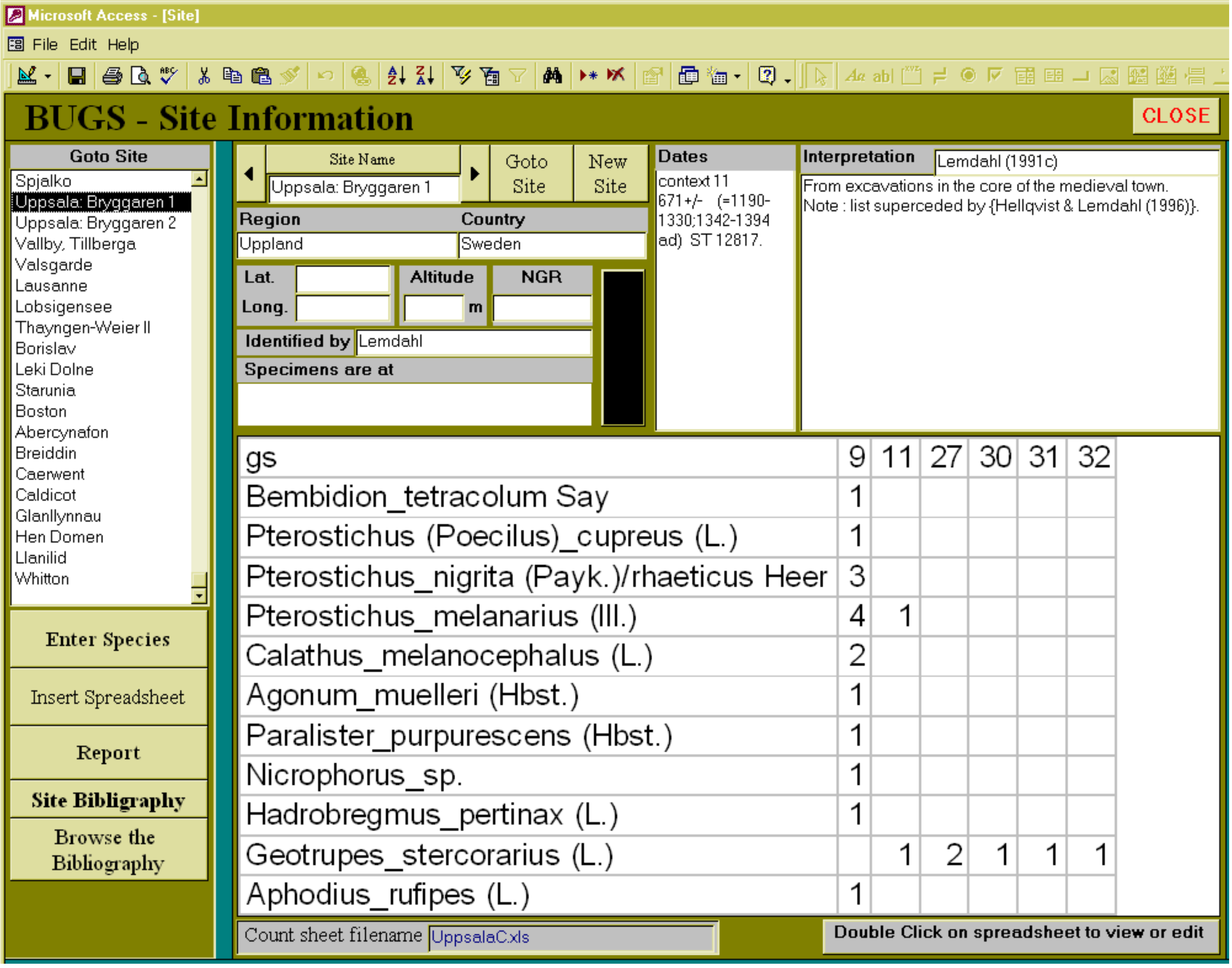

Fig.10. Count sheet and basic site data as displayed in the BUGS "Site" form.

2.2.4 Output habitat information for all the species in a count sheet (at a site)

This function is perhaps the most important function of BUGS, at least in its present form. At the click of a button (and after a processor dependent pause...) a file is created which includes the complete referenced ecology and distribution information for every species listed for a site. Before the release of BUGS this process would have involved the loaning of many books, and a great many hours of page flicking and note taking, each student reinventing the wheel. In this capacity, BUGS has reduced the time involved in palaeoentomolgical or ecological assessment by a massive amount.

From this rapidly produced summary the researcher can get a good overview of what the assemblage in any of the samples represents, in terms of environment and possible human influences. Since each output includes the references to the original texts, the next stage, if it is within the scope of the project, would be to look up some of these papers. The researcher can gain a more detailed understanding of the fauna, perhaps some insight into inter-species relationships, or the relative importance of super-abundants, and look at some examples of previous research. It should be stressed here that researchers should always reference the original papers as well as BUGS when conducting research. We are purely the compilers and programmers, and the credits for ecological investigation should go entirely to the original authors (of course the compiling and programming deserves a lot of praise too...).

2.2.5 The Bibliography

Since the ecology and distribution information compiled within BUGS comes from a wide selection of papers and books it is natural that the program should include a large reference list. In fact there are over 1500 references stored, including those on Quaternary and archaeological studies. Bibliographic information is always accessible by clicking on the [Bibliography] button, which is present on most screens. This always displays the references immediately relevant, such as those that have contributed to the information on the species, site, or list of fossil sites currently displayed. The user can also [Browse] the entire bibliography, and can search for authors or words within the titles.

PART 3: Case Studies and Discussion

Introduction

BUGS is a reasonably flexible tool and has many uses. Two examples of palaeoentomolgical studies, and the possibilities for utilising BUGS within them, are discussed below. The first case study goes into methodology quite deeply, and illustrates the acquisition of modern habitat data, which is essential for our interpretations. The second discusses sampling strategy, and extremely important, and often underemphasized part of archaeology.

3.1 GUS 1995

3.1.1 Overview

Excavations at Gården Under Sandet (GUS, for short), a Norse site farm in Greenland, were undertaken over a period of years in the mid 1990's (Arneborg & Gulløv, 1998). The team consisted of scientists from Denmark, the UK, Canada and Greenland. The project aimed to discover as much as possible about the remains of a large farm which was rapidly being eroded by the wanderings of a braided river. Time was, therefore, an essential factor in the operation, and so work has progressed much faster than is usual, and the final report is expected to be published in the year 2000.

During the summers of 1995 and '96 a great volume of samples were extracted from the archaeological and surrounding contexts for the purpose of palaeoentomology and palaeobotany. In addition, the modern insect fauna of the local area was sampled, as is customary in such investigations. A record of the existing fauna is an important part of the archaeological work, in that it can help to illuminate factors such as:

- the persistence of introduced species;
- how well, if at all, species can survive after the loss of the conditions created by human modification;
- relative change in the natural fauna of the site location, for example: pre-settlement through occupation to post-abandonment. (Hence the necessity of sampling *below* the obviously archaeological contexts - a common shortfall of many archaeologists).

The following year further samples were taken, and the total volume of earth ready for analysis reached beyond 500 litres. Understandably the processing is not yet finished, and the results discussed here a mere fraction of the eventual datasets. The existing data will serve as an introduction to the methods used and provide a few examples of relevant issues for discussion.

Irreplaceable help in the field was provided by Jens Böcher's (1988) book "The Coleoptera of Greenland" which provided a very good guide to the local fauna.

3.1.2 Sampling of the Modern Fauna

3.1.2.1 Aims

This section is intended to illustrate the use of BUGS in a survey of modern insect faunas, and to give some indication of how this data can be useful to palaeoentomologists and archaeologists.

As part of the project, it was necessary to obtain representative samples of the present day surface, airborne and freshwater arthropod fauna in a selection of vegetation zones around the site of the Norse farm. The period of expedition was one month mid June to July, usually a good time for catching adult Coleoptera.

3.1.2.2 Equipment

100 plastic cups (as used at childrens parties).	**-**	The traps.
24 wooden poles of about 50cm height.	-	To elevate half the traps in order to catch the flying fauna.
Hammer.	**-**	For stabilising poles and cups to poles (head must be long so as not to damage cup when fixing to pole).
Nails.	-	To secure cups to poles.
Washing liquid (deturgent), about half a litre.	-	To reduce surface tension (the insects sink more quickly) and loss by evaporation. Some prefer to add a little glycol to reduce the damage if all the water evaporates.
Water canister(s).	-	About 1.5 litres is needed to collect and refill eight traps once each.
100 watertight tubes, preferably plastic.	-	To transport the captured insects. (Take

		many spares).
2 litres ethanol or similar **A spouted squeezy lab bottle** (sealable if possible) is also advisable.	-	For storage of invertebrates (household cleaning spirit, 95% denatured ethanol, was used here due to local restrictions. It smells bad, but not worse than decaying insects).
tea strainer; forceps; fine brush.	-	Improvise! It can be difficult to get all the insects in the tubes.
Dip net; Sweep net.	-	For hunting the aquatic and airborne/vegetation faunas respectively.
Compass.	-	For orientating photos & grids (note that a GPS receiver would be extremely useful, especially in terms of enabling future replication of the survey).
Camera.	-	Photograph *everything!*

Table 4. The equipment used for 48 traps (24 in ground, 24 on poles for aerial fauna) over a one month period.

3.1.2.3 Method

Vegetation zones were chosen after a days scouting of the area in order to determine some dominant characteristics of the vegetation. After further discussion with Julie Ross, who was working on plant macrofossils from the area, and Charlie Schwaiger, her supervisor at the time, six zones were chosen as follows:

Zone	Description
A	Upper flood plain, very low birch and sedges
B	Dwarf birch-rhododendron scrub *(Betula - rhodedendron)*
C	Bog - moss and coarse grasses
D	Willow dominated woodland with Labrador Tea under growth *(Salix - Ledum)*
E	Pondside marshland, sedge and moss dominated
F	Exposed hillside grassland

Table 5. Vegetation Zones in the GUS site area, as used in the trapping exercise.

This is by no means a comprehensive list of definable zones, and the limit of 6 zones was imposed purely by time constraints. A detailed botanical survey of each zone was carried out by Julie Ross, but will be omitted here as it is not the main focus. It is, however, essential to a good insect survey.

The method of establishing a grid of eight traps in each area, four at ground level, four on poles, as suggested by Peter Skidmore (*pers comm.*) was adopted, as shown in Fig.11. It was adhered to where the environment permitted, and subject to only minor alterations to catch specific local factors. Fig.11. shows the system as used here, but it can be extended to use as many traps as is viable, bearing in mind that after a week specimens start to decay, and that typically only sixteen traps can be emptied by one person in a working day.

Into each cup a second was placed, to act as the actual trap thus preventing leakage due to damage occurring during securing. Note that in a windy environment cups on poles must be extremely well secured, the approach here was to cut a flap from the outer cup and fold it inwards. However, even this was initially inadequate in Zone F, where two cups were lost due to extreme winds.

Traps were about 3/4 filled with a weak solution of detergent, which has a lesser surface tension than pure water (in this case only "lemon scented" was available, it is not known what bearing this had on the results, but is a factor worth considering). Again local weather conditions will influence the specific techniques used. A period of intense dryness and sunshine will increase evaporation and could dry the more exposed traps, thus causing damage to the specimens and reduce the effective trapping time. In this case top up trips may be necessary. At the other extreme, rain may flood the traps, washing away victims, and further diluting the detergent solution. In this case overflowed invertebrates can often be recovered, but recovery should be attempted as soon as possible following rain.

In Zone E an experimental variation was tested. A trap was set in a wave cut peat platform at water level, the outer cup pierced and a holding flap cut to prevent water pressure from pushing out the trapping cup. A small drainage nick was cut at the rim of the latter to prevent catastrophic overflow at the expense of the possible loss of the smallest floating specimens. The results will show that this was an interestingly successful venture.

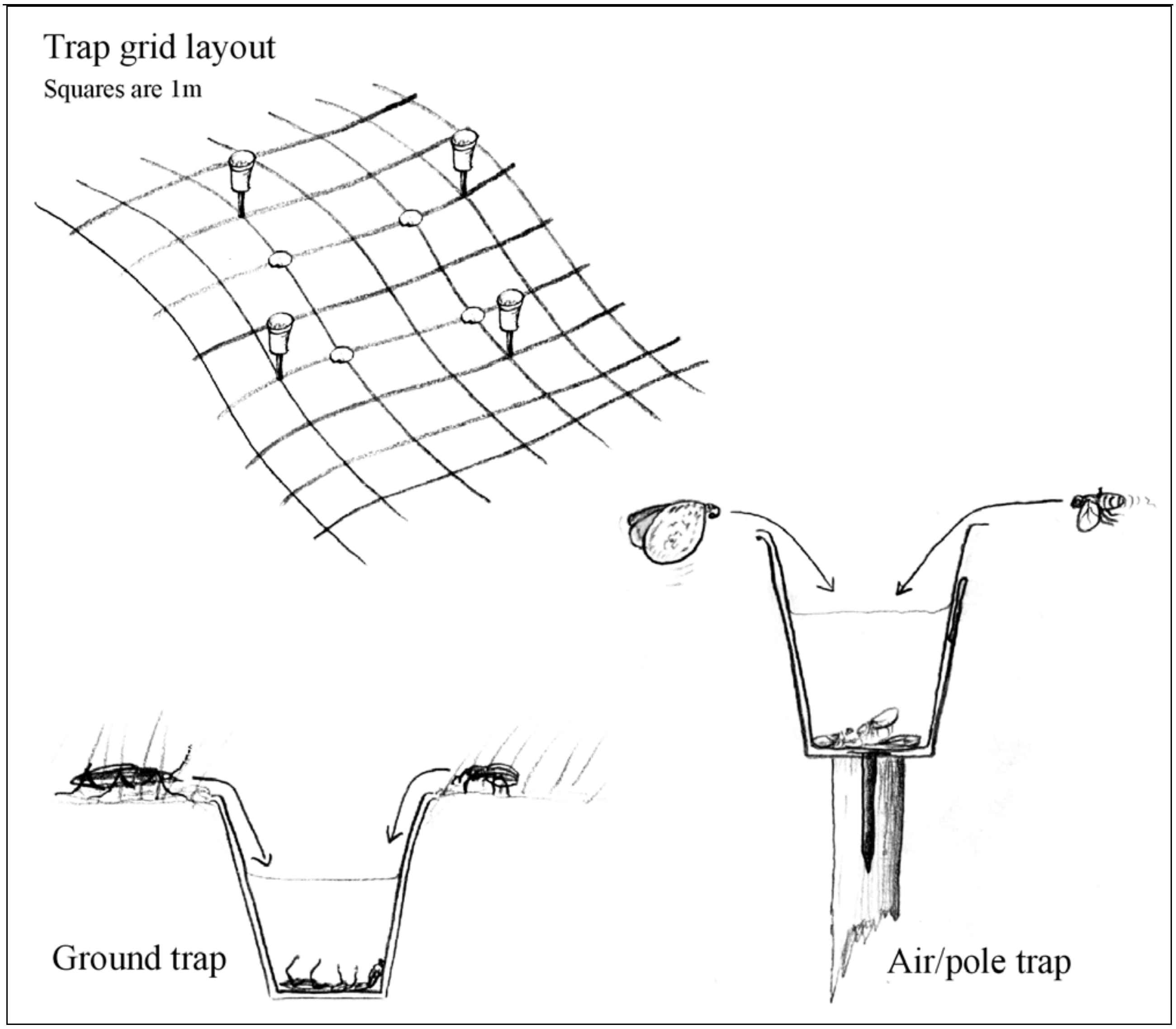

Fig.11. Pitfall trap layout and construction.

The schedule went approximately as follows:

Day 1 - scouting and identification of vegetation zones.

Days 2 - 4 setting up of traps and describing of habitats (it must be noted here that the author had other commitments on site and time was not available for detailed vegetation identification, great debt is therefore owed to Julie Ross for all but the most basic descriptions).

Day 5 onwards - going on the retrospective estimate of half a day to empty eight traps (bearing in mind that none of these traps were more than a kilometre from the base camp), three days of every week were set aside for emptying. In reality there was some juggling to allow for work on site, which accounts for the variations in preservation of the trapped specimens. Traps were emptied in rotation after as close to one week's exposure periods as possible.

Over the expedition period of one month three collections from each trap were possible.

Hunting expeditions were undertaken, and a small dip net was used for capturing aquatic species. The opportunity (which is not to be missed) was also taken to recover fly puparia from the skull of a long dead caribou.

3.1.2.4 Results

Observations

i. Very few terrestrial Coleoptera were observed in general, hunting expeditions failed to bring back many individuals - only 11 over the four weeks. This was also noted when observing the traps.

ii. Co-workers commented that even the presence of mosquitoes and black fly was low. It is possible that the black fly season was delayed by weather conditions in this and the previous year.

iii. Aquatic insects were abundant in all but the most eutrophic (i.e. caribou polluted) ponds.

iv. Lepidoptera were unusually prevalent, and dominate almost all trap assemblages. The exceptions are zone C (bog moss and grass), where spiders were dominant, and zone E (pond side) where flies were exceptionally abundant.

v. Bird droppings around some of the traps in Zone F partially explain low catch rates. It is possible that they preferred coleoptera, a colleague having told me that there were “black beetles” in the those traps before I emptied them, and I have no reason to doubt this.

vi. Much of the willow scrub was in poor condition, looking either dry, or eaten, and in recovery but with new growth sparse. It may be that earlier in the year the species suffered a plague of caterpillars, which would explain the moth and butterfly explosion. The dry previous and present year would make conditions ideal for such a population explosion.

vii. Evaporation was a problem where traps were left unattended for more than seven days.

viii. Reindeer were curious but not destructive.

ix. The decay in traps left for longer may possibly lead to more flies being attracted and caught, hence adjusting the assemblage away from that of environmental background.

TRAP:	A	A1D	A2D	A3D	A4D	B	B1D	B1U	B2D	B3D	B4D	C	C1D	C2D	C3D	C4D
Patrobus_septentrionis (Dej.)													1			
Hydroporus_morio Aube																
Colymbetes_dolabratus (Payk.)																
Gyrinus_opacus Sahl.																
Mycetoporus_nigrans Maekl.			1					1		2						1
Simplocaria_metallica (Strm.)							1			1						
Simplocaria_elongata Sahl.										1						
Byrrhus_fasciatus (Forst.)	2									1	1			1		
Nephus_redtenbacheri Muls.																
Coccinella_transversoguttata Fa	1	1	1	1		1										
Otiorhynchus_arcticus (F.)	1								1						1	

TRAP:	D	D1D	D2D	D3D	D4D	E	E1D	E2D	E3D	E4D	F	F1D	F2D	F3D	F4D	
Patrobus_septentrionis (Dej.)																
Hydroporus_morio Aube						1										
Colymbetes_dolabratus (Payk.)						2			2							
Gyrinus_opacus Sahl.						1										
Mycetoporus_nigrans Maekl.						1		3	1	1						
Simplocaria_metallica (Strm.)								1								
Simplocaria_elongata Sahl.																
Byrrhus_fasciatus (Forst.)												1				
Nephus_redtenbacheri Muls.													1		1	
Coccinella_transversoguttata Fa					1											
Otiorhynchus_arcticus (F.)		1									1					

Table 6 Results of the trapping and hunting, Coleoptera only. The columns with letters alone represent the hunting expeditions into those vegetation zones. The system for the others is Zone (letter); Trap number; Up or Down - whether the trap was elevated on a stick or set into the turf. For example, column A1D shows the total catch for Ground Trap 1 in Vegetation Zone A.

3.1.2.5 Discussion

Although the quantity of beetles caught was low there were some interesting results upon which to build theories.

The small ladybird (nykelpiger) *Nephus redtenbacheri* (Muls.) was collected north of its previously known limit, Table 7 showing the data from the BUGS database. The species was used as an example of the use of insects as indicators of climatic change by Buckland *et. al.* (1996), but those arguments may now have to be rethought. It was believed that the species could be found only as fossils at this latitude (McGovern *et al*., 1983), from the warmer period previous to the Little Ice Age, and that it could not have survived through to the present day. Whether it actually *did* survive the Little Ice Age in situ, or has recolonised the area subsequently is a subject for debate. More extensive sampling of fossil environments could help to establish its presence/absence at various points through time. Without that we can only speculate.

Biology
{Larsson and Gigja 1959} - on Dry ground, Grassfields, Sandy River Banks, Dryas Heaths, Under Stones. Europe, Bogs, Meadows, Outskirts of Woods, Open-Woods. Imagines from May - October. {Lindroth 1931} - feeds on Eriococcus granulatus. {Pope 1973} - outlines the synonymy of the genus. {Lindroth et al. 1973} = limonii Donis. on dry meadow slopes regularly, probably constantly, associated with Coccids feeding on Festuca, in 2 cases identified as Pseudococcus thulensis & Rhizococcus granulatus. Wings full and functional. {Böcher 1988} Greenland: pitfalls show it to occur fairly abundantly in several plant communities, incl birch coppices, hygrophilous vegetation along water courses, grasslands, and dry heaths. Larvae from dry Empetrum heath, often found with Orthecia cataphracta on which it probably mainly feeds. In Europe in more humid situations, heaths rich in mosses, bogs, meadows, along edge of woods and in open, light woods with rich ground cover.

Distribution:
{Waterston 1981} Berneray. {Lindroth et al. 1973} Europe: N to 70N in Norway, V.limonii restricted to Atlantic region. British Isles. SW Greenland. Iceland: throughout but local in N, Heimaey. {Larsson and Gigja, 1959} - most of Iceland but Rarer in N. N and C Europe, Mountains in S. N Africa, England: fairly S. SW Greenland. {Böcher 1988} Greenland: confined to subarctic E part of Qaqortoq and Narsaq districts, also at Pamialluk Island, Kap Farvel. Palaearctic, temperate to subarctic. {Pope, 1973} - Widespread in Europe, South to North Africa, East to Caucasus, West to Pyrenees. Norway, Finland, Sweden, Rare above 62N.

Table 7. BUGS data for *Nephus redtenbacheri.*

The true bug (which differ from beetles by having softer bodies and sucking mouth parts) *Nabis flavomarginatus* was a slightly suprising discovery (although one should perhaps never be surprised in an area that has been examined by so few researchers). It was caught in the traps of Zone F, despite having been thought extinct in the region. *N. flavomarginatus* is considered to have been brought over by the Norse settlers and found a home in the managed hay fields on their farms. It is commonly known from the south of Greenland, and has been found fossil in samples from the Norse site Niqussat (McGovern *et al*., 1983). It now seems to be living on exposed grass slopes in the area close to the GUS farm site. Its survival to the present day suggests that some species may have the ability to persist in conditions which we would regard as quite different from their usual habitat. Some imported species have a tendency to find their niches in new lands.

A third, and most exciting discovery, was that of a species new to Greenland - *Mycetoporus nigrans,* (determined by P. Hammond of the British Museum, London) a small Staphylinid beetle, Table 8 shows the somewhat sparce BUGS data:

Biology
{Koch 1989} green alder and treeline region, on moraine, under turf and leaves, in moss and straw under Alpine rose.

Distribution
{Koch 1989} Europe: subalpine-alpine, E Alps. {Buckland, P. I. unpubl.} Greenland: Ameragla, GUS 1995.

Table 8. BUGS data for *Mycetoporus nigrans.*

It accounted for the highest number of individuals trapped (11), and was found in all zones apart from D and F, so is most probably an established inhabitant of the GUS area. We could attribute its new discovery to factors such as:

- The population is growing. Particularly favourable weather conditions for this species over the past couple of years could have allowed it a significant growth of population. Although it is unclear as to what it eats, it could also be expanding into a vacuum left by a declining species.
- Periodic or cyclic fluctuations in the population. Many species of animal experience such, lemmings (*Lemus spp.*) are of course the classic example, the population booms every 3-4 years creating the popular image of them jumping over cliffS in suicide. Predator-prey relationships permit these cycles to flow around the food webs, so an increase in the species' chief prey could similarly create a population spike (Odum, 1971). If *M. nigrans* feeds on thrips (Thysanoptera) or mites (Acaridae), which were found in most traps, then rises in their populations due to a successive warm dry years could be responsible. If, on the other hand, it is a mould or fungus feeder then dry conditions could have accelerated the growth of dry loving moulds. These are pure speculations, and further work is needed to clarify this find.

- Very little work has been done in the area. Certainly it would be foolish to draw conclusions to a recent immigration of the species with such sparse extant knowledge.
- Luck. Point sampling is always subject to a bit of luck.

The reindeer skull assemblage was dominated by two species of fly which prefer outdoor environments and decaying flesh for the development of their young (*pers com.* Peter Skidmore). This is not surprising data, but it is useful to check such habitats for the presence of newly introduced species, or, as with *M. nigrans* (above), previously unknown species.

Conclusions

Synanthropy - the dependence of a species on man made environments - is often a function of the species' distance from its 'natural' environment. Human constructions create niches which are so ecologically similar to naturally occurring ones that some insects can live there permanently. In the context of Norse farms on North Atlantic islands temperature plays an important role, in that the houses and byres are significantly warmer than the outside, especially during the winter months. Species, such as many of the Lathridiids therefore naturally occur in the Tropics, but are synanthropic in the Arctic. The above discussion of *N. flavomarginatus* gives us a slightly different example, and some terminological difficulties (which Kenward (1997) has tried to address in terms of subclassifications of synanthropy). It is believed that the species did not naturally occur in Greenland prior to Norse settlement, but then survived as a synanthrope in the environment created by the activities of the farmers. Whether it should still be called a synanthrope whilst living in the 'artificial' post-clearance, and post occupation landscape is debatable. The landscape is of human creation, but no longer maintained.

A similar problem is in the discussion of species (in particular *Xylodromus concinnus and Quedius mesomelinus*) which appear both in Norse farms (10th – 15th C) and 19th century Inuit turf houses. It is unknown whether the beetle survived in the period between these habitats, or was reintroduced later (Böcher, 1988).

It is also relevant to discuss here, as a final note, the concept of *ecotones,* which are the zones of overlap between environments. As can be seen in Table 5 ecotones have not expressly been included in the survey, we have only attempted to sample specific vegetational regimes and not the transitional areas in between (although there definition is often a question of scale, and quite difficult to decide). Given more time the investigation would have included some, since there can often be more species found there, a mixture of individuals from all the surrounding zones. This phenomenon is known as the *edge-effect* in ecology, and is well documented in studies of species abundances (Odum, 1971, p157). The edge-effect is, however, difficult to visualise in archaeological contexts because of the spotted nature of the sampling.

3.2 Stratigraphic Sampling - Site Ø34 Greenland

3.2.1 Aims

Of this Section

To provide an example of stratigraphically confined sampling, a farm midden in this case.

Of this Project

The project is part of the Greenlandic-Danish investigation into the Norse occupation of Greenland. Attempts will be made to uncover details of the peoples daily lives and social interactions, as well as their interactions with the surrounding landscape. Particular effort is being extended towards understanding the reasons behind the abandonment of the colonies.

3.2.2 Introduction

Excavation

There are perhaps almost as many excavation techniques as there are archaeologists. Despite numerous prescribed methodologies (eg. Evans, 1978; Greene, 1995), people will have different priorities which will lead to variations in the definitions of boundaries, and ascriptions of relative importance amongst finds and deposits. In addition there are personal psychological variables, such as thresholds of perception, attention to detail, educational presuppositions etc. But although some variation and subjectivism is implicit there are nowadays general rules, some written, some not, for excavation which allow for cross comparisons of data between sites and situations. However, there is still a great lack of consideration for environmental archaeology in many projects - especially when it comes to sampling. I am sorry to say that Sweden is particularly bad. The work at Umeå department of archaeology (among others), particularly the integration of the Environmental Lab, provides us with hope. Through effective information disemination and publicity the situation can, and hopefully will be better in a few years.

Stratigraphic Units and Contexts

An encompassing factor in any palaeoenvironmental sampling strategy is the importance of stratigraphic units (or contexts) - be they seasonally deposited varves in a lake, or room delimited floor layers in a house. Stratigraphic units are deposits which contain the same or similar components in similar proportions throughout their volume, and generally represent what is called a single phase of deposition. In many situations the sediments will have been deposited gradually, and therefore show smooth transitions between different types of sediment. Palaeoenvironmental description systems, such as the Troel-Smith scheme (see Aaby & Berglund, 1986), provide descriptors for difuse boundaries. However in these cases it can be difficult to delimit for sampling, and an arbitrary boundary must be drawn up at the investigators discretion. In other situations the boundaries may be obvious and discrete, and so a sampling strategy can easily follow the features.

Below is described the palaeoecology sampling scheme adopted by the author and coworkers on the excavation of a Norse Greenlandic midden. The midden consisted of the waste deposits from the period of occupation of a farm in the Eastern Settlement of Norse Greenland. Deposition took place into a bog, which probably underwent fluctuations in growth rate due to human and natural variations in water level. Some sediments may be the result of sporadic depositions, such as byre floor cleaning events, for example, and others are more dominated by the continuous growth of vegetation within the bog itself. Bones and artifacts, including the longest runic inscription (on wood) yet to be found in Greenland, were found well preserved throughout the majority of the upper profile. Excavation stopped when it was impossible to dig deeper due to water, but this was well below the obviously cultural layers. Hence pre-settlement deposits were most probably sampled.

3.2.3 Sampling Method

Palaeoentomology was included in the investigation to help gain a greater understanding of the human occupation of the site, and the preceding, concurrent and subsequent landscape changes. The occupation would be represented, to an extent, by the waste thrown into the bog - we can often learn more about real people by what they throw away, than what they save. Many waste deposits in the midden would contain their own endemic insect faunas -the parasites of sheep and cows from a byre; or human ectoparasites and decomposer species, along with their predators, from living rooms. The majority of these insects would die rapidly with this change of environment, and should be well preserved in the waterlogged, frozen sediments.

Landscape changes would be reflected in the insect populations that are found in the natural bog, some of which would most probably permeate some anthropogenic deposits. However, the species found in the bog may represent the local bog conditions more than the prevailing climatic changes. The bog is fed by rainfall and runoff from the surrounding hills, its formation probably the result of a moraine ridge plugging a meltwater stream and late glacial clays sealing the bed. Anthropogenic disturbances, such as forest clearance or burning could have exerted a greater influence over the fauna than the weather systems. For example, a fauna representing a drying out phase could be the result of a few dry seasons, *or* draining of the bog. Table 9 shows some possible cause and effect scenarios which could produce changes evident in the insect faunas.

Factor	**Internal**	**External**	**Possible Effects**
Grazing pressure, deforestation, or local burning.		X	Increased sediment input to the bog, resulting in lower water retention capacity and less surface water. Microclimates less humid.
Burning of the bog surface	X		Temporary stagnation of bog growth; invasion of other plant and insect species.
Geomorphological changes such as landslides or stream channel changes.		X	Increase/decrease in the size of stream/runoff catchments, leading to more/less water input to the bog.
Turf cutting.	X		Artificial lowering of bog surface, changing the surface communities dramatically and producing discontinuities in the dating sequence.

Table 9. Some possible reasons for changes in the environmentally sensitive insect fauna of a bog-midden.

With this in mind samples were taken (from exposed trench faces) which adhered, as far as possible to coherent stratigraphic units. Fig.12 shows the actual sample positions as recorded in the field. In the upper levels delimitation was reasonably easy, and obvious sporadic anthropogenic deposits were demarcated by virtue of their differing colours and composition. For example, some layers were burnt, others contained many bone fragments, and others had a greater proportion of natural bog growth within their matrix. Lower down, however where there seemed to be considerably less, if any human influence. Bog growth was more constant and therefore sampling was adjusted to a more regular interval based system.

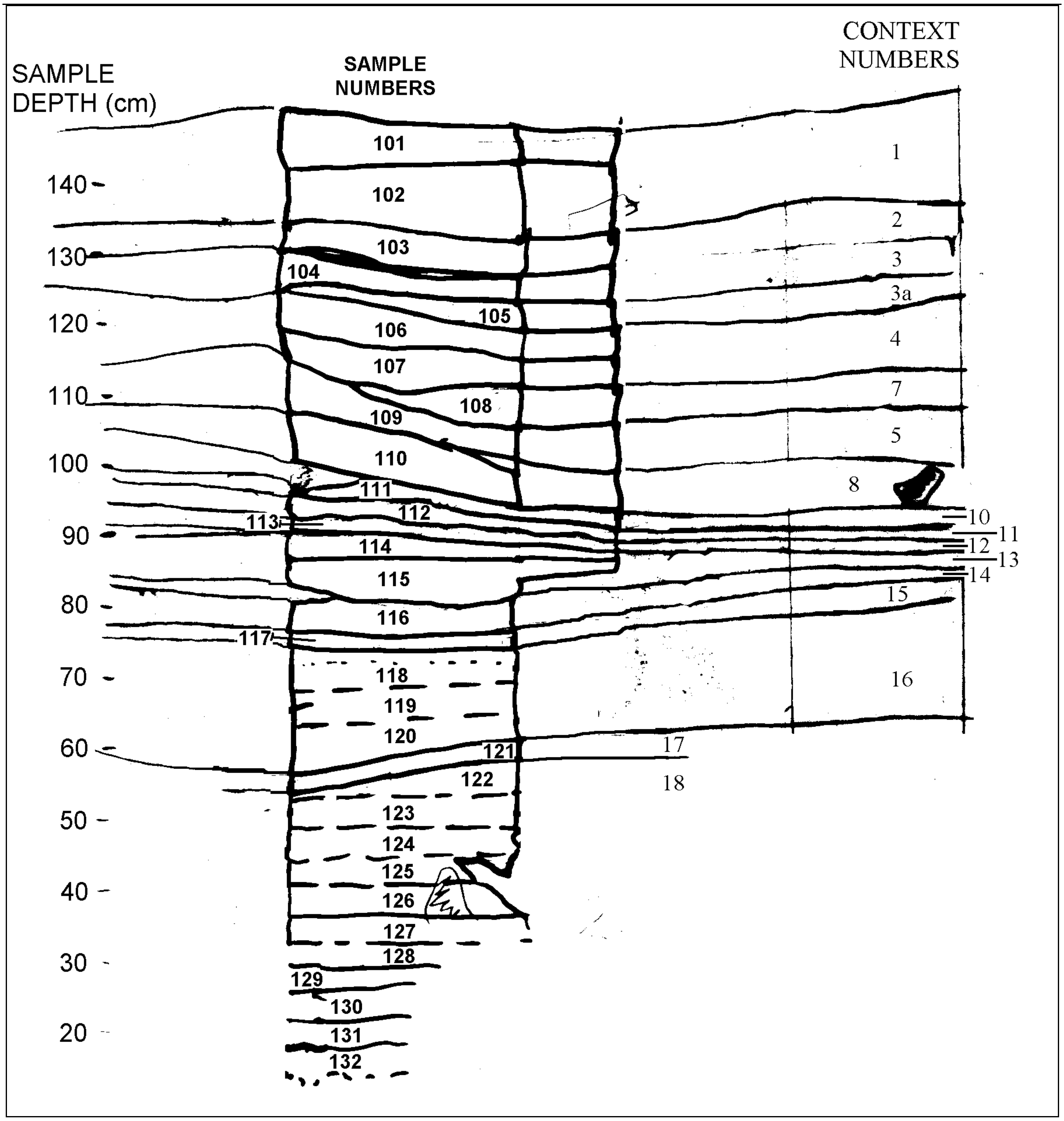

Fig.12. Simple columnar, stratigraphic sampling from the midden at site Ø34 in Greenland. Numbers on the right are context labels, numbers over 100 are the insect sample numbers, thick lines show where samples wholly contain a context, dashed lines where several samples share a context.

Discussion

At the present time only one test sample has been processed. This came from the middle cultural layers and was taken from around the remains of a small wooden bowl. The preservation of insect parts was excellent, and produced a distinctively synanthropic fauna of fleas and warmth loving decay feeders. No definite identifications have been undertaken yet, except for the human flea (*Pulex irritans*).

The investigation here provided us with a reasonably straight forward structure for sampling, which is rare for middens. The fact that waste was deposited into a growing bog helped us to identify periods of inactivity where the natural growth dominated.

4 Conclusions and Final Notes

Palaeoentomology is a time and labour intensive method, and the BUGS program has significantly reduced the overhead inherent in looking up ecological data. The importance of collating of the knowledge of several hundred authors in one package is self evidently important. What remains to be seen is whether we can develop BUGS into a more comprehensive package with increased analytical powers and greater flexibility.

Perhaps one of the most important long term benefits of BUGS could be to increase the number of students wishing to continue with palaeoentomology post graduation. This goes in hand with increasing the general awareness of what the method can achieve and just how useful it can be to archaeologists and quaternary geologists alike. For this to happen it is imperative that site archaeologists are educated in environmental archaeological methods, preferably by onsite training. Good sampling procedure is, of course, essential, but this itself must be backed by problem orientation and awareness of the investigation's objectives – it helps to know why the samples are being taken at all. Just as it helps us to know why we have been sent the samples that have already been taken.

Archaeology seems to hold a fascination for many people, and this will hopefully ensure its survival as a university subject. It only has to break out of it's introverted tendency and explore links with other disciplines to really guarantee its future. Palaeoentomology is just one of many methods through which this can be achieved.

Appendix I - A Brief History of BUGS

Version 1 - DBase & Clipper

The original MSDOS version of BUGS was written in 1984 by Jon Sadler and Mike Rains as part of Jon's PhD project (see Sadler *et al.* 1992) under the supervision of Paul Buckland. It was a DBase 3 database compiled and programmed using Clipper. The text based interface was easy to use and entirely keyboard based, including an excellent *search while you type* routine for looking up species. The program was a major development in palaeoentomology, and greatly speeded up data retrieval, and probably, through its use in teaching, increased the student accessibility of the subject.

It did however have a few short falls as a result of the programming environment. Being a DOS based program there was limited compatibility with other software, such as spreadsheets and word processors. Transfers were possible, but a little time consuming when it came to rearranging the layout of file outputs. The later advancement into the Windows operating system greatly increased the transferability of data. Secondly the reporting functions demanded at least a basic knowledge of SQL (Standard Query Language). The user had to enter search parameters for the output of their data tables in a vaguely algebraic language which had to be exact, and was extremely difficult to remember. Later versions compile the SQL after the user has selected search criteria in a more friendly environment (see section 2.2.2). Thirdly, the program consisted of numerous files on disk, including index, data table, and notes files for every site. The latest version has only two files for the main application, and then one Excel spreadsheet file for each site, held in a separate directory (Fig.13. may help to visualise this).

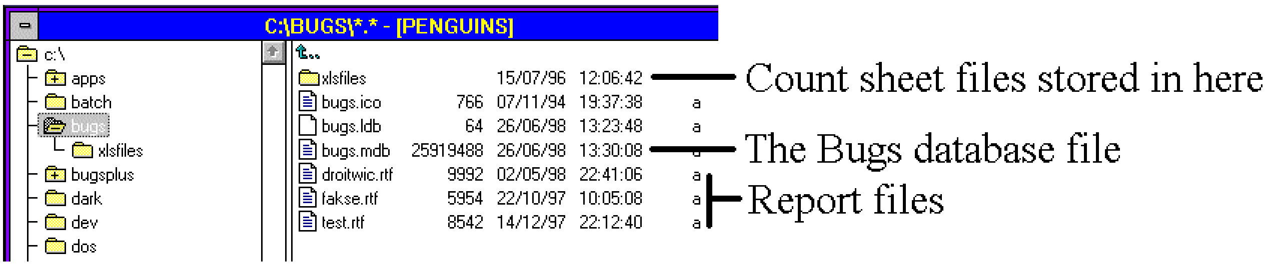

Fig.13. The BUGS directory in Windows for Workgroups 3.11 File Manager. (WfW 3.11 was the operating system under which the distribution version of BUGS was developed).

Version 2 - Visual Basic

An attempt to recreate the original BUGS in the Windows environment was made using Visual Basic - an advanced programming language based on the original BASIC that is familiar to many scientists. The idea was to replicate the actions of the DOS program, which, with hindsight, was probably a bad idea. The GUI (Graphical User Interface) of Windows requires a quite different approach towards the design of software. It is orientated more towards giving the *user* what they want, rather than being limited to what the programming language can provide. There are of course other limitations and problems inherent in the language. But perhaps the main problem here was that Visual Basic is a programming language, and not a programmable database management system (DBMS) as are all the other systems discussed. Because of this many tasks were actually simpler in the older DBase and Clipper programming environment.

Version 3 - FoxPro for Windows

FoxPro for Windows from Borland (but now Microsoft) was used in the development of BUGS version 3. The project existed over a one year period in a combined effort by Paul Buckland, Jon Saddler and a computer science MSc student. This system looked good, and was quite similar in design and performance to the present version. There was however a problem in that the student programmer, while a very capable programmer, was not at all familiar with the concepts of scientific research that we wished to involve. As a result full operability was never really achieved in the time available.

This, however, proved irrelevant in the end as the University withdrew support for FoxPro and switched to Microsoft products. Coupling an anticipated demise of FoxPro and much cheaper Microsoft products we chose to abandon this and move on to Access, which seemed a promising product. Such is the unpredictability of the computer software business that Microsoft recently bought and is continuing to develop the FoxPro DBMS, and it seems to be a powerful and adaptable programming medium..

Version 4 - Access (& Excel) - The Present System

The MS Access DBMS is, as FoxPro, what is called a Fourth Generation Programming Language (4GL). That is a high level - close to English - programming medium with a great deal of powerful commands built in to automate processes. For example, the code which handles the appearance of the application is more or less hidden from the programmer - one need never see any code which describes the screen layout. In addition many tasks relating to database manipulation, querying and data linking have highly automated code generation. The main advantages of Access from our point of view are:

- It is fully compatible with the Windows DDE (Dynamic Data Exchange) and OLE (Object Linking and Exchange) system which allows for the more or less seamless transfer of data within and between programs. (Note that some Macro Viruses are particularly good at disrupting this).
- MS Excel count sheets can easily be linked and stored for the creation of Count Sheets (see part 2.2.3). In fact Excel can be activated from within BUGS to allow for easier data entry. On faster machines Excel can be run *within* BUGS.
- The designing of visual interfaces, data tables and queries is very easy, and the code or SQL written automatically. The linking of program code and actions to screen features such as windows and buttons is also quite simple, working on the basis of object orientated modules.
- The flexibility of the language allows for programs to be designed from the point of view of user needs. Whatever is wanted, could be done, probably, eventually.
- With many of the code based technicalities avoided by automation, the programmer has more time left for designing a useful application, free from struggling with syntax. In theory, at least.

The majority of the original program was written by another Sheffield University Computer Science MSc student, Yuan Zhuo Don, who stayed on to help develop the project for a year after his graduation. Through close contact with the principal researchers (Paul Buckland, Jon Sadler, and Phil Buckland) this *extremely* good student produced a fully useable system with most of the desired features. This author (Phil Buckland) then continued the development over the subsequent two years (up to and including the present day) adding additional features, adjusting and fine tuning the program. Paul Buckland continues to update the database with the most recent information.

Rather than first confronting the user with a menu (as Versions 1 & 2 did) BUGS V.4 displays the insect ecology screen directly after the title page, including a nice bit of welcome and help information in the text windows (Fig.9). Navigation buttons allow the user to easily move through or search within the species names, which are stored in European taxonomic order. Immediately on finding a species the ecology and distribution information is displayed on this screen. Fossil sites can be brought up by clicking on the [Fossil Sites] button, and the [Sites] button brings the user to the site and count sheet display screen.

From the latter section reports can be generated which merge the species list of a site with the appropriate environmental information (see Section 2.2.4).

The addition of a word search query facility allows the user to find species whose text includes any words which are typed in (see Section 2.2.2).

The ability to link count-sheets as MS Excel files improved the portability of the data. Without even loading BUGS the species list and sample data for a site can be loaded into Excel, mailed to others, or imported into Word, for example.

Unfortunately, however, there are a few structural hangovers from the DOS version, in that much of the data is stored in memo (free text) fields. This prevents the database from being truly 'relational' in terms of linking data tables. Relational database management systems are much faster and more powerful than standard ones.

Version 5 - In Development...

Purely an enhancement of Version 4, this has have numerous additional features and alterations which make it more friendly and useful, including:

- Searchable drop down lists for looking up sites.
- *Search while you type* facilities for finding genera and species.
- Full Windows 95 (etc.) compatibility. There are a few problems right now due to lack of compatibility between some Microsoft products).
- Fully customisable reporting, especially useful for the site-species-habitat output.
- Bookmarking of species for quick cross checking.
- Additional modules will be added to perform common statistics, in particular some from population ecology. Such as correlation coefficients, as described in section 1.2.5.3.

Appendix II – Internet Resources – a Brief Overview as of May 2000

Created by this Author

The BUGS Homepage

http://www.umu.se/envarchlab/BUGS/BUGSHome.html

The BUGS Homepage was originally created to allow people to download BUGS over the internet.

Three download sites are presently accessable, one in the US:
ftp://ftp.ngdc.noaa.gov/paleo/insecta/coleoptera/british/
its mirror site (a copy) in France:
ftp://medias.meteo.fr/paleo/insecta/coleoptera/british/
and at the Environmental Archaeology Lab in Umeå, Sweden:
ftp://130.239.52.57/
A further download site at Sheffield (UK) will be linked soon, which will always contain the latest versions.

Since its creation in 1997 the site has grown a little, providing a rough guide to the use of the program. It covers most of the features, with inset graphics of the buttons to be pressed, and links to additional resources. With time the site will be expanded. Greater depth into the use of palaeoentomology, and a more interactive help/tutorial system are envisaged.

The Quaternary Bibliography of Palaeoentomology (QBIB)

http://www.umu.se/envarchlab/BUGS/QBIB/QBIBFRAM.HTM

QBIB is a list of references useful to palaeoentomologists that is maintained (in written form) by P.C. Buckland, G. R. Coope & J. P. Sadler (1997). The web version, created and maintained by Phil Buckland is quite a simple site which allows access to this bibliography over the internet. References are stored alphabetically by first author, with one web page for each letter. The letters can be jumped to by clicking on the alphabet which sits on the left of the screen. Below this are links to the BUGS Homepage and the Environmental Archaeology Lab, Umeå.

A problem with the site is that it is a little difficult to use as a real bibliographic database, in fact the most effective way to use it is to download the text version and browse it in a wordprocessor. This problem exists because the file is split into different pages on the internet version so that slower computers (or computers with slow internet connections) can actually access it. At the moment it is most useful if one knows the author and wishes to look up the complete reference.

In the future it is intended to make a fully searchable version. A searchable version (using the whole text file in one go) for faster machines will be created soon.

The Environmental Archaeology Lab. Umeå Homepage (MALWEB)

http://www.umu.se/envarchlab/
Palaeoentomology part at: http://www.umu.se/envarchlab/MetFrame.html then click on "Fossil Insects".

MALWEB was created as the first web site for the Environmental Archaeology Lab. (Miljöarkeologiska Laboratoriet), at the Department of Archaeology and Sami Studies, University of Umeå, Sweden. The idea was to publicise the presence of the lab, inform people about what the lab does, and provide information on various methods within Environmental Archaeology, including palaeoentomology.

At present the site is somewhat lacking in information, providing only a basic outline of several techniques, along with a staff list and contact details. The palaeoentomology section is perhaps the longest and provides something which more or less resembles a summary of Part 1 of this paper. A (small, but growing) bibliography is found by clicking on "Bibliography" at any point, which contains sections with useful references to all the methods described, along with some more general environmental/archaeology texts.

The prospection section in particular lacks information, although the outline is already created. We intend the site to become as comprehensive a guide to environmental archaeology as is possible (given time/space constraints).

Others (to which the BUGS site links)

Quaternary Entomology Laboratory, Department of Geosciences, North Dakota State University

http://www.ndsu.nodak.edu/instruct/schwert/qel/qel.htm
Codirected by Allan C Ashworth and Donald P. Schwert.
Includes information about the lab, the services it provides, and the equipment they have at their disposal. There is also a publications list, very nice pictures of fossil insects.

The Quaternary Entomology Dispatch Homepage (QED)

http://culter.colorado.edu:1030/~saelias/qed.html

This page give details for obtaining the Quaternary Entomology Dispatch Newsletter (on real paper), and lists the contents of the latest issue. It is maintained by Scott Elias, whose homepage is linked, and summarised below.

The Home Page for Scott Elias

http://culter.colorado.edu:1030/~saelias/elias.html

Scott Elias is a prominent American paleaoentomologist. Brief summaries and ordering information are provided for his books, published by the Smithsonian Institution Press. The titles are:

> "Quaternary Insects and Their Environments"
> "Ice Age Environments of Alaskan National Parks"
> "Ice Age Environments of National Parks in the Rocky Mountains"
> "Ice Age Environments of Southwestern National Parks"

Please see his website for the full references.

The Chironomid Home Page

http://www.sci.ouc.bc.ca/fwsc/iwalker/intpanis/
Maintained by Ian Walker, E-mail: iwalker@okuc02.okanagan.bc.ca

Information on the use of Chironomids in palaeoecology, many links, bibliographies and useful contact addresses.

BEETLES (COLEOPTERA) IN QUATERNARY STUDIES

Department of Geology, Colby College
http://www.colby.edu/geology/Beetles.html

Part of the "Quaternary Paleoenvironmental And Paleoclimate Studies" site at the same college, this is a nice summary of the use of fossil beetle parts in palaeoenvironmental studies, with more useful links.

Invertebrate Macrofossil Biostratigraphy: Chironomidae and Chaoboridae

http://lrc.geo.umn.edu/services/handbook/chirchao.htm

Part of the University of Minnesota's "Limnological Research Center Core Facility Handbook". This page provides comprehensive list of equipment and a description of the processing technique used in their recovery of Chironomidae for palaeoecological analyses. Surrounding this is a wealth of information on their laboratory and its functions.

Department of Quaternary Geology, Lund, Sweden

http://www.geol.lu.se/kvg/egroups.xtm

Describes the courses available within and activities of the department. Unfortunately most of the good explanative material is only in Swedish, but the English resources are quite good in terms of publication lists and subject summaries.

The Quaternary Entomology Laboratory at the University of Waterloo

http://www.science.uwaterloo.ca/earth/qsi/qellab.html
By Alan and Anne Morgan. Email: avmorgan@sciborg.uwaterloo.ca

This is probably the most extensive palaeoentomology (paleoentomology in American!) site out there at the present time. The table of contents looks like this:

The bibliography is quite extensive, and many interesting pictures are included.

Beetles by A. Bochdansky & M. Kriftner

http://www.source.at/beetles/english/navigation.htm

A very nice, but small, site with pictures of various species, plus a game and some animations.

The North Atlantic Biocultural Organisation

http://www.geo.ed.ac.uk/nabo/main.html
Maintained by Anthony Newton.Email: ajn@geo.ed.ac.uk

Although not a palaeoecology website this organisation has provided support, funding and valuable communication links which have helped in the advancement of the science and the development of the BUGS Project. Their site describes many projects which have successfully integrated various subjects, and been truly interdisciplinary.

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