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The scope of forensic entomology

Forensic entomology is a branch of forensic science. Forensic entomologists use information about insect lifecycles and behaviour to help interpret evidence in a legal context relating to both humans and wildlife. On occasion, the term ‘forensic entomology’ is expanded to include other arthropods, mites, spiders, or macro-invertebrates such as freshwater shrimps. The legal contexts in which forensic entomology is of use relate to matters considered in either civil courts or criminal courts. The cases that are heard in civil courts most frequently relate to insect infestation in urban contexts or in relation to stored product pests. Where there is insect infestation of a body, either living or dead, and foul play is thought to have occurred, or a law has been broken, then the case is generally termed a medico-legal case. Such cases can relate to both humans and wildlife.

1.1 Forensic entomology in urban contexts

Cases of infestation of homes or other buildings, such as hospitals, are instances in which forensic entomologists may have a role to play. For example, where structural timber is found to harbour insects such as longhorn beetles (Cerambycidae) an entomologist might be called to assist in determining the cause and source of infestation. Such insects are generally pests of sapwood, but can complete their lifecycle in dry wood that has been harvested. An example of such a beetle is *Eburia quadrigeminata* (Say), the ivory marked beetle, a longhorn beetle, which usually attacks living American oak trees but has been known to survive felling, wood treatment and transformation of the wood into furniture, only to emerge some 10 to 15 years later. In 2007, Cocquempot recorded an instance of this species having been caught when emerging from a bamboo stand in France.

Other examples of the urban application of forensic entomology relate to infestation of food premises and food production sites. For example, the owners of a butcher’s shop in London, was closed in January 2010. The Magistrates’ Court

awarded costs of £560 to the council after meat on sale at the butchers had been found to be infested with maggots and fly eggs.

Poultry production units may similarly be convicted of causing fly infestations that affects residents living nearby. Such was the case in a small Lincolnshire village where, in 2009, the farm owners were fined £20 000 by Skegness Magistrates court, having pleaded guilty to breaching an abatement order, intended to reduce the numbers of flies, which had been put in place in 2008 for a similar misdemeanour.

1.2 Stored product infestation and forensic entomology

In general, only a small number of stored product pest species may be encountered by the forensic entomologist. They include flies, cockroaches, ants, and beetles. The insects that inhabit animal products and their waste include members of families such as larder beetles (Dermestidae), Moth flies (Psychodidae), Scuttle flies (Phoridae), Muscid flies (Muscidae) Blowflies (Calliphoridae) and Flesh flies (Sarcophagidae) such as *Sarcophaga carnaria* Linnaeus, ants (Formicidae) such as the Pharaoh ant (*Monomorium pharaonis* Linnaeus), or the Copra beetle (*Necrobia rufipes* DeGeer). These may also be cited in medico-legal cases (Figures 1.1 and 1.2).

The following are examples of phytophagous insects, which may infest food, resulting in forensic entomologists contributing to court cases.

Biscuit beetles (*Stegobium paniceum* Linnaeus) will infest not only food items such as flour bread and biscuits but also wool, hair and leather material. The saw-toothed grain beetle (*Oryzaephilus surinamensis* Linnaeus) and the Indian meal

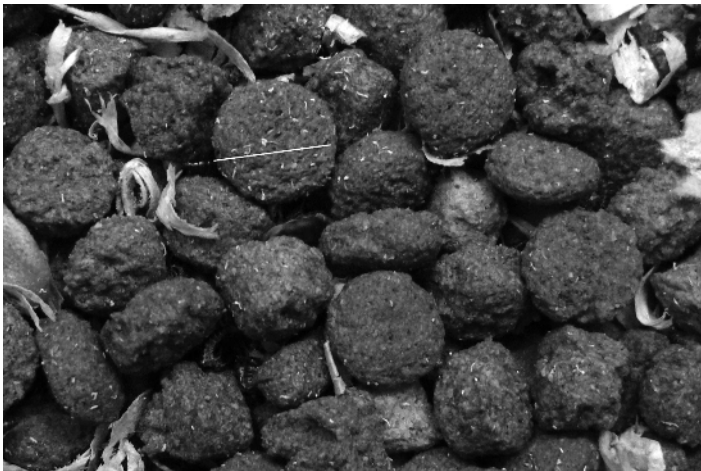


Figure 1.1 Stored product pests

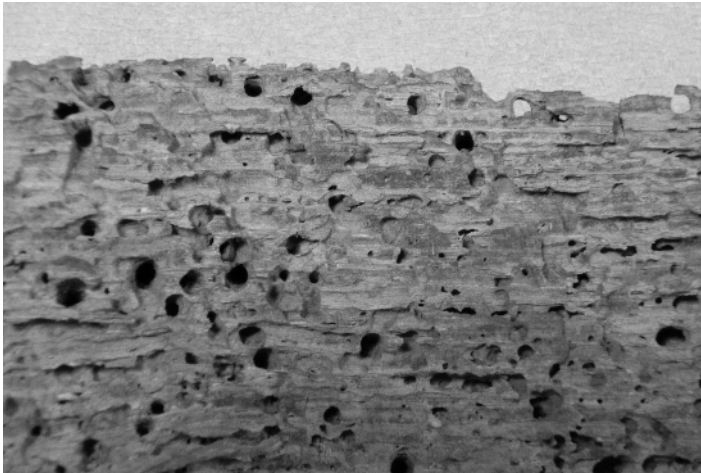


Figure 1.2 Insect structural damage to wood

moth (*Plodia interpunctella* Hubner) both infest dried fruit, breakfast cereals and pasta. The Indian meal moth is also known to consume dried dog food and fish food products. The rust-red flour beetle (*Tribolium castaneum* Herbst) and the confused flour beetle (*Tribolium confusum* Jacquelin du Val), infest grain and flour. The fruit fly (*Drosophila melanogaster* Meigen) will infest any fermenting fruit or vegetable, including tomatoes, onions, and bananas. It can also inhabit compost heaps and piles of rotting garden waste and so could be the subject of urban forensic entomology cases.

Because food-processing plants have difficulty in reducing insect infestation levels to zero, a legal tolerance level is specified in many countries, contravention of which can lead to prosecution. For example, the American Food and Drug Administration considers that, in canned citrus juice, a maximum of five or more eggs of *Drosophila* or other insects per 250 ml is allowable. The presence of one maggot per 250 ml of canned citrus juice is also considered acceptable (AOAC 970.72).

In the majority of instances in stored product and urban forensic entomology, the main focus of the contribution is confirmation of the identity of the insect species and interpreting its biology in the particular context in question. In such instances this aspect of forensic entomology is confirmatory and relates to the work of the Environmental Health Department or the Office of Trading Standards.

1.3 Forensic entomology in the medico-legal context

Insects have a role in crime scene investigations on both land and in water (Anderson, 1995; Erzinçlioğlu, 2000; Keiper and Casamatta, 2001; Hobischak and Anderson,



Figure 1.3 Body in wrappings

2002; Oliveira-Costa and de Mello-Patiu, 2004; Moretti, Bonato and Godoy, 2011). The majority of medico-legal cases where entomological evidence is used are the result of illegal activities that take place on land and are discovered within a short time of being committed. In France for example, 70% of cadavers are found outdoors and, of these, 60% are discovered within less than one month (Gaudry *et al.*, 2004).

All insects could be of potential relevance to a medico-legal question, however a number of species from several families are found more often than others. The insects of particular relevance to forensic entomological investigations include blow flies, flesh flies, cheese skippers, hide and skin beetles, rove beetles and clown beetles. In some of these families only the juvenile stages are carrion feeders and consume dead bodies. In others both the juvenile stages and the adults will feed on the body (are necrophages). Yet other families of insects are attracted to the body solely because



Figure 1.4 Necrophagous insects colonising a body

they feed on the necrophagous insects that are present. Forensically relevant insects can be grouped into four categories based on feeding relationship. These are:

- Necrophages, which feed only on the decomposing tissue of the body or body parts – for example blowflies, hide beetles and clown beetles (Figures 1.4 and 1.5).
- Predators (and parasites) of the necrophages – for example rove beetles and ground beetles.



Figure 1.5 Predatory beetles will consume eggs and larvae of those flies colonising the body



Figure 1.6 Omnivores such as wasps will consume both the body and any insects present

- Omnivores that consume both the live insects inhabiting the corpse and the dead flesh – for example ants (Formicidae), and wasps (Figure 1.6).
- Opportunist (adventive) species, which arrive because the corpse is a part of their local environment – for example mites, hoverflies, butterflies and, on occasion, spiders (Figures 1.7 and 1.8).

On occasion waste material or faecal material may be the attraction (Figure 1.8). The roles of specific species which have these feeding strategies will be considered in later chapters.

1.4 The history of forensic entomology

Insects are known to have been used in the detection of crimes over a long period of time and a number of researchers have written about the history of forensic entomology (Benecke, 2001; Greenberg and Kunich, 2002). The Chinese used the presence of flies and other insects as part of their crime-scene investigative armoury and instances of their use are recorded as early as the mid-tenth century (Cheng, 1890, cited in Greenberg and Kunich, 2002).

Such was the importance of insects in crime-scene investigation that in 1235, a training manual on investigating death, *Washing Away of Wrongs*, was written by Sung Tz'u. In this early medico-legal book it is recorded that attention paid by a number of blowflies to a particular sickle caused a murderer to confess to murdering a fellow Chinese farm worker with that sickle.



Figure 1.7 Opportunist insects – a spider. *Source:* Reproduced by permission of Mr. Ian Ward

Between the thirteenth and nineteenth centuries a number of developments in biology laid the foundation for forensic entomology to become a branch of scientific study. The two most notable were, perhaps, experiments by Redi (1668), an Italian who, using the flesh of a number of different animal species, demonstrated that larvae developed from eggs laid by flies, and the work by Linnaeus (1735) developing a system of classification. In so doing, Linnaeus provided a means of insect identification (including identifying such forensically important flies as *Calliphora vomitoria* Linnaeus). These developments formed foundations from which determination of the length of the stages in the insect's lifecycle could be worked out and the indicators of time since death could be developed.

A particularly significant legal case, which helped establish forensic entomology as a recognised tool for investigating crime scenes, was that of a murdered newborn baby. In 1850 a baby's mummified body, encased in a chimney, was revealed behind a mantelpiece in a boarding house when, during renovation work, Dr Marcel Bergeret carried out an autopsy on the body and discovered larvae of a flesh fly, *Sarcophaga carnaria* and some moths. He concluded that the baby's body had been sealed into the



Figure 1.8 An opportunist butterfly attracted to faecal material. *Source:* Reproduced by permission of Mr. Ian Ward

chimney in 1848 and that the moths had gained access in 1849. As a result of this estimation of the time since death, occupiers of the house previous to 1848 were accused and the current occupiers exonerated (Bergeret, 1855).

The next significant point in the history of forensic entomology resulted from observations and conclusions made by Mégnin (1894). He related eight stages of human decomposition to the succession of insects colonising the body after death. He published his findings in *La faune des cadavres: Application de l'entomologie à la médecine légale*. These stages of decomposition were subsequently shown to vary in speed and to depend upon environmental conditions, including temperature and, for example, size of the corpse and whether or not the corpse was clothed. The similarity in overall decomposition sequence and the role of insect assemblages in decomposition has been demonstrated for a number of animal species.

Knowledge about insect succession and the periods of insect activity on a corpse has become the basis for forensic entomologists' estimations of time since death, although this is acknowledged as being based on assumptions of time of colonisation relative to the point of death. Research continues to be required in order to establish the accuracy levels of estimates of time since death and to interpret variation in different biotopes (Tomberlin *et al.*, 2011).

In the twentieth century, insects were shown to be of value in court cases involving insect colonisation of body parts recovered from water and not just for entire corpses found on land. On 29 September 1935 several body parts, later identified as

originating from two females, were recovered from a river near Moffatt in Scotland. The identities of the deceased were Isabella Kerr, the wife of a Dr Ruxton, and Mary Rogerson, the family's 'nanny'. The presence of third instar larvae of the blowfly *Calliphora vicina* Robineau-Desvoidy indicated that the eggs had been laid prior to the bodies being dumped in the river. This information, combined with other evidence, resulted in the conviction of Dr Buck Ruxton, for the murder of his wife and Mary Rogerson.

The level of acceptance of forensic entomology by the courts has depended upon the results of scientific study. This has been carried out since the early twentieth century, both by academics and practitioners working alongside the police and legal authorities. As a result the subject base has been refined and protocols and rigorous forensic procedures have been developed to raise its level of esteem. However, there remain several areas for which accurate information and levels of error remain undetermined. These aspects of uncertainty with respect to forensic entomology will be addressed with focused research. The requirement for this to happen quickly is dictated both by the professional aspirations of the forensic entomology community and also as a result of reviews and legislation.

In the USA the report concerning the whole of forensic science produced by the National Research Council, was significant. The council recommended that an independent federal organisation – the National Institute for Forensic Science, be set up in order to establish mandatory standards for laboratories, the promotion of scholarly, peer-reviewed research and the establishment and reinforcement of methods of best practice and the use of standardised protocols. A similar approach was taken in the United Kingdom and in 2007 the Office of the Forensic Science Regulator was set up to help establish and maintain standards in forensic science in general. These national organisations influence the work and aspirations of the professional associations who respond to guidance that they provide.

Forensic entomologists in a number of countries have set up professional organisations to provide a forum for the exchange of ideas and experience and to develop and maintain professional standards in forensic entomology. These organisations include the North American Forensic Entomology Association and the European Association for Forensic Entomology (EAFE).

1.5 Professional associations for forensic entomologists

The nature and aspirations of two major professional associations for forensic entomologists are described below.

1.5.1 North American Forensic Entomology Association (NAFEA)

This organisation is a charitable, non-profit-making educational organisation for the promotion of good practice and research in forensic entomology. It

had its first annual meeting in 2003 and seeks to collaborate with other international societies to enhance the moral, ethical and scientific base of forensic entomology. It currently has over 60 members. The strength of the organisation is its inclusivity. To quote its web site (www.nafea.net/, accessed 26 October 2011):

NAFEA is an organization for anyone interested in the application of forensic entomology to civil or criminal matters of law, research on arthropods of forensic importance, or carrion ecology.

From a student perspective it is also a valuable source of support, and conference funding may be available to student members. The organisation seeks to promote good practice and the presentation of scientific research, casework, and cooperative ideas on forensic entomology. As such, it is a forum through which research in forensic entomology can receive peer-review and new developments in approach can be discussed.

1.5.2 European Association for Forensic Entomology (EAFE)

The European Association for Forensic Entomology (EAFE) was founded in 2002. The Association was launched in France and has a number of aims:

- To seek a common protocol for forensic entomology case investigation.
- To foster high standards of competency in specimen collection and analysis.
- To create a solid scientific basis so that forensic entomology can be a valid analytical tool.

In 2006, EAFE produced a protocol of good practice in order to ensure that the methods used in forensic entomology investigations at a crime scene could be standardised and good forensic entomological practice could be developed by following standard operating procedures. Its annual meetings also provide an opportunity for dialogue, discussion and collaboration.

1.6 The UK regulator for forensic science

The regulation and maintenance of standards for forensic expert witnesses is currently voluntary and based on the membership of such organisations as the Academy of Experts or the Institute of Expert Witnesses. In the UK in 2007, the Office of the Forensic Science Regulator was set up by the Home Secretary to operate on behalf of the criminal justice system.

The purpose of the Office of the Regulator is primarily to i) determine new and improved quality standards for organisations and if necessary to take the lead in their development; ii) advise and guide organisations undertaking forensic analysis to ensure that they can show compliance with the generally accepted standards that may be required by the courts; iii) ensure sure that that there are appropriate arrangements for quality assurance and standards monitoring; iv) ensure that there are procedures in place for the determination competence of the individual forensic scientist.

The Regulator is supported in this role by a Forensic Science Advisory Council (FSAC). Amongst other things this committee is responsible for offering advice on accreditation and procedures for validating and approving new technologies. They also have the responsibility 'for tasking and overseeing the work of Expert Working Groups established to advise on or develop quality standards ...'

Currently, forensic organisations are required to be accredited through the United Kingdom Accreditation Service (UKAS) in order to conduct their work and to observe ISO9000 guidelines. These organisations are required to quality control their work and a number of options including participation in blind trials have been proposed.

The accreditation of individuals is under discussion because it is the individual and not the organisation that appears as a witness and is responsible to the court. At present forensic entomologists are not included on the list of expertise that is being considered. Those forensic disciplines that are on the list include more laboratory-based experts such as toxicologists, fingerprint officers, and document examiners. Membership of professional organisations, for the forensic entomologist, therefore remains an important means of standardising operating procedures and ensuring and also demonstrating that good practice is maintained.

1.7 Web addresses of relevant organisations

European Association for Forensic Entomology (EAFE): www.eafe.org (accessed 26 October 2011).

North American Forensic Entomology Association (NAFEA): www.nafea.net (accessed 26 October 2011).

The Forensic Science Regulator

<http://www.homeoffice.gov.uk/agencies-public-bodies/fsr/> (accessed 26 October 2011).