Dipterous remains and archaeological interpretation

Eva Panagiotakopulu*

Department of Archaeology, School of Arts, Culture and Environment, Infirmary Street, Edinburgh EH1 1LT, UK

Received 8 September 2003

Abstract

Fossil flies from archaeological settlements can give information on details of everyday life, hygiene, disease and death. Previous work is reviewed and recent research on material from a Greenlandic farm shows the range of the technique and highlights its potential to reconstruct important aspects of human activities that otherwise go unnoticed.

© 2004 Elsevier Ltd. All rights reserved.

Keywords: Flies; Ectoparasites; Disease; Hygiene; Greenland; GUS

1. Introduction

Although beetles (Coleoptera) have been widely used in palaeoenvironmental reconstructions (cf. [4]), true flies (Diptera), with the exception of chironomids from lake sediments (e.g. [10]), are rarely included in palaeoenvironmental research. In part this reflects limited expertise in identification, particularly of their pupal stages, but also their significance in site interpretation is perhaps less generally appreciated. This paper reviews previous work, bringing together some widely scattered sources, and provides new data on research in Greenland, which highlights the utility of larval Diptera in archaeological interpretation.

The study of flies is better known for its use in forensics. By examining the insect faunas found on and around a body, one can obtain an informed opinion about the time, the place and sometimes the way, or the reasons behind death. Diptera and on some occasions Coleoptera and ectoparasites from the death scene are part of the forensic evidence [64], and Dipterous larvae in particular are very useful, because they breed in specific places, and more importantly stay there [34]. Their surrounding environment determines their development, and their study provides extremely detailed information about location, time, and way of death. In the archaeological context, this methodology has been applied to the bodies from Lindow Moss in Cheshire [17,31,61].

A long list of flies are pests on a variety of crops and stored commodities, others live on faecal material or fungi, or are predatory. Some are linked to serious diseases, such as malaria, recently recorded by its DNA from a Roman burial [1]. Although the name of the disease comes from the Italian for bad air, a reflection of the prevalence of the disease in marshy areas, it is transmitted by the bite of mosquitoes, which breed in profusion in wetlands. Flies are also responsible for the spread of trachoma, an infection often causing blindness, which is still widespread in Africa, and, judging by the prevalence of recipes for eye salves in contemporary sources, was a serious problem throughout the Roman Empire [9]. Maggot infestation of living tissue, termed myiasis, can also occur, but on a more positive note, before the advancements of modern medicine, some calliphorid maggots have been used for cleaning wounds [20,39]. The study of Diptera is of particular importance because it tackles issues of economic, medical, environmental health and veterinary importance [64]; such issues can also be examined in the past. Abundance or absence of fly remains may signify changes in the environment or the ways of living on an occupation site, and the species which are vectors in the spread of diseases would have had significant impact on ancient societies. The examples of malaria and trypanosomiases...
(sleeping sickness) in Africa are particularly well known, and the accidental spread of flies and associated diseases around the world has had significant impact upon settlement patterns and populations [26,27].

2. The taxonomy of flies

Aristotle was the first natural historian to write down observations on true flies. He christened them Diptera, the ones that possess two wings. Although, some of Aristotle’s notions are wrong [6], he was quite accurate in this occasion; a single pair of wings is the main characteristic of true flies, the hind wings being modified to two balancing organs, term halteres [49]. Flies show complete metamorphosis from a larval stage, often referred to as a maggot, to the adult fly, through the intermediate stage of the pupa, and the latter may retain sufficient characters in the fossil state to enable identification.

Until recently, there have been several reasons for research on Diptera from archaeological contexts to have been neglected. The Diptera are a larger group than the Coleoptera, with up to >6200 species, as opposed to <4000 species of Coleoptera, in the UK alone, and a significant number have yet to be described in the larval and pupal stages. They also often have higher dispersal capabilities, and the adults are less sclerotised and therefore do not preserve as well as the beetles. With the exception of species of medical importance, their taxonomy, biology and ecology are less well known. However in his seminal study, Skidmore [62] pointed out that in archaeoentomological research, the dipterous synanthropic faunas tend to belong to a restricted range of species, as a result of a combination of different parameters, such as geographical location, specialised habits and competition between species. The research on most fossil Diptera is based on the study of puparia, the heavily sclerotised final larval stage inside which the pupa is formed before metamorphosis, and these tend to occur close to, or within the habitat in which the maggot fed. The real problem encountered during archaeoentomological research is a lack of background research on the larval environments of certain dipterous families, and the availability of suitable expertise; some of the habitats, which are prolific in fly remains, such as cess pits, are not popular in experimental archaeology (but see [50]).

The order Diptera can be roughly separated into two groups: Nematocera and Brachycera form the first one, and Cyclorrhapha the second [41]. The pupae of Nematocera/Brachycera are generally obtect, that is their appendages, head, wings, legs, lie in small sacs attached to the surface of the body and these often carry characteristic impressions of wing venation on their surface (Fig. 1). Aquatic groups, such as Chironomidae, Culicidae, Chaoboridae and Simulidae, as well as

![Fig. 1. Pupa of a typical Nematoceran fly (Culicidae) (from [62]).](image1)

![Fig. 2. Puparium of a typical Cyclorrhapous fly (Muscidae) in dorsal (upper) and ventral (lower) view (from [60]).](image2)

Bibionidae, Cecidomyiidae, and Tipulidae, are part of Nematocera. The Cyclorrhapha pupae are exarate, their appendages are free, but the pupa is not very visible because it is covered by the puparium (Fig. 2), the last larval skin ([65], p. 29), which preserves characters that enable identification. From the archaeological viewpoint Cyclorrhaphous puparia have the advantage that they are very heavily sclerotised and are often found as subfossils in both anaerobic and desiccated archaeological deposits, where they may constitute the majority of the insect material. However in natural sites they are less numerous, compared with Nematocera and Brachycera. Chironomids for example are found in large numbers in aquatic environments and have been widely used in reconstructing changes in the environment, both in terms of trophic status (e.g. [67]) and climate [10]. The abundance of Cyclorrhapha from archaeological assemblages and the type of information they provide, makes them a vital source in archaeological interpretation, and they may be preserved in a wide range of conditions, from wholly desiccated to waterlogged, as well as by mineral replacement (e.g. [35b]).

3. Flies and the literary record

Upon death, the decomposition of the body begins and a succession of flies, a process spotted by the experts on preserving the dead for eternity, the Egyptians. They were aware of different ‘varieties’ of flies ([42], p. 194; Rameside papyrus), and used spells to prevent maggots processing mummies (Gizeh papyrus No 18906:4:14). There are also
spells and recipes to prevent flies from biting and infesting houses (Ebers 97). Among the Egyptian hieroglyphs, there is one for the fly, and a depiction of what looks vaguely like a house fly, Musca domestica, was a very frequent amulet in Egypt during the pharaonic period. The same depiction of a house fly was also used for pendants for military decoration of high ranking soldiers, for their bravery in battle. It is thought that the persistence of the flies was compared with the morale of the good soldier in battle [22]. Fly whisks were a common accessory in pharaonic Egypt, and Tutankhamun had two for his after death journey. Anyone who has travelled extensively in Egypt will be aware of this utility, and Skidmore has suggested that the house fly probably originated in Egypt (Skidmore pers. comm.); their puparia are common fossils in Egypt.

What seems to be one of the first mentions of myiasis in the literary record is reported in Ebers papyrus (78, 8), a collection of medical recipes dated to 1500 BC, but probably going back to 3000 BC. In the text there is a description of a finger/toe that was infected, swollen, and smelled badly, and eventually produced small worms, presumably maggots. There are several other mentions of flies, fly dirt and fly blood in the same papyrus. These were used as ingredients for treatments mainly against swellings and in one occasion against trichiasis, a condition related to trachoma. It is apparent that pharaonic Egyptians knew the connection between flies and infection, and the frequency of recipes for eye infections in later papyri indicates the widespread nature of problems probably borne largely by flies. There are, however, earlier references to flies in Mesopotamia from ca. 3000 BC, and together with the first urban centres developed the first synanthropic association with flies. On cylinder seals from the Uruk period, there is a quite accurate representation of a fly [37], and the same author notes that 11 different “species” of fly can be recognised in an Akkadian text of ca. 1600 BC. There are frequent mentions of flies in the Greek literature [6,30], and they had also distinguished different species of fly. They made observations about their morphology and life cycles, not always correctly. In Classical texts there is mention of fly whisks used by the Persians (Menander fr 437) and the Indians (Aelian NA 5.17), and there are even deities that drive them off (Zeus the averter of flies Ζεύς Απόμυτος, and Apollo, a god connected with flies and disease), or catch them eating ones, εὔλιθι (e.g. Iliad XIX.25-6,31). One of the most fearsome deaths described by the Classical writers is being eaten alive by the vermin (Herodotus IV.209, [6], 223) There are also lots of recipes on how to avoid fly infestation in a house, on stored meat, on an injured animal or even one’s self (Pliny XX.184, XXIV.53, XXV.61, Geoponica XIII.12, Cato DeAg 162.3 in [6]). Classical writers also had knowledge about flies infecting wounds and about fly borne infections. In many cases, trachoma is treated with concoctions that include flies or fly blood or fly ashes, probably as homeopathic medicine (Pliny XXVIII29, XXIX.115, XXX134 in [6]). An early connection of outbreak of disease and flies was made by Strabo who mentions that the reason for the disease amongst the Romans was often the flies, and they were paying men to them! [37].

Medieval naturalists such as the Goodman of Paris in the 14th century and John Gerard in the 16th, largely copied the Classical writers, especially Pliny and Palladius often mediated through Arab sources, and they recycled their recipes against mosquitos, gnat and flies [35,56]. As the reviews of later literature on insects and disease show [21,23], the extensive range of literature on flies reminds us that the fly-free contemporary house has nothing to do with life in the past, a point well indicated by the archaeological record of Diptera.

4. The use of flies in archaeology

The first scientific observations on archaeological flies were made by people unwrapping mummies. During the unwrapping of the Leeds mummy, the entomologist F. W. Hope observed at least two different species of numerous fly puparia, and remarked that mummification must have been a lengthy task ([53], p. 54). The Egyptologist Pasalacqua was under the false impression that the Diptera he found in a box from Thebes had been embalmed ([53], p. 182). More recent research in Egypt has revealed the first records of M. domestica L., Chrysomyia albiceps (Weide.) and Piophila casei (L.) [28,29,52a]. Until recently, there was only a limited amount of work on flies, and this has been reviewed by Buckland and Coope [13] and by Elias [32] in connection with other Quaternary insect research. Despite his propensity for describing extinct species from Pleistocene fossil material [47a], Pierce [55a] had noted a case of myiasis in animal bones from the Rancho La Brea tar pits in downtown Los Angeles, California, and Gautier [34a,34b] has recorded the blowfly Protoforma terrae-novae (Rob.) in both bison and woolly rhinoceros remains from Late Pleistocene sediments in Belgium. Grunin [37a] recorded one of the few cases of extinction in the Quaternary insect record, describing the now extinct mammoth botfly, Cobboldia rusanovi from a frozen Siberian mammoth. In the archaeological context, some work has been done with material from burials, including material from a Viking burial on the Isle of Man [41a] and an Anglo-Saxon burial at Sewerby in East Yorkshire [35b]. Fly remains from Canadian prehistoric burials at Augustin in New Brunswick, enabled the excavators to reconstruct the burial practice [65a]. The
presence of the heliophilous phorids *Phormia regina* and *Protophormia* allowed them to argue that the bodies had been exposed for a considerable time before burial, whilst *Musca domestica* and the Helomyzinae had processed the bodies after the burial. Gilbert and Bass [35a] discussed the possibility of defining the season of burial based on fly faunas in the context of aboriginal graves in North America.

Other studies have examined more directly the living conditions based on fly faunas from sites. Belshaw [8] and Skidmore [62] both noted the presence of the now coastal seaweed fly *Thoracochaeta zosterae* in inland medieval deposits apparently associated with cess. It seemed unlikely that seaweed was being shipped inland in very large quantities, and the problem was only solved when Webb et al. [68] showed that inland specimens of *T. zosterae* had an entirely terrestrial carbon and nitrogen isotope signal; their disappearance from modern cess situations reflects increased levels of hygiene. In the Neolithic, of Switzerland, at Thayngen-Weier [38,47b,65b], and at Alvastra in Sweden (Skidmore in [36]), it has been possible to use the fly faunas to support the hypothesis of leaf and hay fodder storage for domestic animals. Both sites have produced large numbers of the house fly, *M. domestica*, and samples from the former site also include the stable fly, *Stomoxys calcitrans* [38]; both species had previously been recorded by Skidmore from Anglo-Scandinavian York [11]. In contrast, the absence of a fly fauna associated with fodder could be used to argue that the medieval site at Langenes in northern Norway was a dedicated fishing station, rather than a farm from which fishing took place [15a]. Recently, work on faunas from Norse farms in the Faroes, Iceland and Greenland has provided more detailed spatial and temporal evidence based upon fossil fly faunas.

Whilst Belshaw [7,8] and Phipps [54,55] also recognised the value of the study of fly puparia from archaeological contexts, the research was effectively developed by Peter Skidmore (cf. in [12,61a,66a]). Interpretation relies upon the fact that whilst the imagines are vagile and liable to turn up far from their primary breeding context, the maggots are attached to quite specific contexts and give immediate information about living conditions, although they may move short distances, often vertically, to pupate. The larvae can be extremely sensitive to humidity, light and temperature changes, to the extent that under adverse conditions they may enter diapause and regeneration may be delayed. In optimal environments, however, their breeding cycles tend to be shorter, their sizes larger, and they reproduce in great numbers sometimes reaching plague proportions (Fig. 3).

For purposes of interpretation, Diptera can be roughly grouped into six different categories, according to their feeding habits: stercoricoles (dung feeders), endophilous necrophages (in corpses), exophilic necrophages (on corpses), phytophages (plant feeders), algae-coles (feeding on algae), fucicoles (seaweed feeders), hydrophiles (living in water), humicoles/muscicoles (feeding on fungi and slime moulds) [62], and all of these may occur in either autochthonous or allochthonous situations in archaeology.

5. Processing and identification

The method used for retrieving the dipterous material from waterlogged remains, paraffin (kerosene) flotation is the same as that for the Coleoptera described originally by Coope and Osborne [25] (see also [13,32,44]). For desiccated material, the appropriate method is gentle dry sieving over a 300 μm sieve [52b]; from experience, wetting and drying of the material by flotation, as used for plant macrofossils, tends to be destructive of insect remains. A range of characters is used in the identification of fly puparial remains: prospiracular processes, the posterior spiracles, the arrangement of perispiracular papillae on end-segments, the anal plate and the adjoining papillae, cuticular features, larval mouthparts, and pupal respiratory horns. Size and shape of the puparia are also important. Some families, such as the Fanniidae and Phoridae, are very distinct and therefore easier to identify. The impressions of wing venation on the pupa of Nematocera can also allow identification to the species level. Whilst keys are available for some groups (e.g. [33,65]), comparison with securely identified reference material is often essential [62], and availability of this further restricts work on the group.

6. Flies and archaeological sampling

In an effort to reconstruct human activities from archaeological sites, the flies from the context under study are treated in the same way as in forensics. The questions posed in archaeological research are similar to those at a crime scene, and it is not surprising that they

![Fig. 3. A complete puparium of *Heleomyza borealis* (Diptera, Helomyzidae) with the unemerged adult fly inside, from the Norse farm at GUS in the Western Settlement, Greenland.](image-url)
are better answered on sites with a short period of occupation, or where, because of catastrophe events, for example, volcanic eruptions or sudden site abandonment, a certain moment of the life of the settlement is captured archaeologically. As forensic entomologists try to fill the gaps in the story by retrieving the faunas from over, inside and around dead bodies, archaeoentomologists should get the chance to do the same work in human settlements. Different species of flies in different parts of the settlement, the house or the room itself, indicate diverse media available for the flies to breed in, temperature and humidity variation, light or shade. However in archaeological research, there are a number of taphonomic biases that need to be addressed.

A good way of obtaining intimate information on people’s lives is by looking in their garbage, and this also applies to archaeological research. Middens show details about everyday life, eating habits, domestic animals, hygiene levels, food pests, etc. Several species of fly deposit their eggs on garbage, and the maggots feed on the various materials in the midden, different species on different material; their puparia are therefore excellent in reconstructing the nature of decayed matter, even where the latter has rotted away completely. A midden however may be an accumulation of debris from different parts and different phases of a house or a complex of houses, and not everything is likely to have been thrown onto the midden. The midden itself may be turned over by animals, invertebrate as well as vertebrate, utilised by people as a rich seedbed for garden agriculture, or removed for other purposes such as fertilising fields or to provide turves for building. So, although the garbage heaps are excellent indicators of what happened in the past, the record is often heterogenous, and only a part of the story may be found in them; only general information about past times is obtained, and the advantages of relating the fly faunas to different parts and phases of the occupation, particularly of individual rooms of house, barn and byre are largely lost.

In order to use fully the dipterous material and the ectoparasites, and even context specific beetles like the pests of stored products, sampling inside the houses of floors, collapsed walls and roofs, etc., which follows the matrix of the excavation, is absolutely necessary. This usually requires the specialist to be on site for much of the excavation, a situation rarely met. Even then, there is the problem of cross-contamination while taking the samples. Penecontemporaneous bioturbation can often be indexed by cross-comparison with the artifactual and stratigraphic record, but it is frequently impossible to sample exclusively fine contexts and some time averaging of materials is usually inevitable, a problem when the objective may be to look at factors leading up to the desertion of a site or a change of use of a structure. In addition, the maggots of certain families, such as Sarcophagidae for example, move slightly while pupating, sometimes into a vertical position in the underlying deposits, contaminating the immediately preceding phase. Some of the problems, and advantages of study of Diptera from archaeological contexts are well illustrated by recent work in the Norse Western Settlement in South-West Greenland, where occupation of farms appears to come to an abrupt end ca. AD 1360 after about 350 years of settlement [5,12].

7. Greenland

Like farms elsewhere in the North Atlantic region, the medieval farms of Greenland were squalid, dark places. Windowless, they were built from turves, often on a stone foundation, and roofed with driftwood, overlain by turves. Twigs, moss, hay and other materials covered the floors, providing an insulation layer over the permafrost [14,15,18], and an agreeable environment in the house during the long, cold, dark winters. Domestic stock was stalled overwinter in the farm complex, providing additional warmth for the people, and food for both was also brought in and stored in the farms. As time passed by, foul material accumulated on the floors and when it was too much of an obstacle for everyday life, some of it was disposed outside onto the midden. Whilst in Iceland occupation on many farms has been continuous to the present day, often resulting in the build up of a considerable farm mound [14], the story from Greenland is completely different. The settlers arrived at the Eastern Settlement at the end of the 10th century, and expanded rapidly to the Western Settlement, in the fjords, east of the modern capital at Nuuk [43]. The settlements prospered for several hundred years. However, first the Western Settlement during the 14th century and then, one hundred years later, the Eastern Settlement were abandoned. There is no information to explain what triggered farm abandonment in Greenland, and alternative theories are legion (most recently, see [5,59]). Similarly nothing is known about how the abandonment took place; was it an evacuation, or a gradual process, and what happened to the people involved? The limitations of radiocarbon dates from the farms fail to clarify whether the process was one of gradual attrition (cf. [46]) or precipitate departure from all the farms. The extinction of the Greenlanders is a classic forensic mystery and calls for forensic archaeological techniques.

The farmhouses and their middens were ideal places for the flies to live and breed in. In the harsh Greenlandic environment, the native fly fauna is restricted [63]. However both flies and beetles were introduced accidentally with the Viking settlers in the dungage of their ships [57], and they managed to get established in the artificially warmed environment of the farmhouses, rapidly spreading, perhaps in the transport of fodder on
the backs of ponies, to the most remote of inland farms. In Greenland, these new species disappeared together with their Norse hosts. Fly diversity is a mirror of the activities related to a farm, and therefore comparison of the fly faunas from different farms provides information about site status and activities. A drop in synanthropic flies and an increase in species that reflect the natural environment signify abandonment and lower internal temperatures in the buildings. The same applies to animal and human ectoparasites. In terms of behaviour, ectoparasites are very similar to maggots as opposed to the flies themselves. They are attached to their hosts in the same way that the fly larvae are attached to their contexts. Both are extremely sensitive and therefore restricted by temperature and humidity changes, even more so in the Viking farmhouses, which provide islands of warmth in a cold landscape. Like many of the flies, not only are they confined inside the houses or on their hosts, but also they are restricted in their specific niches. Complete absence of ectoparasites in living quarters or byres, when not connected to a preservation bias, usually means no people or animals in the farms. On the other hand, large concentrations of ectoparasites, and particularly the ked, *Melophagus ovinus* L., a wingless fly ectoparasitic on sheep, could be an indication of activities such as delousing (cf. [18]) or wool processing [16]. Presence or absence of synanthropic flies and ectoparasites reflects presence or absence of humans.

8. Unanswered questions

Væbek [66] interpreted the human bones in the passage of farm Ø 167, in the Eastern Settlement, as those of the last inhabitant of the area. He thought that the man died in the passage, and as there was no one to bury him, the body had been left there. As Lynnerup et al. [45] point out, the radiocarbon date of the skeletal material is very early, centering on AD 1275, and even allowing for a significant marine component in the diet [3], this seems unlikely to reflect the last Norseman, tempting though the story is. It is not unusual to find scattered fragments of earlier burials on archaeological sites, and the bones probably represent secondary deposition, as opposed to an actual death in situ. Væbek’s excavation took place too early for a forensic approach, but an easy way to gain a secure verdict on the matter would have been to have studied the dipterous remains in the soil around the human bones. A dead person in the house is quite a discovery for the archaeologist, but more importantly it was a great meal ticket for the contemporary necrophagous flies of the house. A buried body will have a different fly fauna from an exposed one (cf. [34,64]), and disarticulated, redeposited bones as opposed to a corpse will have no fauna, unless there was meat or sinew attached. However no soil samples for analysis are available, and therefore no answer can be given concerning the taphonomy of the human remains. We await the next last Norse farmer.

9. Living on the edge

The fly faunas studied from Greenland have mostly been from middens. Skidmore [62]; in Barlow et al. [5] noted no marrow eating species in the middens at the small farm at Niaqussat (V48) or in the large church farm at Kilaersavik (Sandnes V51). In contrast, there were large numbers of meat and marrow eating species, Calliphorids and Piophilids, from a palaeoeskimo middensite at Qeqertasussuk [62]. McGovern, utilising Skidmore’s comments [5] after looking at the fragmented bones from the Greenlandic middens, came to the conclusion that all the marrow had been removed from the bones, and argued for an economy that was living on the edge, exploiting all the farm resources available, and Outram [51,52] has developed the model further. In contrast, the semisedentary Palaeoeskimo pursued a boom and bust economy, and would kill and eat as many animals as possible on the spot. Constant movement was definitive of their way of living, leaving surplus carcase and food debris for vertebrate and invertebrate scavengers and processors. Their mobility in the face of changing often equally mobile resources is perhaps also a major part of the reason why their Thule Inuit successors outlived the Norse Greenlanders. The farmers, on the other hand, were relying on a restricted territory, the land around their farms, in part supplemented by marine and caribou resources. They did not have the flexibility to move around in order to exploit seasonal resources, but were able to use more effectively all their venues of food, marrow being one of them. In classic biological terms, the contrast could be seen as between cultural *r* and *k* selectors (cf. [24], p. 484). In both cases, their subsistence strategies are more a reflection of extreme specialisation, as opposed to impoverishment, and the characteristic fly faunas of the Norse farms, poor in calliphorids and piophilids, occur from the bottom to the top of the middens, and do not merely reflect adaptation to extreme stress close to abandonment. Fly faunas from the middens of sedentary and nomadic groups are likely to be dissimilar, even if the range of introduced species with the former in Greenland is set aside, but more comparative material from late Thule sites, where European influence leads to a progressively more sedentary lifestyle is essential.

10. The evidence from GUS

Gården under Sandet (GUS) is the site of a Norse farm situated in the Western Settlement, Greenland. Like the other farms in the regions, including Kilaersavik
The body, about 3 months after death in the north of England. In summary, the fly faunas and the ectoparasites present demonstrate the unique preservation on site is a dead goat found inside the farm, buried under...
the collapsed roof of Room 22. The goat was found intact, even to its stomach contents. It was recovered from the fourth phase of the farm, and belongs to a phase quite some time before the final abandonment. Mummified animals, that keep their shape even after the flesh is gone, are frequently found in the Arctic [47,64], but the case of this naturally mummified animal is particularly interesting from the fly’s point of view. The fly fauna recovered from on top of the goat comprised 14 D. fabricii, 12 Scatophila stagnalis, and one member of the family Heleomyzinae. The fly fauna which processes dead bodies in the subarctic parts of the world is not as diverse as in the temperate regions [63], and the fact that the goat died inside a dark room made it impossible for the exophilic fauna that processes corpses to reach it. However no endophilic necrophagous species, apart from the single specimen of Heleomyzinae, managed to feed on it either. The collapsed roof, that perhaps trapped the goat sealed it and preserved it for the archaeologists, but would not be a substantial obstacle for the flies that feed on dead bodies. These flies smell their meal and find it even when it is buried. The fauna expected to have processed the goat in the dark room, would be the trogloidyic heleomyzids, especially H. borealis, and the thermophilous T. flavipes, already existing in the floors of GUS in large numbers. Apparently, during the different decay stages including caseic fermentation, it was too cold even for the cold resistant H. borealis to process the body. When the temperatures went up again the body of the goat had completely dried out and was no longer attractive for the flies. As a result, the animal, even its stomach with the full contents, was preserved. The high numbers of phytophages and algaecoles in the goat sample could be connected to the roof turves. Perhaps some of the liquids from the dead body were incorporated in the surface over it, providing fertiliser, and vegetation grew lush when the weather changed. Rich vegetation around and over dead bodies is very frequent in Arctic and subarctic conditions [40,48]. The room was later rebuilt over the goat and continued to be in use until the final abandonment of the farm. The end of the farm shows little difference in the fly faunas and an orderly desertion seems probable; we are no closer to knowing where the last farmers went, but at least at GUS they did not die in situ.

11. Conclusions

As the Greenland case study shows, fly remains from archaeological environments present a unique opportunity to reconstruct the past in close detail. Fly puparia are strongly attached to their contexts and are highly sensitive to changes. They can be used to reveal details of everyday life, or give clues about death. Occupation and abandonment phases, parameters of death and ways of subsistence can be recognised and interpreted based on the fly puparia. Compilation of data on fly remains and ectoparasites provide extremely refined information about life, death and abandonment, as these two groups when in synanthropic environments provide us with strong signatures for human activities.

There is still much to be learnt from the dipterous remains from archaeological sites. Application of the technique widely will provide valuable information on the biogeography of Diptera, trade, palaeoeconomy, the history of disease, and perhaps forensic answers to unsolved mysteries.

Acknowledgements

This paper is based upon research carried out during tenure of a Leverhulme post-doctoral fellowship at the University of Sheffield. The author is particularly grateful for the training and continued advice provided by Pete Skidmore as well as discussions and comments by Paul Buckland. Work on the Greenland material was facilitated by Jette Arneborg of the National Museum of Denmark and Gudmundur Olafsson of the National Museum of Iceland.

References

[48] P. Nuorteva, A three year study of the duration of development of Cynomyia mortuorum (L.) (Dipt., Calliphoridae) in the conditions of a subarctic fell, Annales Entomologici Fennici 38 (1972) 65—74.
[67] W.F. Warwick, The impact of man on the Bay of Quinte, Lake Ontario, as shown by the subfossil Chironomidae succession, (Chironomidae, Diptera), Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie 19 (1975) 3134—3141.