Chapter 3

Insect detection and monitoring

Where do insects come from?

Historically, it was thought that insects were spontaneously generated, but we now recognise that if an infestation develops, it must have originated from some other source. The most obvious way for insects to gain access to houses and museums is through doors and windows. Carpet beetles and furniture beetles fly readily in warm summer months, and just one fertilised female is enough to start an infestation. In general, the warmer the climate, the more insects fly, and the greater the risk from invasion.

However, it is far more likely that insects are already occupying the building unnoticed. Most old buildings – and many newer ones – harbour some insects, and it is quite common to find pests living within a building for many years without apparently causing a problem. It is not until their numbers increase and they spread into collections on display or in storage that serious damage occurs. Birds' nests and dead animals in blocked chimney flues and attics are the natural habitats for many pests, where they can live quite happily on feathers, hair and excreta. Many buildings also have cavities, voids and dead spaces where organic debris accumulates in sufficient quantities to feed insects. When temperatures rise and insect numbers exceed the food available, they will spread out in search of other food and breeding sites.

One of the main routes of infestation into collections is from newly introduced material which is already infested and may remain undetected until a serious problem develops. This is a particular problem with wood-boring beetles, with larvae hidden in the wood which may take months or even years to develop. Packing cases and packing materials may also be a source of insect infestation. Material sent out for display or loan may be at risk if it is returned with an infestation acquired while it was away. There are documented cases of textiles and costumes being returned to museums infested with tiny clothes moth larvae that had hatched from eggs laid by moths on the objects when they were on open display. Many organisations have now adopted an inspection and quarantine programme to combat this threat (see Ch. 4).

How to find insects: where and what to look for, and how to look

Many adult beetle and moth pests are very small, and their eggs and young larvae are even more difficult to see. Nevertheless, visual inspection of stores and objects is the most important part of any pest control strategy. It is vital to know where and what to look for, and how to look.

Where to look

As already mentioned, all material vulnerable to insect attack which is on display or in storage should be inspected regularly. If there are insufficient staff, inspection should be concentrated on areas of highest priority, such as those that contain material at greatest risk and/or value (historical or fiscal). The building should also be inspected and high-risk areas identified (see Ch. 9).

A rolling programme in which the building and its contents are systematically examined using a regular timetable is preferable to a random 'blitz' inspection every few years. The inspection sequence should be decided using a detailed plan of the building to include display areas, stores and unused areas. It is essential to record all inspection details on a spreadsheet, record form or logbook.

The inspection should concentrate on dark corners and dead spaces, particularly in attics and basements. Search for areas of poor hygiene and look for debris, birds' nests and old 'abandoned' or damaged displays or objects. Examine windowsills for dead insects; carpet beetles may be attracted to north-facing windows in spring and summer. Other catchment areas, such as air-conditioning ducts and filters, may house clothes moths and carpet beetles. Historic houses are particularly prone to cluster flies that hibernate in the autumn, and their dead bodies provide an ideal food source for carpet beetles. There are many instances of damage to historic carpets and curtains caused by carpet beetles being traced to dead flies in attics and window voids.

Inspect display cases and storage boxes containing material at risk, such as wool garments and animal skins. Look under objects (and move them if possible), into pockets or behind seams of textiles and clothing. Check inside wooden objects and behind the polished veneer fronts of furniture, as beetles often concentrate their attack on the poorer-quality backing timber. Examine display cases and racking or storage systems, as these may themselves be infested. Felt linings or door strips can also be a source of food for clothes moths and carpet beetle larvae. Dead spaces under display cases and storage furniture may not be cleaned regularly and so support infestation.

Workrooms and dark corners in refreshment and staff mess areas may harbour debris and food spillages that should be checked. Other introduced objects such as ornamental pot plants can be a particularly troublesome source of stray insects. Food supplied to live animals, sometimes used in displays, can also be a source of nutrition for insects. Biscuit beetles and moths may occupy dried animal food, and live larvae or crickets used to feed reptiles may escape and become established in the building. The dead bodies may then provide food for pests such as carpet beetles. Kitchens, restaurants and staff rooms should be inspected regularly for insects such as cockroaches.

Active furniture beetle infestation is usually found in areas that are damp or have been exposed to water ingress at some time. They may also be found on objects which have been introduced from moist environments.

What to look for

Live insects are tangible evidence of infestation, but other clues are needed to be able to pinpoint problems before they become obvious. Dead insects or insect fragments can be important signs but may also be misleading if they are the remains of a treated or long-dead infestation. Pellets of frass, silk webbing or the cast skins of larvae are frequently the first signs of infestation (Figs. 3.1–3.3), and fresh evidence of this sort suggests that a more thorough examination of material is needed. Failure to find any live insects may indicate that the infestation is no longer active and that there is no need for concern. However, it is also possible that the infestation is either dormant or active at such a low level that it has remained undetected. For this reason, a follow-up inspection after a short period will be needed to check for any additional signs. Inspections for seasonal pests, such as adult carpet beetles and furniture beetles, should be carried out in late spring and early summer, when they are active and flying.

Active infestation of wood-boring beetles may be indicated by the presence of new holes or piles of fresh dust and frass. If the object has not been moved recently, this is a warning that there is an active infestation that needs to be investigated immediately. However, old frass from a long-dead infestation will often fall out of exit holes when objects are disturbed or moved. When wood dries, it may shrink, and old frass may

Figure 3.1 Piles of furniture beetle (*Anobium punctatum*) frass.

Figure 3.2 Webbing clothes moth (*Tineola bisselliella*) frass and webbing.

Figure 3.3 Carpet beetle (*Anthrenus*) cast skins and larvae in an insect drawer.

Figure 3.4 Woodborer frass. Top: drywood termite; left: deathwatch beetle; right: house longhorn beetle; bottom: furniture beetle.

then fall out of cracks. Some insect species produce distinctively shaped frass, and Figure 3.4 illustrates frass from three types of wood-boring beetles and drywood termites.

Keeping objects and their environment clean and free from dust ensures that cast larval skins and fresh boring activity will become obvious. A dirty display or storeroom will make it difficult to distinguish between old and new infestations. Some displays of natural history specimens include bark, gravel, stones and vegetation, which make detection of insect activity very difficult. Identifying infestation on material entering museums can be problematic, so a quarantine/incubation system can help detect infested material by breeding out insects if they are present (see Ch. 4).

How to look

In the gloomy conditions that frequently prevail in old houses, museums and stores, it is essential to use a bright flashlight for inspection. A methodical search is preferable to a sporadic examination, and good records should be maintained in an inspection logbook. Carefully examine each object which is being inspected, and make a note of any changes since the last inspection. When damage to valuable artefacts by textile pests or woodborers is detected, a photographic record should be made to show whether, on subsequent examination, any additional damage has occurred.

An excellent way of determining the activity of wood-boring beetles, such as furniture beetles (*Anobium punctatum*) or deathwatch beetles (*Xestobium* *rufovillosum*), is to paste rectangles of tissue paper over areas of wood with emergence holes: new emergence will be clearly indicated by new holes in the tissue. Marking new exit holes with a coloured marker pen will give a record of yearly emergence patterns and show if an infestation is declining or increasing and needs remedial action (Fig. 3.5).

Figure 3.5 Deathwatch beetle (*Xestobium rufovillosum*) emergence through tissue paper.

Insect traps

Insects are small and secretive, so even a thorough inspection may still not detect their presence. It is also usually logistically impossible to examine all objects and areas in large buildings or stores. For these reasons, insect traps should always be used to supplement visual inspection. Insect traps developed for use in the public health and food industries have been successfully adapted for the detection of museum pests. The use of insect traps for monitoring is the first priority in setting up an integrated pest management programme in historic houses or museums (Child and Pinniger 1994; Child 2011). Traps enable insects to be detected at very early stages of infestation, greatly improving the chances of preventing damage. Over a period of time, a detailed picture of infestation problems can be built up to enable appropriate action to be taken. They can also provide a useful check on the effectiveness of control measures.

Sticky blunder traps

Non-specific sticky traps should be used for the basic monitoring of insects such as silverfish, booklice, carpet beetles and other crawling insects. Sticky blunder traps are good for monitoring the residual population of insects in a building to assess the risk to the collection. They can also provide a useful indication of the number of crawling insects that are entering from outside the building.

There are many different traps available, some of which perform better than others. Large traps designed to catch cockroaches are very successful for large insects, such as oriental cockroaches and crickets, but are not very effective for small insects, which may have to climb over a folded and raised lip to get into the trap. The simple triangular card types without a folded lip (Fig. 3.6) are preferable, some of which have a sticky patch under the trap designed to enable the trap to be stuck to a surface. This sticky area underneath will often trap very small insects, such as booklice or newly hatched carpet beetle larvae, which cannot easily climb onto the top surface of the trap. The card traps are liable to physical damage and are ineffective if they become damp, in which case a plastic trap with a sticky insert can be used. These low-height traps are not so effective at catching insects, as the insects may find it difficult to climb a ramp; another drawback is that clothes moths may not be able to fly into the trap. Some museums have made their own traps from glued card or sticky tape, but the adhesive is rarely as effective in catching insects as that used on commercial traps.

Traps should be placed in a regular grid pattern against wall-floor angles, preferably in corners where they will catch more wandering insects. Traps placed in unused fireplaces will catch insects that fall down the flue. Low-height traps can be tucked under shelves and storage units. Traps on windowsills, shelves and in drawers or cupboards rarely catch many insects. All traps should be checked regularly – at least four times a year – and the insects caught identified and documented using a trap record form to simplify the recording and analysis of the data (Fig. 3.7). Traps should be replaced when they become dirty or if the adhesive has failed. Traps may need changing if they have caught large numbers of insects, as these will become

Figure 3.6 Sticky blunder trap.

EH Insect ID Monitoring Sheet

Site ID: Location: Year: Quarter: Date of return:

Trap No:	TRAP CONTENTS ONLY	Brown House Moth	Case Bearing Clothes Moth (a)	Case Bearing Clothes Moth (l)	Webbing Clothes Moth (a)	Webbing Clothes Moth (l)	White Shouldered House Moth	Deathwatch Beetle	Furniture Beetle	Varied Carpet Beetle (a)	Woolly Bear (l)	Guernsey Carpet beetle	Two Spot Carpet or Fur Beetle (a)	Two Spot Carpet or Fur Beetle (l)	Biscuit Beetle	Hide or leather beetle	Plaster beetle	Wood Weevil	Australian Spider Beetle	Golden Spider Beetle	White Marked Spider Beetle	Booklice	Silverfish	Woodlice	Mealworm	Other Insects Count	Others Only list other non-insect pests and quantities for example Black Ground beetle, Rove or Devil's Coach Horse beetle, Powder Post beetle, Pseudo scorpion and flies. Only list all the others for example bird mites, thrips, springtails etc if found in large quantities (over 10 or more) & if there are lots then try to make an approximate count.
	Room/Position (NB. Please mark with 'CBCM' or 'WCM' against trap number if trap has a moth pheromone lure on it ie.'WCM 14').	●	●	X	●	X	●	●	●	●	X	+	●	X	■	■	■	▲	■	●	■	●	●	▲	▲		
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Figure 3.7 English Heritage pest trapping Excel recording sheet.

food for pests (Fig. 3.8a). The more traps used, the greater the chance of finding pests, but a trapping programme should not exceed the resources available to check the traps – numbers should be matched to the priorities of the collection (see Risk Zones, Ch. 9).

Food attractants

Food attractants have been used to lure insects into traps for many years, for example, beer was once recommended as a good bait for cockroaches. Specific food attractants have been developed to successfully attract some species of stored-product insects in the food industry (Fig. 3.8b) (Mueller 1998). There have also been a number of different food baits used to enhance trap catches of silverfish. Baits have also been

Figure 3.8 (a) Sticky trap full of non-pests and spider beetles.

Figure 3.8 (b) *Anthrenus* larvae on food bait.

used to trap larvae of some heritage pests, but there is a risk that if the baits are not removed regularly, they can be a source of food which increases the number of pests.

Pheromones

Many insects produce attractant chemicals called sex pheromones to lure mates, and these have been used very successfully in agriculture and horticulture for a number of years. Some of the pheromones of museum pests have been identified, and a few are available as synthetic lures for use with traps (Pinniger *et al*. 2003). The most successful lure is that used for the common clothes moth; others are available for case-bearing moths, carpet beetles, biscuit beetles and cigarette beetles. However, because of the varied behavioural responses to pheromones, placement of traps and interpretation of the results are more complex than for simple sticky traps. The pheromones generally attract only males of the target species and may even repel other insects. The lures are also more expensive than simple blunder traps, and they are usually only used in areas where there is a high risk to valuable objects or where one of the pest species is suspected. As the lures generally attract only flying males, to use them effectively, it is essential to understand the pest's biology and the performance of the pheromone.

Common or webbing clothes moth (*Tineola bisselliella*)

The pheromone components are incorporated either into a separate lure or into the sticky glue on a lure board (Fig. 3.9), both of which have proved very successful. The flight activity of the males is stimulated by the pheromone, and suspended

Figure 3.9 A common clothes moth (*Tineola bisselliella*) pheromone trap.

traps provide a very useful early warning of infestation. When temperatures are high enough to promote flight, up to 20 times as many moths may be caught on traps with pheromone lures as on unbaited ones (Cox *et al.* 1996). However, when temperatures drop below 20°C, the males are reluctant to fly, and suspended traps may be relatively ineffective. In these situations, the pheromone traps can be placed on the floor. The traps with lures will always catch more male moths, and as the males respond quickly to the lures, pheromone traps can be deployed in a grid to locate the source of an infestation. After a few weeks, the traps will provide an indication of areas of higher activity, and, if necessary, they can then be moved to pinpoint the source of the infestation.

As pheromone traps are so effective, they should be used to monitor any collection containing material vulnerable to attack, such as wool, fur and animal skins. If no moths are trapped in the warmer months, then it is likely that they are not present in that area. A mating disruption system called Insectrac (formerly Exosex), based on the common clothes moth pheromone, is sold commercially as a control measure for webbing clothes moths (see Ch. 5).

Case-bearing clothes moth (*Tinea pellionella*)

A specific lure is also available for this moth, but there is less evidence of its effectiveness when compared with the common clothes moth lures.

Indian meal moth (*Plodia interpunctella*)

Lures for this species are very effective if the source of an infestation in food needs to be pinpointed.

Furniture beetle or woodworm (*Anobium punctatum*)

The synthetic pheromone is known as anobinone, but the results of trapping using these lures varied (Pinniger and Child 1996). The pheromone-baited traps were sometimes very effective in trapping beetles, even at very low levels of infestation. However, on some occasions, there was a very poor response from traps located in areas known to be infested. The success of the lure seemed to depend on the design of the trap, temperature, humidity and light levels. Anobinone is extremely difficult and expensive to synthesise, and so lures have not been commercially available for some years (Child and Pinniger 2014).

Biscuit beetle (*Stegobium paniceum*)

Stegobinone, the pheromone of this species, is reported to be identical to that of the furniture beetle (*A. punctatum*). There are traps available containing a lure which is an analogue rather than the authentic stegobinone. Traps with these lures are effective and will catch more adults when placed in warm, well-lit areas when the adults fly freely. However, at lower temperatures, the lures seem to be less successful. In trials in two small museums, more *Stegobium* adults were trapped with the anobinone analogue lure than on traps without the lure (Child and Pinniger 1994). Harvey *et al.* (2018) demonstrated the effectiveness of lures containing a stegobinone analogue called stegobiene produced by Fuji Flavour Co. Ltd, when they carried

Figure 3.10 *Stegobium* pheromone trap catch.

out an extensive trial in a *Stegobium*-infested herbarium (Fig. 3.10). Accurate identification of insects is essential as shown by one museum where an expensive and unnecessary roof timber treatment was carried out because the biscuit beetles on the anobiid traps were incorrectly identified by the contractor as woodworm (*A. punctatum*).

Cigarette beetle (*Lasioderma serricorne*)

The pheromone for this species is known as serricornin. A number of successful traps have been designed for the tobacco industry, some of which have been used in museums and herbaria (Gilberg and Roach 1991; Harvey 2001). A combination of the pheromone lure and a food lure enables the trap to attract both male and female beetles. As with biscuit beetles, these lures only work well when it is warm and the beetles are flying.

Carpet beetles (*Anthrenus* sp.)

The pheromone of the varied carpet beetle (*Anthrenus verbasci*) has been identified and is available in lures. A different pheromone exists for the Guernsey carpet beetle (*Anthrenus sarnicus*) which was tested in museums in the United Kingdom but is not available commercially (Ackery *et al.* 1999). The pheromone of both species was far more effective when the insects were also attracted to light from windows – very few adults were caught on traps placed in dark areas on the floor. There is also a pheromone for the black carpet beetle (*Attagenus unicolor*) which is available in the United States. This does not seem to be effective for other *Attagenus* species.

Ultraviolet (UV) traps

Suspended or wall-mounted traps, known as electric fly killers, with a UV light source are attractive to flies and some moths but are not so effective for museum pests. UV traps with sticky boards have been used to control cluster flies invading buildings (see Ch. 5).

General principles of insect trapping in museums and historic houses

The deployment and interpretation of trap catches must be determined for each situation and need to be targeted at both the environment and the collection (Kingsley and Pinniger 2001; Xavier-Rowe and Lauder 2011). The following points are general guidelines:

- Survey the site, prepare a plan and decide where to place traps.
- Place sticky traps in a regular grid pattern.
- Place traps on floors in corners and near walls, not in the centre of open areas.
- Date-label and number traps, and mark their position on a plan.
- Check traps at regular intervals (minimum four times a year).
- Identify and record insects caught on traps.
- Record whether insects caught are larvae or adults.
- Replace traps that have become dirty or if the adhesive has failed.
- The more traps used, the greater the chance of finding insects.
- The workload should not be underestimated, and trapping programmes should be designed to be manageable.
- Large numbers of non-pest insects may be caught on traps if they are near external doors or windows. In this event, the traps should be replaced more frequently to avoid the trapped insects becoming food for pests.
- Over a period of time, a record of catch will build up a picture of the distribution of insects.
- Additional traps should be placed in areas where pests need to be more accurately pinpointed. Clothes moth pheromone lures and traps are very good for accurate monitoring and early warning in sensitive areas. They should be checked more frequently.
- Traps should be utilised as a supplement to visual inspection and the information used to target preventive and remedial measures.
- Traps can also be used to check on the effectiveness of control treatments.

Wooden objects: X-rays, ultrasonics and incubation

It is extremely difficult to identify hidden infestations of some wood-boring beetle larvae which, as previously mentioned, may take years to develop before the adult emerges from the wood. Examination of holes and damage in wooden objects can be confusing because of the many different ways in which the damage may manifest itself (Ridout 2000, 2012). Ethnographic objects have been found with tunnels in the timber made by longhorn beetles when the tree was standing. These tunnels are usually large, and the carving and form of the objects often indicate that the hole existed before the object was made. Damage by bark beetles may also be seen as fan-shaped patterns resulting from the long-vacated larval tunnels between the wood and the bark. More difficult to diagnose are the smaller holes caused by past infestations of felled timber by ambrosia beetles. Adding to the confusion is the possibility that some objects may have been previously damaged by termites.

It is important to determine if the holes are a sign of active infestation by one of the damaging woodborers such as *Anobium* or *Lyctus*. Small objects can be X-rayed to show activity, but the interpretation of X-ray photographs is a skilled technique. Large larvae can be seen in tunnels, but smaller larvae may be overlooked because of the density of the wood and the lack of clear opaque structures in the larvae. It is usually very difficult to distinguish larvae in objects with large-section timbers, and it may be impossible to X-ray large objects. Therefore, incubation is usually the only way of determining whether a suspected infestation is really active.

As mentioned previously, an excellent way of determining the emergence activity of wood-boring beetles such as the furniture beetle (*A. punctatum*) or deathwatch beetle (*X. rufovillosum*) is to paste rectangles of tissue paper over areas of wood with emergence holes (Ridout 2000; Pinniger and Lauder 2018). If this is done in March before the start of emergence, then any new emergence will clearly be seen as fresh holes in the paper. They can then be marked and recorded (Fig. 3.5) to build up a picture of the extent of emergence.

Active infestation in wood can be detected by the carbon dioxide produced by the respiring larvae (Koestler *et al.* 2000; Stusek *et al.* 2000). Although there is no doubt that this can be done in laboratory conditions, with the sensing equipment currently available, it is far more difficult to produce a reliable method that can be used in practical situations. There have also been a number of studies on the use of ultrasonic or sound sensors to locate woodborers in structural timber. Heavy and active infestations of wood-boring beetles can be detected but low levels can easily be missed, particularly when temperatures are low and insects are inactive. Thermal imaging has also been used to examine structural timber for signs of mould and insect activity (Ridout 2012). These systems are more effective for the detection of termite infestation which exhibits higher levels of activity and generates more heat than beetle larvae.

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