# Integrated Pest Management for Collections

Proceedings of 2021: A Pest Odyssey, The Next Generation

This book is dedicated to Bob Child
Our friend and colleague

# Integrated Pest Management for Collections

Proceedings of 2021: A Pest Odyssey, The Next Generation

Edited by Suzanne Ryder and Amy Crossman

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*Cover illustration:* The hatching of a grey silverfish (*Ctenolepisma longicaudatum Escherich*, 1905) after an unsuccessful treatment in the course of a series of experiments. (Photo © Judith Wagner)

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# Contents

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## Organising committee

Nigel Blades; Amy Crossman; Adrian Doyle; Kerren Harris; Yvette Harvey; Sam Higgs; Mel Houston; Dee Lauder; Armando Mendez; Suzanne Ryder; Helen Smith; Jane Thompson Webb; Alex Walker

# In memoriam: a personal tribute to Bob Child (1951–2019)

Many readers will have heard of Bob Child through his involvement and promotion of IPM in cultural heritage. He presented papers at both the first Pest Odyssey conference at the British Library in 2001 and the second in 2011 at the British Museum.

I first met Bob way back in 1984 and although I did not realise it at the time, our meeting turned out to be a pivotal point in my career. Jim Black (International Academic Projects) had organised a series of short courses in London on museum collections care and pest management. Bob was then working as a conservator at the Welsh Folk Museum at St Fagans and gave the talks on pest control. I was then a research entomologist at MAFF Central Science Laboratory in Slough. After the courses were over, Bob asked if I would like to join him on some of his workshops to talk about insect pests. As he was a chemist by training and I was an entomologist, he thought we would make a good team. Working closely with Bob, I soon found out he was one of the most interesting and infuriating people I had ever met. He was an inspirational and entertaining teacher with an abundant supply of very funny stories, many of which would be regarded as politically incorrect today. I learnt a lot from Bob about conservation and working with museums, and we had some great times together in London, Cardiff, Ottawa, Rome and Vienna (and also some embarrassing ones).

Over the years we became firm friends and worked on many projects together. The most important of these was to fill the need for insect traps and pheromones and safer insecticides suitable for museum use. This led to Bob establishing his own company Historyonics, which eventually supplied traps and Constrain micro-emulsion insecticide to most cultural heritage organisations in the UK and many overseas. Bob acted as a consultant to many organisations in the UK and other countries and was a key figure as advisor to the National Trust in England and Wales. Most of the National Trust house staff will have had some training in IPM from Bob which they will probably still remember with a smile. Bob was a great advocate of gaining practical experience of things that he might recommend as a consultant and we carried out some of the first nitrogen anoxia treatments to be used in the UK. We collaborated on 12 papers for journals and conferences, and some of these were pivotal in the development of pest management.

In recent years Bob was a key figure in helping to negotiate the labyrinth of the European Union Biocides Directive. Thanks to his guidance, we were successful in preventing pheromones in insect traps from the irrationality of being classified as biocides which required very costly registration. Nitrogen anoxia treatments were an even more complex challenge for everyone involved in cultural heritage IPM, and again Bob's practical experience and understanding of the regulations provided us with the means to mount a campaign to exempt nitrogen treatments from restrictive regulation.

Bob and I remained friends for over 30 years and I will always value his help, encouragement and sometimes extreme bluntness, which enabled me to pursue an enjoyable and very worthwhile career as a consultant after leaving government research. On behalf of all of Bob's many friends and colleagues in cultural heritage pest management, I would like to pay tribute to Bob, a true legend in his time.

Thank you Bob. You cannot be replaced, but you are with us in spirit and your memory and legacy will live on.

David Pinniger
August 2021

# Introduction

With contributions from 16 countries and delegates from more than 30 countries, it is evident from this volume that integrated pest management (IPM) has been adopted globally. IPM is now the accepted strategy within the cultural heritage sector to mitigate the risk posed to our unique collections by damaging pests.

The Pest Odyssey group was born out of the small number of UK IPM professionals who put together the second in this series of conferences: *A Pest Odyssey 2011: 10 Years Later*. The group continues to advocate, promote and advise best practice in pest management. The Pest Odyssey committee worked together, despite a global pandemic, to deliver the third in this series of conferences: *A Pest Odyssey 2021: The Next Generation*. This conference was the first online conference in the series and reached an even wider audience.

We continue to see IPM become embedded within our institutions and work. There have been notable changes and enormous progress since the first meeting in 2001. In 2001, beetles and anoxic environments were the main topics for discussion and in 2011, moths and risk zones dominated our thoughts. In 2021, after an unprecedented period of change in our work practices in response to restrictions during the COVID-19 pandemic, we see yet another evolution within pest management: there is a greater emphasis on collaboration, remote monitoring and, of course, silverfish.

As we see the distribution of pests change and the introduction of new pests, we as IPM professionals respond and develop to continue our quest to protect our cultural heritage. In a digital age we now have access to comprehensive online resources and training, remote monitoring and sophisticated software to record trap data and correlate this with environmental information to allow useful analysis and interpretation of data.

The conference proceedings from the meetings in 2001 and 2011 are widely recognised as essential text for pest management in cultural heritage institutions. This volume contains 46 contributions from across the world and we hope it will prove to be another valuable resource in the pest manager's tool kit.

Suzanne Ryder and Amy Crossman

## Editors' note

Several papers in this volume discuss silverfish and it is worth noting that the genera *Lepisma* and *Ctenolepisma* are now considered neuter in gender following a ruling from the International Commission of Zoological nomenclature (ICZN) in 2018, Article 30, opinion 24. Consequently, the correct name for the silverfish *Lepisma saccharina* is now *Lepisma saccharinum* and *Ctenolepisma longicaudata* should now be referred to as *Ctenolepisma longicaudatum.*

# IPM strikes back: reviving a slumping IPM program

Alan P. Van Dyke

**ABSTRACT** In 1990, small insects were discovered near some books in the folio room of the Harry Ransom Center at the University of Texas at Austin. Conservation staff were alerted, and it was determined that it was a dermestid beetle infestation. As a result, the Ransom Center's integrated pest management (IPM) program was born. Over the next few years, a robust program was developed by one of the Center's book conservators and significant improvements were made to the building. Over time, however, the program started to develop problems. Over-trapping led to a heavy workload when traps were collected for examination. Tensions between the IPM coordinator and building management led to poor cooperation. Lastly, fatigue set in, making motivation to maintain the program difficult. As a result, the Center developed large numbers of odd beetles (*Thylodrias contractus* Motschulsky, 1839) in the building, seasonal cricket infestations, and an established house gecko population. In 2016, after over 20 years of management by the conservator who devised the program, duties were reassigned to a preservation technician. The trap collection schedule was restructured and regular spot treatment by a pest control company was implemented. Improved communications with the building manager allowed additional improvements to be made to the building. The renewed program has yielded results: a reduction of pests in the building.

**KEYWORDS** Integrated pest management; IPM; insect pests; library; prevention; program revival

## Background

The Harry Ransom Center at the University of Texas at Austin is a humanities research center with an emphasis on literary and historical collections, including books and archives, as well as holding a significant photography collection and collections in the performing arts, film, and the fine arts. The building has eight levels and a footprint of approximately 3000 m$^2$ with a total of about 7000 m$^2$ of collection storage space. It opened in 1972 when the University's various rare book and manuscript collections were relocated from older buildings on campus (Henderson 2007) and in 1980 a conservation department was established.

## Beginning of IPM at the Harry Ransom Center

In 1990, a Ransom Center staff member was working in the folio storage room and discovered small insects crawling near a book. Conservation staff were alerted, the insects were identified as carpet beetles (Dermestidae), and a plan of action to eradicate them was adopted. Books were removed from the shelves and cleaned, and shelving was vacuumed. Careful inspections of the area were carried out routinely to monitor the effectiveness of the cleaning. Door sweeps were installed on the doors to contain any missed carpet beetles. The efforts proved successful and the infestation was eliminated (Fig. 1).

**Figure 1** Ransom Center staff cleaning books after a carpet beetle infestation in 1990 (© 2021 Alan P. Van Dyke).

**Figure 2** Installation of the blast freezer at the Ransom Center in 2003 (© 2021 Alan P. Van Dyke).

This incident marked the birth of the integrated pest management (IPM) program at the Ransom Center (Baughman 1992).

## Building an IPM program

In 1992, an assistant book conservator, Mary Baughman, was assigned the task of building an IPM program in response to the carpet beetle infestation (Baughman 1992). She researched how to implement IPM and set up a regular monitoring program with assistance from Center staff members to place and collect traps. Sticky blunder traps were initially collected on a two-month rotation. Staff members were assigned areas to place and collect traps, while Baughman was responsible for evaluating the catch (Baughman 2001).

Large numbers of crickets regularly entered the building every fall and Baughman was able to identify the front doors as one of the entry points. She arranged for door sweeps to be added which helped manage the number of crickets on the lower levels of the building, but their numbers on the upper levels remained high.

Early in her work, Baughman identified pigeon nests along balconies and ledges on the second and third floors as potential sources of pests. She worked with Center building management, the University's facilities staff and an external contractor to install an avian aversion system. This was very effective at keeping birds from nesting near windows. She also arranged for windows that could be opened to be fitted with new weather sealing.

The Ransom Center had been dependent on either the University's Housing and Dining Division cafeterias or remote contractors for freezer space when a large item or numerous items needed to be frozen due to insect issues. Changes in food handling regulations eventually precluded continued use of the cafeteria freezers, and transportation issues made the use of remote contract freezers difficult. The Center pursued installing a walk-in blast freezer in the basement. Baughman came into contact with Jeff Hunt, a contractor in Houston, Texas, who expressed an interest in building a custom freezer as a donation to the Center. A 20 m$^3$ walk-in freezer capable of –30 °C was installed in 2003 (Fig. 2), allowing conservation staff to rapidly treat infected materials on a relatively large scale.

**Current status of the monitoring system**
Since September 2000 the monitoring system has been at a standstill, due to resignations and reassignment of staff that formerly performed monitoring duties. Of the original eight personnel responsible for the monitoring system, two remain

**Figure 3** Excerpt from a July 2001 report explaining the discontinuation of monitor traps at the Ransom Center (© 2021 Alan P. Van Dyke).

| | | | |
|---|---|---|---|
| Jan 1 | 7th floor | Feb 26 | open |
| Jan 8 | 6th floor | Mar 5 | 1st floor |
| Jan 15 | open | Mar 12 | Basement |
| Jan 22 | 5th floor | Mar 19 | open |
| Jan 29 | 4th floor | Mar 26 | open |
| Feb 5 | open | April 3 | 7th floor |
| Feb 12 | 3rd floor | April 10 | 6th floor |
| Feb 19 | 2nd floor | April 17 | open |

**Figure 4** Sample trap collection schedule (© 2021 Alan P. Van Dyke).

## Decline

Even before the freezer installation, the IPM program was in decline. Staff turnover and heavier workloads had made it difficult for non-conservation staff members to help place and collect blunder traps, putting more of the responsibility for the work on Baughman. At about this time, she became concerned that management was not willing to support the IPM program or provide relief to the workload. In one document she stated that she wanted to free up her time for other activities, such as book treatments, and requested more help from other staff members for IPM duties, but little action was taken. Understandably, this lack of support had a demoralizing effect. In September 2000, Baughman gathered all the monitor traps and discontinued monitoring (Fig. 3), instead relying on inspections of collections and reports from staff members as to any pest encounters (Baughman 2001). Coupled with these problems was a building manager who was disinterested in cooperating with Baughman on some projects. This meant that needed building attention was not addressed, such as resealing caulking on roof vents to keep out crickets, causing further frustration (Baughman 2001).

Limited trapping resumed by 2004 but collecting and evaluation was sporadic. Traps placed in December 2010 were collected and counted in October 2012, those placed in October 2012 were collected in February 2014, and traps placed in September 2014 were collected in November 2015. Odd beetles (*T. contractus)* and booklice (*Liposcelis* spp.) were common in traps, and field crickets (Grylloidea) were numerous. American cockroaches (*Periplaneta americana* (Linnaeus, 1758)) were common, especially in the basement. There was a robust resident population of Mediterranean house geckos (*Hemidactylus turcicus* (Linnaeus, 1758)) within collection storage areas, a rather unusual and large indicator species. Many of the traps contained large insects and geckos that had been devoured by odd beetles and other dermestids.

In 2015, the decision was taken to hire a contract pest control service to address some of the issues at the Ransom Center. Baughman worked with the pest control technician to identify potential entry points and determine how to best control the situation. Mitigation strategies were suggested, and a limited spraying regimen was instituted.

## Rebuilding

In 2015, with a new Preservation and Conservation administrator at the Ransom Center and Baughman's

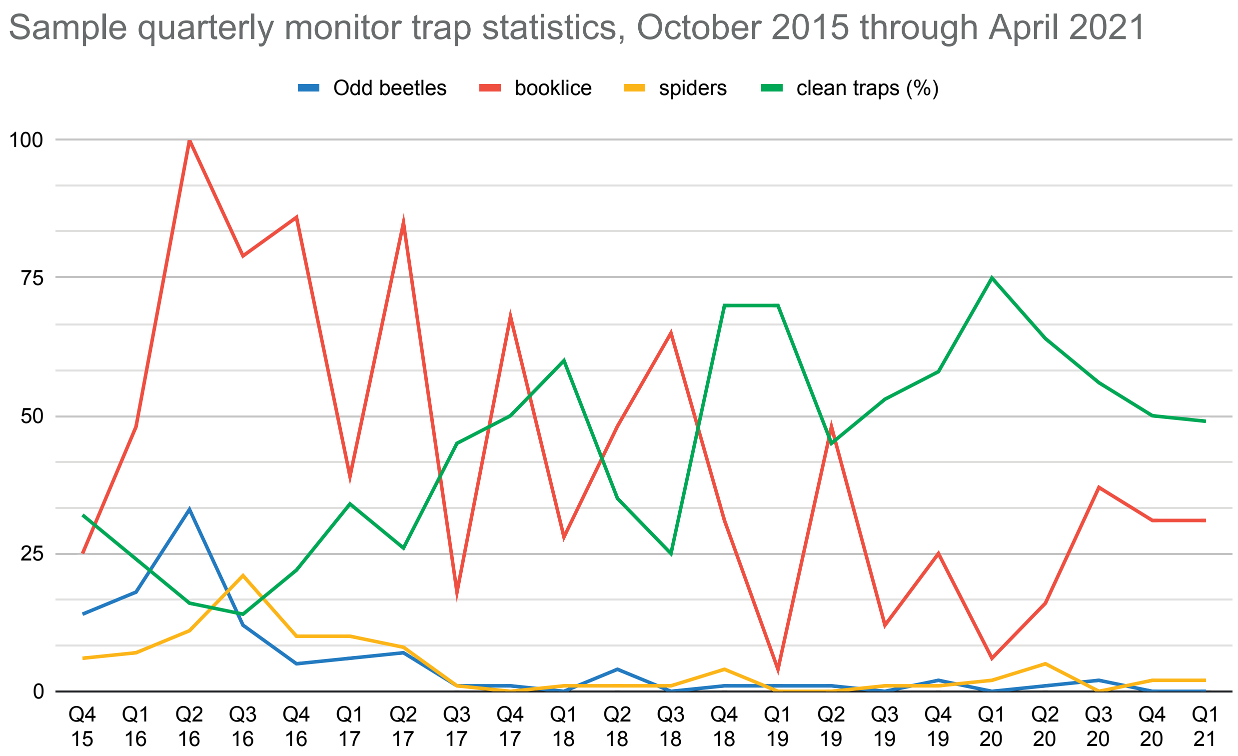


**Figure 5** Graph showing the decline of odd beetles, booklice and spiders caught on the seventh floor, and increase of the number of clean traps (© 2021 Alan P. Van Dyke).

impending retirement, IPM duties were reassigned. As a preservation technician with a background in preventive care, I was assigned these duties as part of a larger programmatic change that centralized preventive care tasks within the Preservation team of the Preservation and Conservation Division, along with custom enclosure-making for collection materials and environmental monitoring. This change also afforded Center conservators increased time to concentrate on treatments rather than other tasks. After training by Baughman, I assumed sole charge of IPM activities in early 2016.

When I became responsible for IPM at the Ransom Center, an evaluation was conducted of the state of IPM functions. Of the three floors that primarily function as collection storage, only two were fully and heavily trapped; some rooms contained 10 or more traps and the top floor had over 100 traps. Other floors with little or no collection materials were also monitored with a large number of traps.

A revamping of both collecting schedules and Trapper sticky blunder trap placement was in order. The number of traps was reduced to a more manageable level, and traps were added to every floor in the building, with a focus primarily on collection storage areas. Rather than trying to collect and count all the traps in the building in a single week, a staggered schedule was developed. Traps are collected on a quarterly cycle, with each week dedicated to a single floor. This allows for traps to be replaced and counted on the same day and has the added benefit of allowing a year-round monitoring of pest activity. The Ransom Center has eight levels so there are some off weeks. If there is an alarming increase in pest activity within the building, shifting to a two-month monitoring cycle could be easily implemented without causing an excessively heavy workload (Fig. 4).

## Repaired relations with building management

Since the restart of IPM at the Ransom Center, and as I already had a positive working relationship with building management, issues concerning the

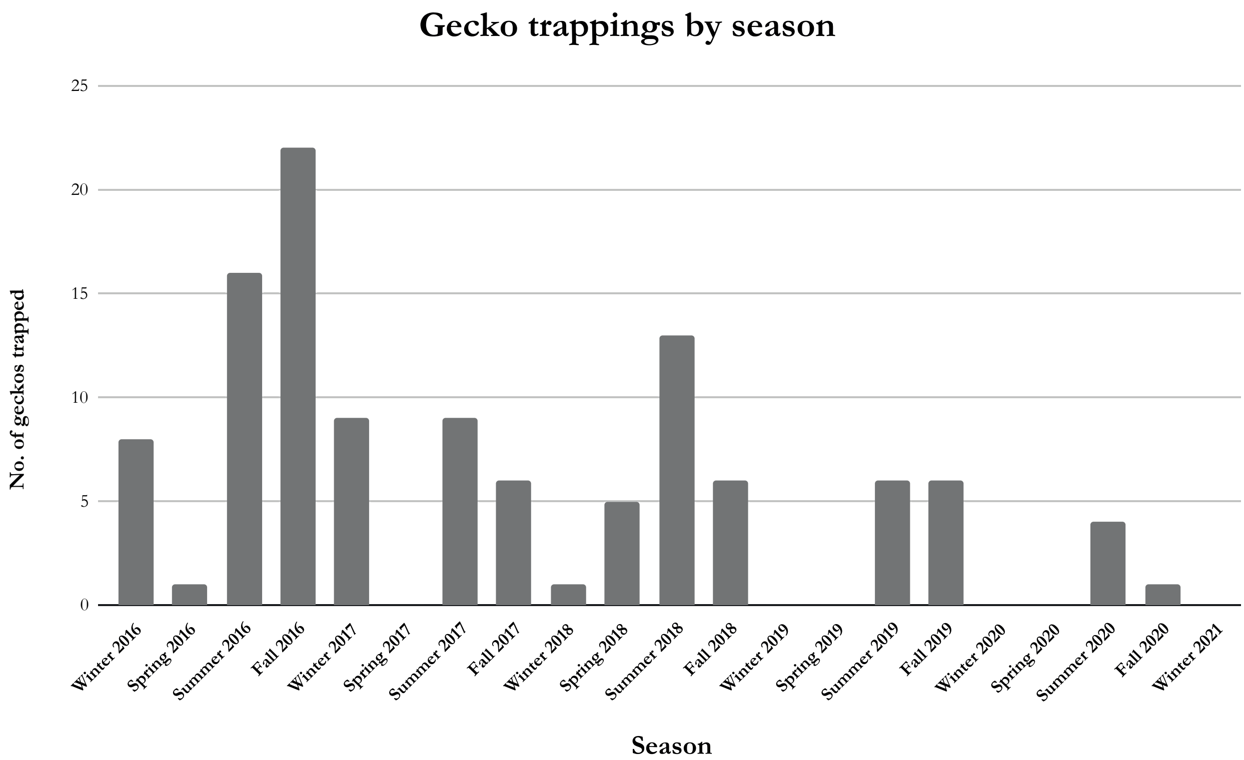


**Figure 6** Graph showing the decline of geckos within the building (© 2021 Alan P. Van Dyke).

building were more easily addressed. At my request, door sweeps were installed on emergency stairwell doors in collection areas where crickets and other pests had been entering. Due to the success of this endeavor, the following year, building management proactively installed door sweeps on all emergency stairwell doors throughout the building. Likewise, dried and cracked caulking around screens and vents on the rooftop were replaced, also helping mitigate pests entering the building. A disused custodial closet with a chronic American cockroach (*P. americana)* problem was addressed when building management added screens to the floor and sink drains to prevent cockroaches from crawling out of dry pipes. Finally, building management worked with Center administrators to develop a long-overdue comprehensive food policy within the building that removed break rooms located near or adjacent to collection storage areas.

It was decided to continue using an outside pest control company for spray pesticide application, however since using sprays around collection materials can have negative effects, application continues to be very limited. Only entry points, areas with water sources and areas with food such as break rooms are treated with synthetic pyrethroids, as well as the exterior perimeter of the building.

## Results

The number of pests caught in sticky blunder traps at the Ransom Center has dropped. Although crickets are still entering the building, they are mostly relegated to inside the emergency stairwells, where it is easy to sweep away their bodies. Odd beetles (*T. contractus*) rarely show up in traps, and certainly not in a consistent manner. Due to more frequent trap replacements there is increased visual monitoring during rounds, and as a result a rat was discovered in the basement shortly after it had entered the building. There has also been a reduction of geckos in the building due to a reduction of the insects on which they feed (Figs 5 and 6).

There are still issues to be faced: although fewer in number, booklice (*Liposcelis* spp.) are still present, perhaps a result of an aging heating, ventilation and air conditioning (HVAC) system and poor humidity control. Small mites were discovered soon after I assumed responsibilities, and although they, too, have reduced in number, it is uncertain why they are in collection storage areas except that perhaps they are predatory mites feeding on immature booklice. It is unknown where the geckos nest, which means cleaning up those areas is not feasible. Finally, American cockroaches (*P. americana*) are still a problem in the basement, largely because of an equipment room with standing water.

## Conclusions

When the Harry Ransom Center first implemented an integrated pest management program, a conservator without a background in IPM was tasked with this duty alongside her regular duties, something that is very common in many institutions with smaller conservation staff. The book conservator who oversaw IPM had support from management and was able to achieve many accomplishments, including addressing issues with the building and securing a walk-in blast freezer. Over time, however, the conservator felt she had lost a degree of support from management, which was complicated by difficult relations with building management. Monitoring was overwhelming and became sporadic at best. When a new IPM manager was appointed, new ideas and energy rebuilt the program. A new associate director for Preservation and Conservation was appointed and repaired relations with building management led to a renewed IPM effort with positive results. Management support, good working relations with building management, realistic workloads and, when IPM duties involve just one set of responsibilities and there is enough staff, rotating the position of IPM manager every few years to prevent burnout are key to maintaining a successful IPM program.

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# An oasis for pests? Setting up IPM in the Emirate of Abu Dhabi

Maickel van Bellegem, Eleonora Bosetto, Anabela Ferreira, Anthony Read, Fatima Al Tamimi and Mafalda Veleda

**ABSTRACT** The Department of Culture and Tourism – Abu Dhabi developed an integrated pest management (IPM) policy and procedures in 2020. This was followed by IPM implementation at the storage facilities for the Al Ain Museum and at Manarat al Saadiyat, and exhibition areas at Qasr al Hosn, Qasr al Watan, Jahili Fort, Qattara Art Centre, Qasr al Muwaiji and Al Ain Palace Museum. The monitoring programme started in May 2020 at the Al Ain Museum storage facility and was gradually rolled out across the other venues. Glue traps were used, sometimes using pheromone lures or luminescent patches and statistical data were recorded in the collection management system, EMu. After teething problems such as disappearing traps, the main challenge proved to be the identification of insects and assessing the risk they posed. The collections of archaeological finds, ethnographic objects, diplomatic gifts, contemporary art and rare books consist of a wide range of materials, each with their own vulnerabilities. This paper summarises the main aspects of the IPM policy, as well as its implementation and the first measures taken based on monitoring.

**KEYWORDS** United Arab Emirates; UAE; desert environment; museum collections; implementing integrated pest management; policy; procedures

## Introduction

The Department of Culture and Tourism – Abu Dhabi (DCT) is driving sustainable growth of the Emirate's culture and tourism sectors. Its vision is defined by the UAE's cultural heritage, language and landscape, working to enhance Abu Dhabi's status as a place of authenticity and innovation (Department of Culture and Tourism 2021). This includes the aim to preserve and protect Abu Dhabi's cultural heritage. The authors of this paper are responsible for collections management and conservation at several venues. We jointly prepared the IPM policy and collaborated with colleagues from Registration, Facilities Management and Operations on its implementation.

The history of integrated pest management (IPM) at the various locations was mostly based on methodologies for buildings or site management using bulk treatments such as pesticides against termites. The only known pest control relating to collections was an anoxia treatment for rare books which took place in 2019, and monitoring with glue traps at a temporary exhibition in 2011 at Qasr al Hosn. Using the newly developed policy, a monitoring programme was implemented from May 2020 at the storage facility in Al Ain and rolled out to other venues. Additional procedures were adopted to support the IPM process. This paper describes the DCT policy and procedures for IPM and their implementation at the Abu Dhabi and Al Ain venues, with conclusions relating to observations made and actions taken.


**Figure 1** Various trap types in use and the 'alert' sign which is placed near the traps.

## Policy and procedures

The policy document, along with other recently developed policies, was approved and signed off by the DCT chairman. Our aim for this document was to be concise and for the contents to highlight the main elements of IPM:

- Preventing the entry of pests
- Discouraging pests
- Monitoring for infestations
- Targeting treatment

To support the implementation of the policy, we also implemented three procedures that provide more detailed information for those working with or around the collections with the aim of stimulating routine in the work, best practice and documentation. The procedures – on the topics of prevention, monitoring/data analysis and remediation[1] – detail that monitoring for pests and damage by pests will be both reactive (e.g. incidents) and proactive (e.g. regular monitoring). All damage caused by pests to collection material must be documented in condition reports as well as in a pest visual inspection record within EMu, and all coincidental sightings of pests or insects recorded as a pest incident record.

Monitoring takes place using glue traps, with the number of traps and specific locations decided upon based on the situation for each location and collection material type present. Additional traps using pheromones or photoluminescence may be chosen based on the vulnerability of collection type materials, the location or pest sightings. For example, near an entrance or kitchen/restaurant areas, pantry moth and cockroach pheromone lures will be deployed, and close to textile collections, clothes moth pheromone can be included.

## Implementation

The policy was mostly prepared during the period of COVID-19 'work from home' restrictions (22 March–17 April 2020). We began implementation by speaking to the location managers via video calls to explain the aims of IPM and gain their support. The next step was to gradually roll out the placing

**Figure 2** Aerial photograph of Qasr al Hosn *c.*2019.

of traps, which was when we made contact with regular users of the spaces including colleagues from Registration, Security, Visitor Services and cleaning staff. We had developed a sign (in both Arabic and English) to alert staff to the presence of traps, with contact details for the conservation team. The sign was later also translated into Urdu and Hindi (Fig. 1). For the selection of trap types, we had to explore their availability in the UAE and deal with issues around repeat orders. We mainly use standard glue traps but have also been able to source traps with pheromones for cockroach, clothes moth, pantry moth, silverfish and with photoluminescent patches (Fig. 1).

The aim of the monitoring programme is to gain an insight into how insect pests move through the building, to determine seasonal variations in pest occurrences and routes of entry. We identified the insects and classified them as either pests, non-pests or environmental indicators, mostly using a microscope and comparison to images and descriptions from Notton (2018) and the Smithsonian Institution (1997). For some specific situations, such as to differentiate winged ants and winged termites, we found a poster from Australian Pest Specialists (2021) useful.[2]

We have also started retaining insects found in a reference collection. The data collected from the traps include photographic evidence, species names (common and if possible scientific), life stage, count, location (position within the building) and actions taken. These data will eventually be saved in the collections management system (CMS) and we are working with EMu software specialists to enhance the data and allow it to be extracted in graphs to improve interpretation.

## Abu Dhabi venues: preliminary findings and measures

The city of Abu Dhabi is host to various cultural heritage venues: art storage facilities, exhibition centres, a historic fort, and a major museum – Louvre Abu Dhabi. The IPM strategy considers venue type, collections and ongoing cultural heritage activities. The fort of Qasr al Hosn, the oldest building in the city, was restored and opened to the public with ethnographic displays in 2018. The quadrilateral fort presents the typical historic local building type, characterised by a two-level open portico structure (Fig. 2). Permanent exhibitions are displayed in the new closed-space area and in the old fort, requiring implementation of preventive conservation strategies.

At the site, pest identification played a crucial role in risk evaluation. Common insects identified classified as non-pests included the Pharaoh ant (*Monomorium pharaonis* (Linnaeus, 1758)) and the brown-banded cockroach (*Supella longipalpa* Fabricus, 1798). Their presence is monitored in terms of quantity and access paths. Given the semi-open space, a trapping system was not considered suitable therefore a strategy was adopted of employing hermetic display cases to prevent infestation. Temporary

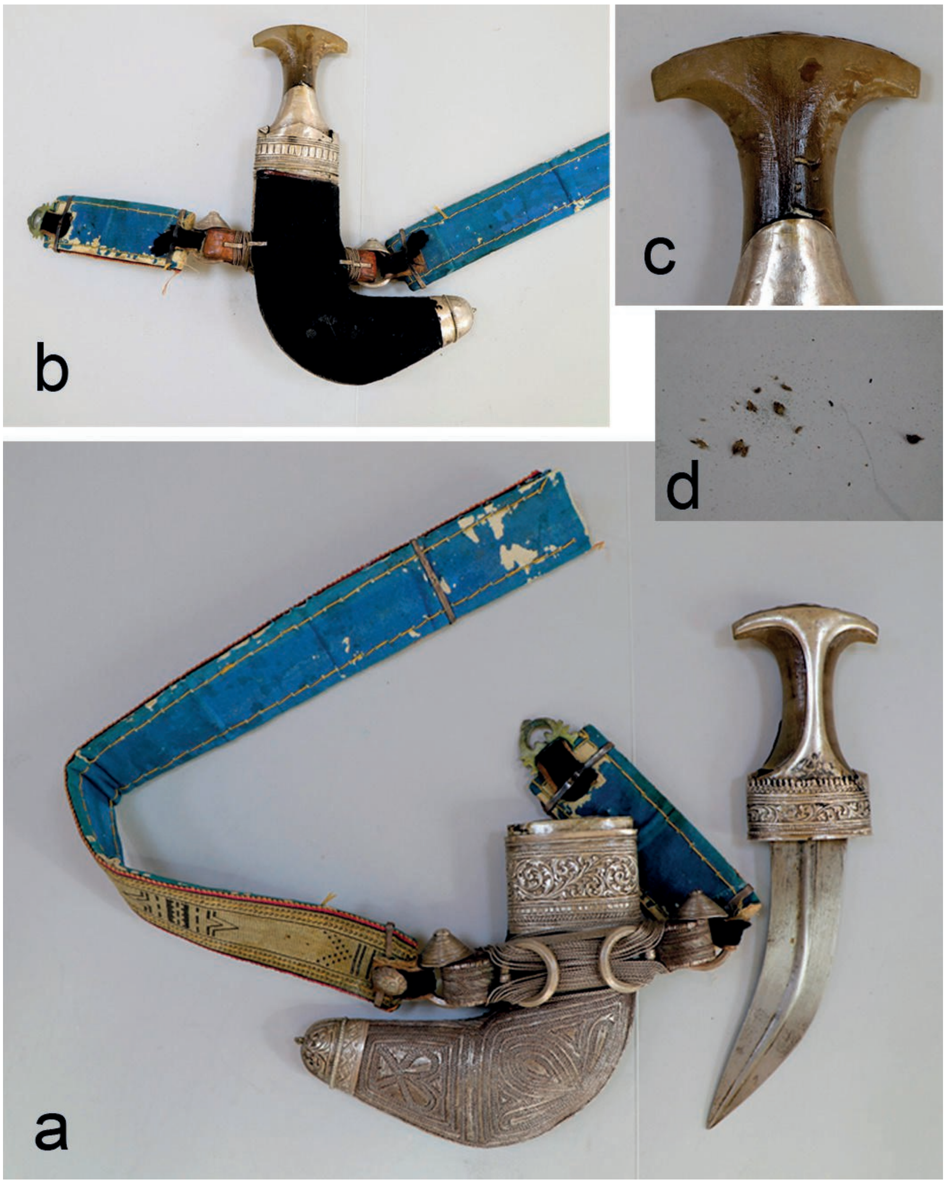


**Figure 3** (a and b) Front and reverse of khanjar AA.03360 (photos: Anna Balysheva); (c) detail of the horn of the khanjar showing pest damage; (d) dirt and loose woolly bear cast skins retrieved from the khanjar scabbard.

**Figure 4** Adult gecko found on the first day of the monitoring programme.

exhibitions frequently take place at the venue with the nature of the objects displayed being influenced by IPM. Loaned objects made from low-risk material categories, such as ceramic and metals, are selected as a prevention strategy against pest attacks.

## Al Ain venues: preliminary findings and measures

The Al Ain Museum conservation laboratory team is tasked with preparing the display collections for

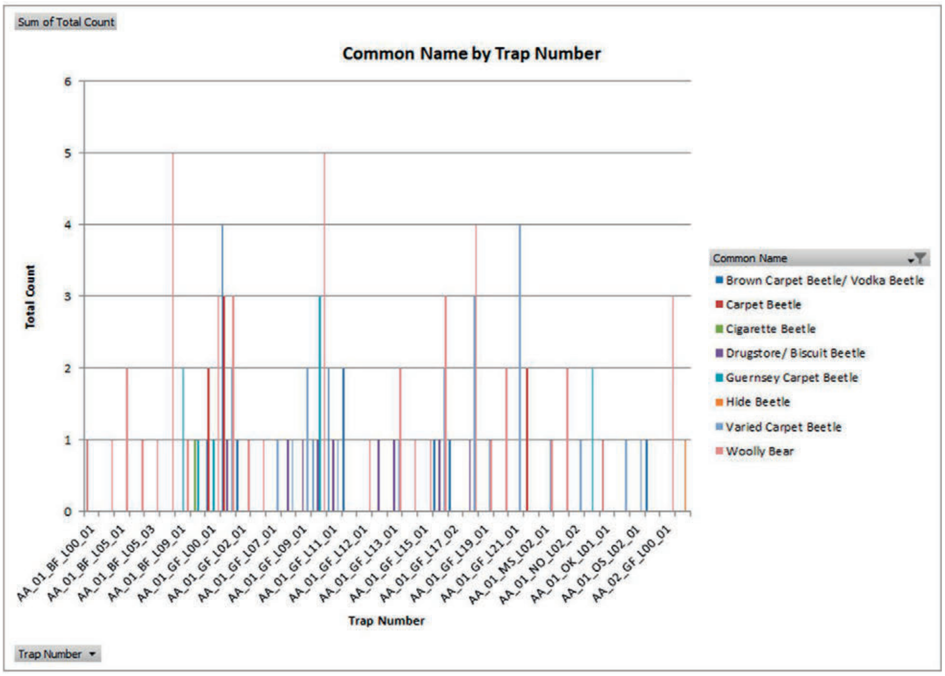


**Figure 5** Graph showing various beetles and woolly bear counts in traps at Al Ain venues. Key: AA_01: Al Muwaiji storage facility; AA_02: Al Ain Palace Museum.

future exhibition in the refurbished museum, as well as collections care at other venues. A small random selection of about 400 objects from the display collection were condition assessed in 2018 and no damage caused by pests was observed. Therefore, initially there were no major concerns but during conservation of the collections, we observed old damage from pests such as that on the horn of a khanjar (Arabian dagger) (Fig. 3a–c). There was no indication of an active infestation but woolly bear cast skins were found within the sheath of the dagger (Fig. 3d). We use the term 'woolly bear' as a general term for either larvae or the cast skins from larvae of *Anthrenus, Attagenus* or *Dermestes* beetles where it is not possible to make a distinction.

One unfortunate consequence of using glue traps is that they catch unintended prey such as geckos (Fig. 4), which are predators for our museum pests. When possible we release them from the traps using vegetable oil and then set them free outside. We check weekly for the presence of live geckos in traps and we are exploring the option of using a cage over the traps in future.

Based on the abovementioned previous damage, carpet beetles are carefully monitored. Figure 5 shows the trap event counts (of no more than five in a trap) to date of beetles and woolly bear – they are all included as species identification is not always straightforward and may be incorrect. In March, 7 carpet beetles and 18 cast skins were found in the packaging of a loom and accessories (wool and wood) but fortunately there were no obvious signs of frass or damage to the material. Although some beetles or larvae were found in traps, there was a larger presence in the objects. These, as well as other organic materials in the vicinity, were immediately isolated by double wrapping and prepared for anoxia treatment. A deep clean of the room was also carried out. The likely source of the woolly bears and carpet beetles was nesting and debris from pigeons on the façade and roof of the building. Actions such as decoys and physically chasing them away at dusk has resulted in many pigeons relocating to neighbouring buildings. Cleaning of the façade and roof has recently been undertaken by facilities management in response to the problems identified.

The total counts for pests and non-pests (currently including environmental indicators) during the monitoring of 94 trap locations across five venues between May 2020 and June 2021 are shown in Figure 6. These reveal an increase in count until March 2021 at the Al Muwaiji collections villa locations (AA_01). The maximum count belongs to trap number

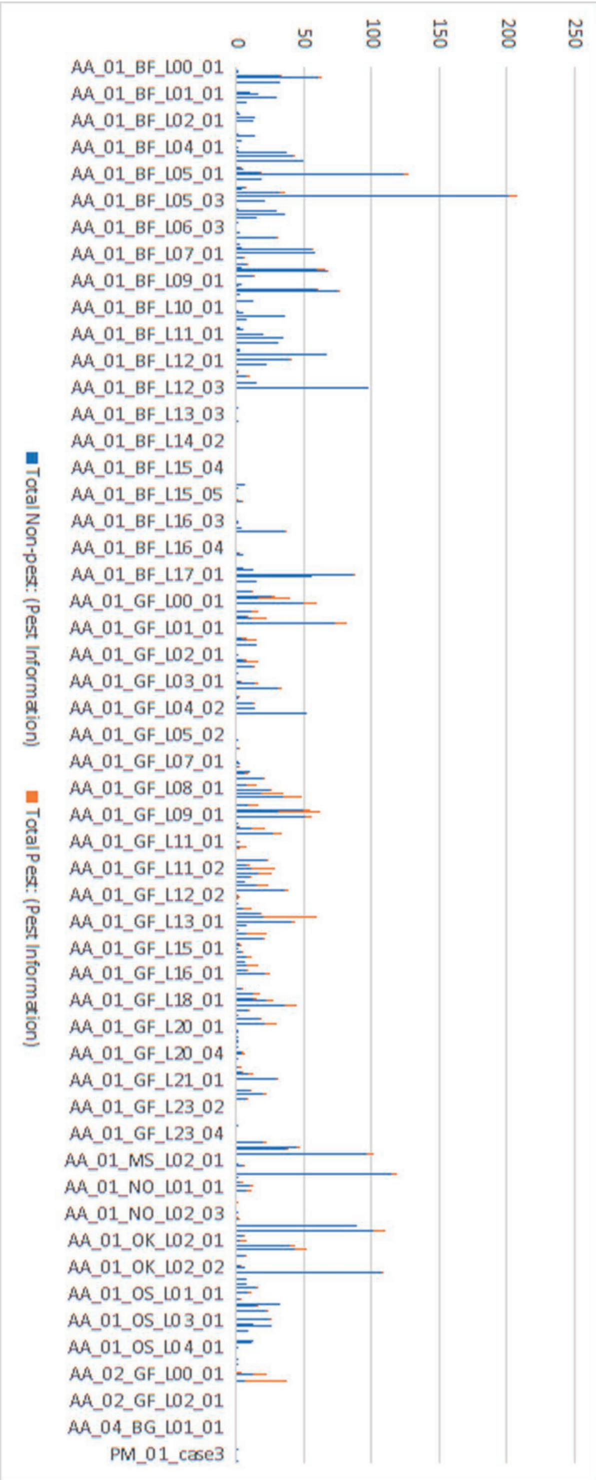


**Figure 6** Graph showing the counts for pest and non-pests (respectively indicated in orange and blue) in traps for Al Ain venues between May 2020 and June 2021. **Key:** AA_01: Al Muwaiji storage facility; AA_02: Al Ain Palace Museum; AA_04: Qasr Al Muwaiji; AA_PM: Police Museum.

AA_01_BF_L05_03 (208 of which 201 are springtails (*Collembola*) on 24 March 2021). Springtails feed on mould/detritus and are considered to be environmental indicators for localised high humidity (Notton 2018). The store has a relative humidity ranging between 33 and 49%, allowing for seasonal fluctuations. The findings in the trap reflect issues that had developed around floor cleaning during the COVID-19 pandemic. Since March, weekly vacuuming of the floors has shown improvements: the count for June in the same location was reduced to 14 springtails. The overall counts indicate a difference between the basement floor, the ground floor and outer stores. Traps with GF (ground floor) in the trap number show a higher pest count (indicated in orange in Fig. 6), which probably relates to the more varied use that is made of some spaces, the presence of entry doors from outside, and windows which are not sealed.

## Conclusions

The DCT Collections Section is responsible for the care and preservation of tangible cultural heritage in the Emirate of Abu Dhabi. During the COVID-19 pandemic in 2020, staff developed the IPM policy and procedures. With support from location managers, curators, and Operations and Facilities Management staff, we have been working on implementing these across the venues in Abu Dhabi city and Al Ain. After initial problems such as disappearing traps, the main challenges now are the identification of the insects and the risk to collections. The interpretation and overview of counts depends on extracting the data from the collections management system.

The environment(s) found in locations in the UAE vary from dry and hot desert conditions to more 'usual' conditions indoors where the temperature is controlled by air conditioning. Related to this, catches of geckos, firebrats and ants can be explained. The presence of springtails, moths and woolly bears, and various beetles are considered as either environmental indicators or pests, and will require immediate action to be taken.

Although, prior to the development and implementation of the IPM policy, there were no signs of insect activity within the collections, since then cases have been identified both within the traps and some posing a direct risk to collection material. The policy and procedures, and more specifically the results from monitoring traps, are now being used to take actions to reduce the opportunities for insects to spread within the buildings thereby reducing the risk of damage to the collections.

## Acknowledgements

We would like to acknowledge the help of the various colleagues at the venues where IPM is being implemented. It is through their support and effort that the IPM programme will be successful in reducing the risk of exposure of the collections to damage by pests.

## Materials and suppliers

- Dekko Silverfish Bait (6 packs) boric acid: www.desertcart.ae
- Pest No More GP430 Silverfish Trap with lure (6 traps per pack): www.desertcart.ae
- Catchmaster cloth moth traps (2 per pack) 96 packs/192 traps: www.desertcart.ae
- Catchmaster insect trap and monitor, 30 pack: www.desertcart.ae
- Catchmaster 812sd pantry moth traps, 6 pack: www.desertcart.ae
- Catchmaster AA1170 72MAX Pest Trap, 72 pack, Mouse glue boards: www.desertcart.ae
- Trapper Insect Trap (for bedbugs, spiders, cockroaches) – includes 90 traps: www.
- Biocare clothes moth traps with lure, 10 pack: www.desertcart.ae
- Panko L-trap 5 pieces traps for flying beetles: www.deffner-johann.de
- Panko solaris LED light: www.deffner-johann.de
- Lo line insect traps (with cockroach pheromone) 10 pack: https://conservation-resources.co.uk/

## Notes

1. For the development of the policy and procedures we consulted MuseumPests 2021 and Faheem and Abduraheem 2019.
2. For a general introduction on insects occurring in the United Arab Emirates, see Gillett 2005.

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# What's bugging you? Research involved in the development of collection-specific IPM software and pest databases

Melissa King, Ana Martins, Nathan McMinn and Austin Senseman

**ABSTRACT** Data science, improved visualizations, and methodologies to enhance the user experience have the potential to make integrated pest management (IPM) more ubiquitous and accessible among cultural heritage collections. To understand the needs of professionals performing IPM for collections preservation, researchers at Conserv in the United States (Birmingham, AL), a company built by and for preservation professionals, sought to survey practitioners about their experiences through phone calls, questionnaires, and interaction on social media channels. The goal was to inform the design and implementation of a freely accessible integrated pest management application, and to integrate it in Conserv's environmental and light monitoring platform. The main objective – to support the preservation community's long-term research efforts into IPM – is achieved by facilitating access to the publicly available MuseumPests.net IPM database to help with the identification process. Another objective is to contribute to a Pest Occurrence Database to better understand overall trends in pest activity across collections. Since the early release of the IPM software in April 2021, more than 60 users in 20 countries have signed up and interacted actively with the IPM feature. By creating channels that facilitate direct feedback from software users, Conserv has been able to adapt its software to serve the needs of the field and prepare for future feature development.

**KEYWORDS** IPM application; Pest Occurrence Database; environmental monitoring; survey

## Introduction

Conserv, a technology company based in Birmingham, Alabama in the United States, is focusing on the creation of sensors and software to address risk management in cultural heritage through preventive conservation. The business model supports a free version of the cloud-based software to address one of its core missions: to make quality preventive conservation tools accessible to cultural institutions large and small. The team at Conserv is constantly seeking feedback and input from preservation professionals and is devoted to the creation of a full suite of tools to benefit the cultural heritage community. The authors have spent hundreds of hours speaking to collection professionals to build a deep understanding of their everyday challenges and aspirations. The feedback from these conversations are distilled and recorded within a product management software (Productboard, Inc) to help software engineers at Conserv prioritize which features to create within the software. Collection professionals can also contribute directly to the Productboard, either from the Conserv software or feedback solicited via social media channels (Fig. 1).

## Justification for the creation of IPM software

Conserv initially focused on the creation of environmental monitoring software, and then began developing an IPM component to the software in earnest at the end of 2020. The team prioritized it for several reasons:

- IPM is a key part of a complete preventive conservation program and is a core part of Conserv's mission to develop software to support such programs.
- Interviews with contacts and customers suggested that there were limited solutions available on the market to collect and visualize IPM data catered specifically to collection preservation.
- Bringing analytics for environmental and IPM data together could help users identify and understand potential correlations between pest activity and environmental conditions.

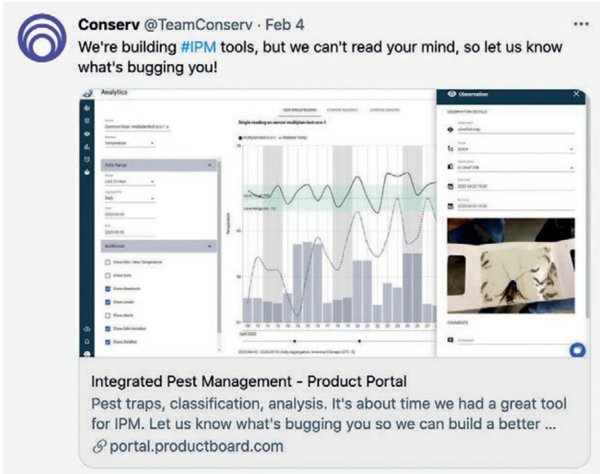


**Figure 1** Screenshot of a Twitter post calling for users to submit suggestions on how Conserv should build the IPM module, using the link of the Conserv Productboard (https://conserv.productboard.com).

## Consultation: pre-design phase

Decisions and choices for the early design of the IPM module within Conserv were guided by the information collected in Productboard and by a new round of IPM-focused feedback calls with approximately a dozen collections. Professionals from these collections generously shared the tools and spreadsheets they use for collecting and managing IPM data, which helped engineers at Conserv identify and structure the attributes to include in the initial platform. Conserv also looked in detail at the existing commercial IPM products on the market, and at the literature (U.S. National Park Service 2000; Querner 2015; Henderson *et al.* 2017; Baars and Henderson 2020). Initially, it was clear to the software engineering team that the product should include access to images of pests within a database, the ability to identify pests within the tool, and some data visualization capabilities.

## Early access to the software and pre-onboarding survey

Early access to the IPM software was released in early April 2021 and priority was given to those who expressed interest in trialing the software through Conserv's social media campaigns. Access to the software includes a short survey on users' current/pre-existing IPM and environmental monitoring experience, challenges, and goals. Once the survey is completed, participants are provided a login to

**Table 1** Conserv software sign-up pre-onboarding survey.

| **Do you have an integrated pest management (IPM) program?** (165 respondents) | **What IPM software do you use the most?** (109 respondents answered yes to having an IPM program) | **What frustrations do you have with current integrated pest management tools?** (109 respondents answered yes to having an IPM program) |
|---|---|---|
| Yes (66%) | Excel or paper (95%) | No frustrations (23%) |
| No (34%) | Others – zPest Tracker, PowerBI, Microsoft Word (5%) | Frustrations in efficiencies and actionable ways to respond to the data (77%) |

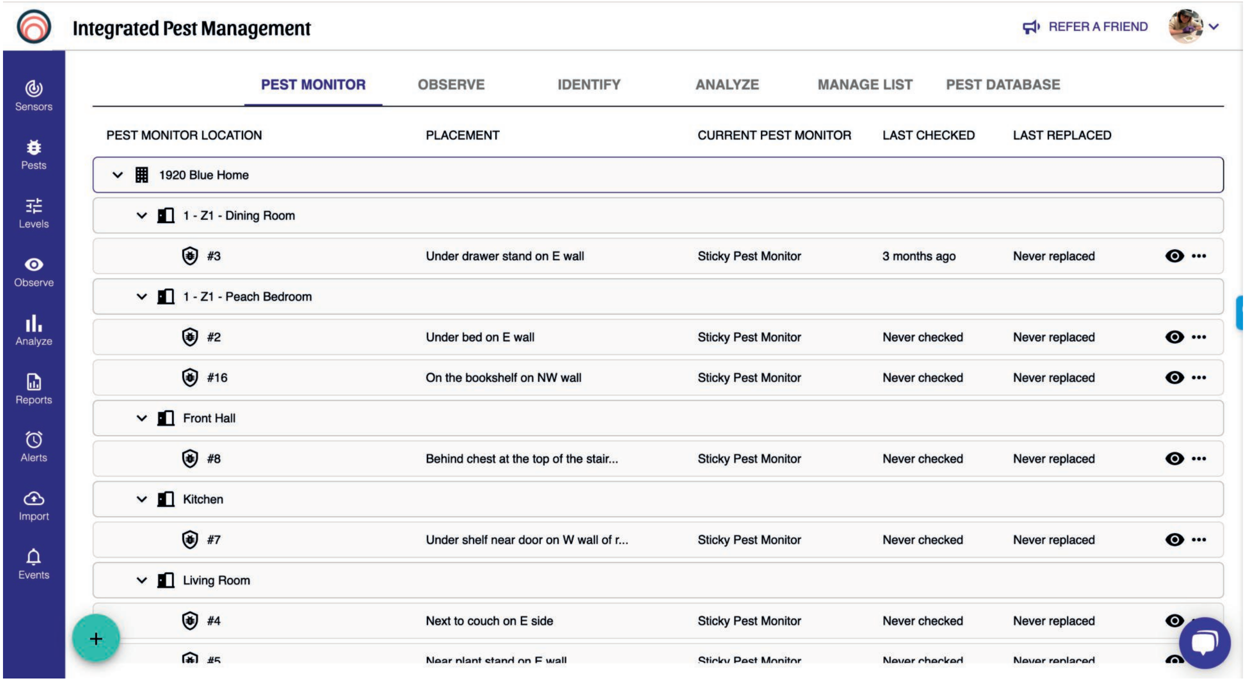

**Figure 2** Screenshot of the IPM dashboard showing the hierarchy of placement for the pest monitors in the Conserv software.

the Conserv software and invited to an 'onboarding session' with a team member from Conserv to introduce the software. The pre-onboarding survey includes questions about IPM (Table 1)

## Pre-onboarding survey results

Conserv is still collecting data through the pre-onboarding survey. At the time of writing, there were 165 contributions. Within that group, 109 (66%) had an IPM program, only 5 respondents (5%) were using a dedicated IPM software, while the remaining 104 (95%) were utilizing Excel or paper to record pest monitor identifications. Out of the 109 respondents undertaking IPM, 25 (23%) reported no issues with their current process, while 84 (77%) listed frustrations, mostly that their process was inefficient or lacked clarity in actionable ways to respond to the data. Examples of some these frustrations include:

- There's no easy way to track everything – from what we see to how often we need to remember to check/reset the monitor traps.
- We don't know what to do with the data if it's not an obvious infestation.
- We would like to make better use of our IPM data, which is currently recorded in Excel. Flexibility with data visualization and the ability to create a range of reports for a variety of stakeholders would be beneficial.
- Not able to link photos. Difficult to track pests, doesn't give a comprehensive understanding of what is happening within the building.
- It's a very disjointed process and the work tends to fall on one person.

In summary, of the collections with IPM programs surveyed so far, only 5% are using dedicated IPM tools and 77% are experiencing major frustrations.

## IPM software at a glance

The Conserv IPM software is composed of several tabs to help organize user workflow. The user must first create a location for each pest monitor within the same hierarchy of buildings and spaces (Fig. 2) that is used for the environmental monitoring features (this will allow users in the future to more easily correlate IPM and environmental data). Users can specify the type of pest monitor (e.g. sticky or pheromone), include a description, and upload an

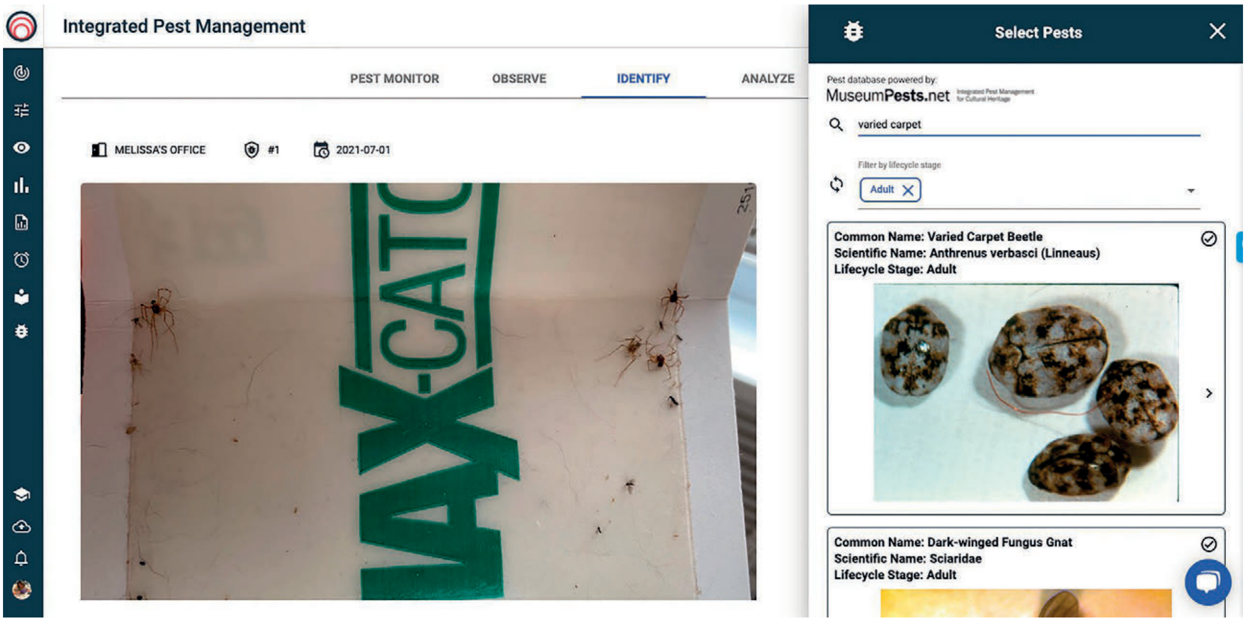


**Figure 3** Screenshot of the IPM dashboard for the pest identification step in the Conserv software.

image of the pest monitor's location. They can also indicate when the monitor was last replaced.

Once pest monitors are accounted for within the software, users can start recording observations such as images of the pest monitors, which can be uploaded *in situ* in the galleries when utilizing the Conserv mobile application, but they can also be more generalized and associated with a space. The observations are then processed in the 'Identification' step. The user has access to the images uploaded to the 'Collection Pests Database' (CPDB) to carry on the counting and identification of the pests. The CPDB is maintained by the MuseumPests.net Working Group in the United States[1] and is a continually growing list of insects and vertebrates compiled by entomologists and experts in IPM. This database is maintained in a cloud collaboration database service (Airtable).[2] It is considered to be a comprehensive list of species that pose a risk to collections, called 'pests', and also those that might indicate a building infrastructure or environmental problem within the space, referred to as 'indicators'. The user can search the database and use a lifecycle stage filter (Fig. 3).

Another aspect of the Conserv IPM module is the analysis tab. The tools included in this tab allow users to visualize their IPM data as a time series graph for overall pest counts and as pie charts that show the distribution by pest types and spaces. The analysis also includes visualization for normalized data utilizing the Pest Occurrence Index (POI) (Baars and Henderson 2020). This visualization is intended to reduce bias in data interpretation by normalizing it against the number of pest monitors and surface area of the space, and against the duration of the monitors' deployment.

## Adoption and feedback of IPM software

As of June 2021, Conserv had approximately 60 monthly active users interacting with the IPM feature specifically. Of those, 36 have created 1227 IPM observations overall (1121 linked directly to pest monitors and 106 to spaces). Given the relatively slow pace of IPM programs (most users only check monitors every 1–3 months), this represents a good software adoption rate.

Users are also providing feedback during directed or spontaneous feedback calls, email communications, and support cases (an average of five observations per user has been recorded into Productboard). So far, the feedback for Conserv's IPM software falls into four main categories:

*1. The list of important pests is very specific to the institution*

Since the MuseumPests.net database primarily includes insects/vertebrates that are considered pests or risks to collections, many insects/vertebrates collected on pest monitors by users are not included in the database although users would still like to capture that information. Having the possibility to select pests from a shorter and more personalized/dedicated database would also agilize data entry. This feedback encouraged the Conserv team to develop a feature that will allow users to create customized pest lists that include their own entries into a customized database per organization.

*2. Data entry has to be efficient, or people simply will not do it*
User interviews helped the team at Conserv understand the different ways they collect and enter pest data. Novices may need a lot of help, with large images, zoom functions, and other tools designed to help them reach an accurate identification. Experts, on the other hand, look for bulk entry and editing with less of a need for identification help since they are already aware of which common pests are causing problems in their institution. Allowing identification to happen directly in the mobile application as users make observations *in situ* would also streamline the process. It has become clear that the IPM module will need to serve users along the continuum of IPM expertise by offering multiple ways to enter pest data.

*3. People want better tools to manage the whole process*
Feedback from Conserv IPM's early adopters indicates that there is a clear need for features within the tool to better manage the overall IPM process. Some of these requests have included the ability to easily mark pest monitors as 'checked' even if there were no identifications (i.e. an empty pest monitor). The ability to indicate bulk replacement of pest monitors and set up replacement reminders would also be useful.

*4. More options for data analysis*
It is still too early for users to reap the full benefit of the analysis portion within the software since most people have not entered more than a few months' worth of data. However, much of the feedback surrounding data analysis indicates that users would like a POI variant that would allow the inclusion of pest observations found outside of pest monitors. Additionally, they have been requesting the ability to separate the data along multiple dimensions to look, for example, at pest distribution by space (which space has the highest count?), look at pests by type (which pest is the most common?), and to be able to filter out irrelevant data. The first request is the most common within large institutions where different users may be responsible for different areas of the museum. Finally, users commonly ask for the ability to visualize IPM data overlaid on building floor plans. Spatial analysis can help both to visualize problem areas within a building and follow the spread of pests from one space to another.

## Future developments

The Conserv IPM feature is available to anyone who signs up on the Conserv website,[3] but future developments are already in discussion:

- There is great potential for utilizing forms within Airtable and inviting users to contribute user-generated images to the CPDB managed by MuseumPests.net. For example, if a user is uncertain about an insect identification, Conserv could build a tool to allow them to forward the image to MuseumPests.net listserv to obtain the opinion of pest identification experts.
- It will be helpful to layer both IPM and environmental data on floor plans to contextualize the space in order to build a better understanding of insect activity and its correlation with the building environment and envelope.
- Conserv would like to make it possible for users to opt into a Pest Occurrence Database (PODB), an anonymized dataset of pest identifications to be compiled into a big data structure. Users entering data into the IPM software will be addressing their individual collection challenges while also effortlessly contributing to a rich dataset for future academic research. Transitioning from siloed IPM spreadsheet solutions to a large data structure will empower the field to use artificial intelligence and machine learning processes to develop predictive models for classification and infestation.

## Conclusions

Based on conversations with Conserv's software users, the team determined a clear need for updated IPM software to serve the field of cultural heritage. This was confirmed through hundreds of hours of direct conversations with collection professionals, written suggestions through Productboard, and survey results. These conversations and feedback from early adopters to the software helped Conserv develop specific features that address the need to simplify IPM methodologies and assess the data using analytical tools developed for the field. There is still more work to be done to address requests for more features and enhance the software experience. However, the early feedback suggests it provides a much-improved approach to IPM data capture and reporting in a collection setting. Conserv is committing to a free version of the software to benefit the field of cultural heritage preservation.

## Acknowledgements

We wish to acknowledge the MuseumPests.net Working Group for their expertise and time in the creation of the Collection Pests Database. Special thanks to Rachael Arenstein, Matthew Mickletz, and Pat Kelley for coordinating the effort to transition MuseumPests.net's former database into Airtable. In addition, the many people who provided direct feedback are gratefully acknowledged including: Gretchen Anderson, Hilary Jarvis, Dara Lohnes-Davies, Michael Millican, Jessica Lewinsky, Ashley Bowersox, Marie Desrochers, Margalit Schindler, Catherine Silverman, Karen Macke, Bhavesh Shah, and Alexander Kikutis.

## Notes

1. See https://museumpests.net.
2. See https://www.airtable.com.
3. See https://conserv.io.

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# Remote monitoring for museum pests: a 21st-century approach

Adrian M. Doyle, Patrick Kelley, Fabiana Portoni, Tatiana Marasco and Carlos Austin Gonzalez

**ABSTRACT** Monitoring insects is a fundamental element of integrated pest management (IPM), and advanced planning is crucial to allocate staff sufficient time to replace monitors, identify insects and respond to concerns. As is fairly standard in museums and other cultural heritage collections, the British Museum undertakes quarterly monitoring. Teams of trained collections care staff check catch numbers, differentiate species and take actions based on 'normal' expectations derived from previous data, knowledge of their collections and experience. However, several situations can make monitoring challenging such as restricted access to traps, loan agreements, difficult-to-reach and poor line-of-sight areas sometimes requiring complex coordination, and fast response time to unexpectedly high catch numbers. The remote monitoring in this study focuses on the battery-powered SightTrap system and its accompanying software ForesightIPM used in conjunction with pheromone attractant lures for webbing clothes moths (*Tineola bisselliella* (Hummel, 1823)). The British Museum is the first UK cultural heritage organisation to pilot this innovative remote monitoring system in two selected locations: a high-profile temporary exhibition and two areas identified as problematic with persistent pest populations. This pilot aims to inform future decisions as to how to make insect monitoring more accessible and effective.

**KEYWORDS** Integrated pest management; IPM; IPM in museums; remote pest monitoring; IPM new technologies

## Introduction: background to the project

The notion of trapping insects with sticky materials to monitor for their presence is not a new concept: it is documented that the ancient Greeks filled bowls with goat grease to capture insect predators such as bed bugs and fleas (Beavis 1988; Child and Pinniger 1994). More recently, advances in pheromone technologies (Trematerra 2012), adhesives and evolutions in trap design (Mullen 1994) have considerably improved the effectiveness of pest monitoring. Today, monitoring with strategically placed pest monitors within cultural heritage settings is a recognised integral and efficacious part of an integrated pest management (IPM) programme that informs collections teams of pest populations. However, it is a high-resource strategy requiring staff availability to remove, replace and inspect insect monitors which may be positioned in challenging locations that need complex coordination for access.

Remote pheromone monitors that send a daily photographic image of pest captures to a software programme via wireless internet signals first became available for indoor storage spaces in 2019, and this technology may be an integral part of overcoming these challenges in a cultural heritage environment. Entomologists employed by the manufacturer can identify, count and record daily trap captures and then publish this information within the software programme. The recorded information and images are then sent to a smartphone app and website for simple review by museum staff. Appropriate actions can be taken based on activity.

## Remote monitor: SightTrap

The remote monitor described in this study, the SightTrap, is used in conjunction with the software platform ForesightIPM (Fig. 1). SightTrap and ForesightIPM are manufactured and sold by Insects Limited (Westfield, IN, USA).[1] The SightTrap device utilises a built-in 5-megapixel camera and LED lights to capture a daily image of the contents inside a monitoring trap in two configurations: hanging or floor mounted (Fig. 2).

Besides being placed in typical locations for ongoing pest monitoring, SightTraps can also be positioned in areas where opportunities for real-time pest information is not possible. Continuous pest monitoring in restricted access spaces, electrical/plumbing/HVAC conduits, voids beneath floors, off-site storage locations and highly secured storage areas is very desirable, specifically when an active infestation has been identified. Global trends in pest monitoring seem to be leaning towards the increased use of the Internet of Things (IoT) and monitors which collect pest information that can be instantly accessed from remote locations seem very attractive. According to IPM expert Robert Corrigan, 'Monitoring is a critical part of prevention and IPM, and remote sensors take us there with data, take us there with assurance and take us there with 365/24/7 coverage. … There is no better way to monitor than with remote sensors in the right places' (Schröer 2021).

Unbaited traps can be used as simple blunder traps to monitor for pest activity passing through an area while enhanced monitors with sex pheromone lures can be employed to lure insects into the photographic capture area of the trap (Figs 3 and 4). Pheromone lures specific to museum pests have been shown to be effective at drawing in insects

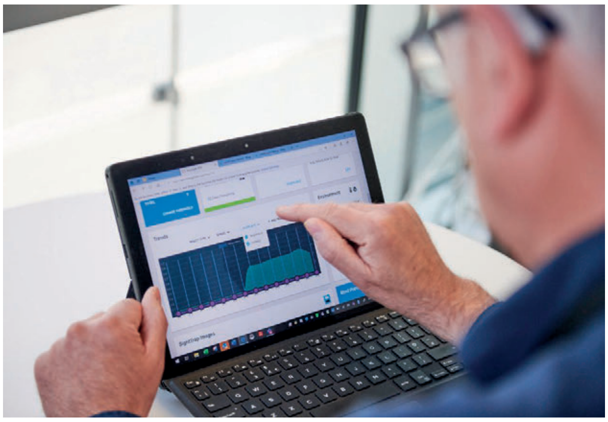

**Figure 1** An over-the-shoulder view of the software.

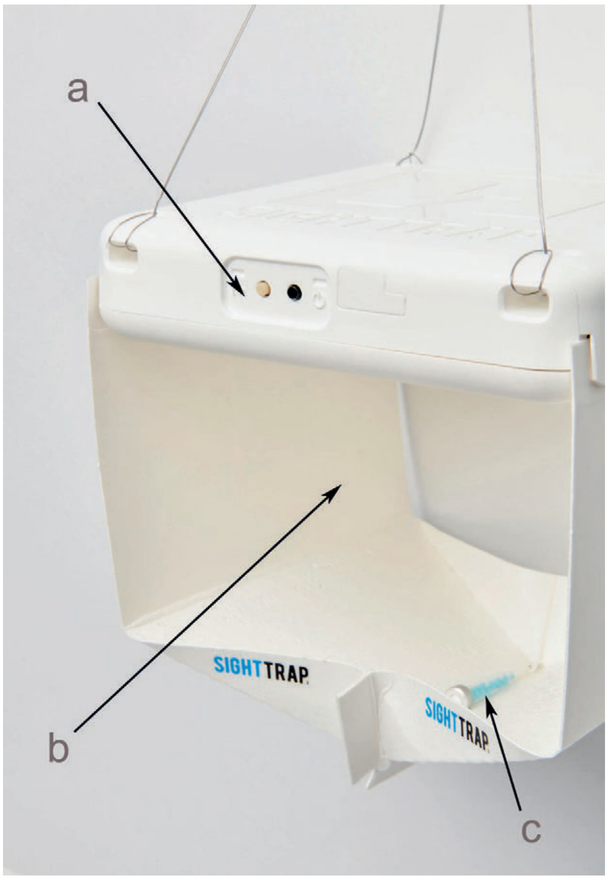


**Figure 2** Close-up of a hanging SightTrap with replacement pheromone pad: (a) built-in 5-megapixel camera, (b) photographic capture area of the trap, (c) pheromone lure.

such as the webbing clothes moth (*Tineola bisselliella*), carpet beetles (*Attagenus unicolor* (Brahm, 1791), *Anthrenus verbasci* (Linnaeus, 1767) and *Anthrenus sarnicus* Mroczkowski, 1963), biscuit beetle (*Stegobium paniceum* (Linnaeus, 1758)) and cigarette beetle (*Lasioderma serricorne* (Fabricius, 1792)) (Pinniger *et al.* 2003). Trained entomologists view the captured image that is taken once


**Figure 3** SightTrap standard arrangement supplied hanging.


**Figure 4** SightTrap standard floor-mounted arrangement with bullet lure.

each day by each SightTrap and that information is counted and inserted into the ForesightIPM software program.

The software is accessible remotely via a login and password-protected web browser. It allows the data to be filtered and viewed in a graphic format or as raw data: graphic displays show temperature and humidity readings taken from the trap itself, alongside the insect capture data. This feature is particularly useful to help to understand the correlation between the presence of insect species and specific environmental conditions. Even though the British Museum monitors temperature (T) and relative humidity (RH) across the estate using a radio telemetric system, the standard T/RH sensors are intentionally placed in areas where objects are stored or displayed. However, these areas do not always represent environmental microclimates within the building. The nature of some of the spaces to be monitored, such as areas with restricted access and voids beneath floors, means that their environmental conditions often vary significantly from the conditions logged by the ambient sensors. The fact that the traps are able to log environmental data from the exact location where pests are monitored helps to provide precise environmental datasets. This information can facilitate understanding of the environmental microclimates in the monitored areas as well as the link between behaviour and movement of the insects within specific environmental conditions in the museum. Moreover, in the future this monitoring feature has the potential to help offset the need for extra T/RH monitors in some of these areas.

## SightTrap technical specifications

The whole system is powered by a rechargeable lithium ion battery and the trap communicates through a WiFi connection that needs to be supplied in the same location as the traps. The ForesightIPM dashboard displays the current day's image as well as those from the previous six days. This allows the user to visually compare capture rates over the period of a week and the wide selection of editing tools enables locations to be changed, reports downloaded and information to be shared. The choice of location for the technology was dependent on several criteria. Bearing in mind the project was intended to establish opportunities for remote monitoring, we decided to include:

- Areas where there is adequate WiFi provision
- Areas where current active monitoring is undertaken
- Areas with persistent active webbing clothes moth activity

In addition, a high-profile exhibition was selected as part of promoting the study.

For the SightTraps to be able to communicate using WiFi, they need to be connected to the network via a broadcast SSID.[2] A secure non-public SSID, already used at the museum for carbon dioxide monitors, was selected. Initially, its name was not broadcast in order to prevent visual clutter on devices used by visitors to search for available WiFi networks, as well as being an auxiliary security measure (e.g. hiding the network to discourage attempted connections from malicious parties). We had to broadcast the name, however, in order for the SightTraps to be able to connect.

Before connecting to the secure SSID, the museum liaised with Insects Limited to collate a list of URLs, with which the SightTraps regularly communicate, to be allowed through the firewall. SightTraps communicate upload images directly to Amazon Web Services (AWS) servers and also with time servers to get a timestamp; they must be able to successfully contact both types of server in order to complete an upload. Devices that have failed to complete all steps during a 10-minute period, due either to insufficient WiFi signal strength or firewall permissions, will reattempt to upload their backlog of data the next time they turn on.

There may be regional variations in AWS server URLs that should be checked and accounted for in the firewall and may not be obvious before the first attempt at connection. To avoid frustrating connection difficulties it is helpful to have another person with oversight of the network infrastructure on the line. A SightTrap's ID is one and the same as its MAC (Media Access Control) address, the unique identifier for a network device, which allows for easy matching of the physical device with its presence on the network. WiFi connectivity was configured locally using the mobile app in conjunction with the trap (Fig. 5).

The QR code on the side of the SightTrap stores the unique device ID, which is also its MAC address. Scanning this QR code through the mobile app allowed museum staff to input the WiFi name and password. Once the device had been turned on and the WiFi credentials entered on the app, the mobile device communicated credentials with the trap via Bluetooth. To maintain secure access to configurations, the ForesightIPM mobile app was cleared for installation by the museum's Information Services (IS) department and installed on a museum-provided phone assigned to the IPM manager. Access to the phone is locked behind the British Museum Active Directory credentials of the user to whom it is assigned.

**Figure 5** Photo showing a mobile (cell) phone linking to SightTrap.

## SightTrap pilot sampling locations at the museum

The following locations were chosen where all the selection criteria could be met: the requirement to test the effectiveness of the WiFi, accessibility to the SightTrap units, and the need to investigate increases in webbing clothes moth activity:

- Greek and Roman galleries
- Middle East galleries
- 'Nero': a high-profile temporary exhibition gallery

Setting up the SightTrap in these areas was straightforward and relied on previously identified areas where the equipment could be suspended via the magnets in a void behind a showcase as well as a floor-mounted monitor inside a plinth, beneath a showcase. The British Museum uses webbing clothes moth pheromone lures in the standard 'AF' monitors and as a test, a pheromone 'pad' was cut to fit inside the hanging monitor as a comparison against a second monitor with the supplied 'bullet lure'. The floor-mounted monitor was fitted with a supplied carpet beetle lure to test this configuration.

## Conclusions

This was a unique opportunity to undertake a one-year trial period while the team evaluated the performance of the hardware/equipment in a selection of configurations, locations and situations. The SightTrap hardware and the ForesightIPM software have been providing ongoing, real-time pest data to large food processing plants and food warehouses since 2019. This information has proved to be extremely valuable to those organisations, enabling them to not only react more quickly to increases in pest activity but also to monitor areas that were previously inaccessible to human inspection.

To evaluate the technology in a 'live' museum setting is invaluable and as more live data are produced, increased assessments can be made. Further evaluations of the original British Museum IS project research proposal will be made after a 12-month pilot of the 10 traps. The British Museum's digital and technology board will be presented with a closing paper that analyses the impacts, successes and shortcomings of the SightTrap, which will inform the museum's strategy for implementing the SightTrap in the future.

The project will help to increase understanding of the presence of insect species, in particular webbing clothes moth, across the museum. Areas identified to have webbing clothes moth activity can be monitored in real time, helping to keep track of pest activity close to objects or collections particularly vulnerable to pest damage. The project report will include the option for SightTrap to become part of permanent IPM monitoring, complementing the traditional monitoring on a quarterly basis for investigation in areas which are inaccessible or hard to access, such as voids under floorboards. This will provide a better understanding of the movement of insect populations across the estate and promote a prompt response to mitigate any increase in insect numbers.

Additionally, we can consider this technology as an opportunity to increase the need for remote monitoring of pests for our own institution, reducing the need for staff commitment, as well as complementing existing monitoring during exhibition or new building installations. Perhaps more significantly, alongside other institutions, the British Museum is developing off-site storage, a facility located at a considerable distance from the museum's central London main base. Due to possible limited staff at off-site storage facilities, remote monitoring will be a particular advantage for collections, including those highly susceptible to pest damage where quarterly monitoring programmes may be the only opportunities provided for staff to inspect these collections.

## Future developments

Future developments with the SightTrap and ForesightIPM include a better defined and permanent set-up to record the capture of crawling insects, and a more robust software dashboard that will feature a wider variety of stored product pests including more museum pests. Future versions will also look at adding multiple cameras or advanced camera lenses to give higher resolution pest images for identification purposes.

## Notes

1. See https://www.insectslimited.com/.
2. SSID stands for Service Set Identifier, the unique name given to a WiFi network that can be seen by all users connected to it.

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- Carlos Austin Gonzalez, Project Manager, The British Museum, London, UK

# Training, tools and technology for managing IPM at the Victoria and Albert Museum, London

Bhavesh Shah, Valerie Blyth, Maria Ines Carvalho and Anne Bancroft

**ABSTRACT** Integrated pest management (IPM) at the Victoria and Albert Museum (V&A) in London has been established for nearly 30 years and was formalised in 2006 with the creation of the Preventive Conservator post. As new sites are being added to the V&A family, using remote technology to help with the collection, analysis of data as well as training staff is being adopted in a post-COVID-19 working environment. The availability of state-of-the-art data science tools, low-cost sensor-camera technology and the retirement of experienced Senior Preventive Conservator Valerie Blyth has provided the motivation for introducing these new platforms. The three emerging themes that are being explored are data science tools, online training and technology. Tools to capture data are being developed with the IT department that allow inspections to be recorded remotely and the data integrated into an online reporting platform. Online training modules are being added to the training package for V&A staff. We have also developed a mini 'security camera' using a Raspberry Pi and low-cost camera technology.

**KEYWORDS** Data science; IPM; Raspberry Pi; training; technology; R Shiny

## Introduction

The provision of integrated pest management (IPM) at the Victoria and Albert Museum (V&A) in London was a vital part of continuing to provide care of the collections during the period when the population of the UK was confined to their homes under lockdown to prevent the spread of COVID-19, and the closure of all museums and galleries. Staff who were normally engaged with checking insect traps were either working from home or furloughed. Staff who remained on-site during this time, such as the security and cleaning teams, were asked to assist with and maintain the programme under the remote guidance of the Conservation Department. This experience allowed us to action ideas that had been in development but had not yet been implemented, namely, using recent developments in data science and digital tools that could be integrated to provide additional support in the future.

The recent advancements are expected to become a regular feature of IPM following the departure of Valerie Blyth who, after working at the V&A for 32 years, retired in September 2020. She was instrumental in promoting IPM throughout the museum and was responsible for developing the 'risk zone' strategy as well as naming the brown carpet beetle (*Attagenus smirnovi* Zhantiev, 1973) as the 'vodka beetle' (Pinniger 2011). The V&A will be moving to multi-site working in the near future as part of the current expansion. Once the new site in Stratford is up and running this will require IPM for a new museum as well as storage space. With this expansion in mind and in order to maintain and advance the IPM work, a new preventive team has been created and will be responsible for looking at preventive issues in a more holistic way (Smith and Blyth 2005).

## Tools

There are approximately 1,000 pest traps and pheromone lures being used at any one time across the main sites of the V&A museum estate, making analysis of the data collected and presenting the results challenging. The increasing availability of data science technology allowed for the development of tools for reporting and recording pest monitoring data. Different platforms were used during the lockdown period to inform the creation of digital and online tools such as, for example, the map of trap locations that had traditionally been managed locally on paper-based systems. Data science tools are ideally suited for these kinds of challenges.

### Deciding which platform to use

A number of platforms were explored, each supporting different aspects of IPM and each with its own advantages and limitations. It was determined that no single platform could perform all the necessary functions for IPM, however, the ability to record data online and in the iCloud meant that data could be accessed and linked to other data science tools such as creating a real-time interactive website.

### Creating the tools

Some of the challenges faced during lockdown included locating the traps and asking staff who were unfamiliar with IPM to record the findings (Blyth and Smith 2011). During the lockdown, there was no access to the original documentation such as floor plans and locations of insect traps. In order to decide on a plan of action, the data needed to be gathered into a new IPM management system and placed into a new data collection system. Data science tools proved helpful for this task and were developed to address the following:

- A quick reference of the insect pest trap and moth lure locations was added to a Google map. The map locations were colour coded according to a risk zone and an image of the trap or location.
- A Google Form was used to replace existing paper records and spreadsheets to collect pest trap data.
- An interactive website was created using R Shiny[1] to present, analyse and communicate findings.

These tools are freely available online and are reasonably easy to set up. Online resources are available to show how to create them. We experienced issues with using Google Forms, as it records the IP addresses of the user and requires a Gmail account therefore it will not be used to record data in the future. A Microsoft Form is being developed as an alternative.

The benefit of moving to data science platforms is that it provides the ability to utilise state-of-the-art techniques for the analysis of IPM data in the future for:

- the creation of interactive online tools;
- data visualisations and mapping;
- customisable and downloadable reports;
- statistical analysis and machine learning techniques.

The limitations of modern data science tools have also become apparent: they are generally more complicated to set up and issues of security and data ethics also need to be considered:

- Coding can be intimidating the first time and it may be difficult to adapt a code for a new project, even for experienced coders.
- Where and how to store data is a challenge.
- Having to maintain the coding after updates and fixing 'bugs' is difficult.
- Possible data security and user privacy issues.

Using temperature and humidity data, an online interactive website application was created to display the data and report key incidents. The application was designed to only present critical information and draw readers' attention to items requiring action. All the preventive issues were combined to provide a one-page summary of the issues highlighted on the V&A map. The online tool is still being developed, including seeking ways to present the data to the key stakeholders (Fig. 1).

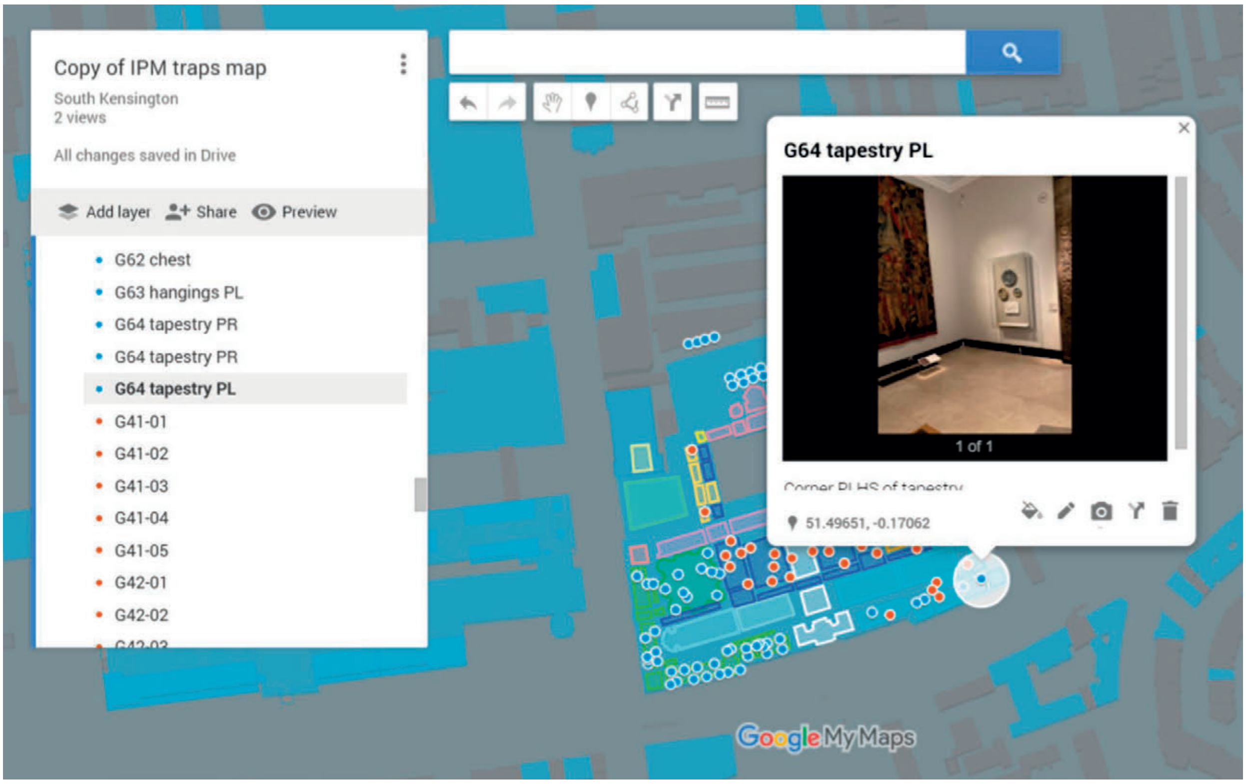


**Figure 1** Screenshot of the IPM form created in Google forms (top left) and images of the map.

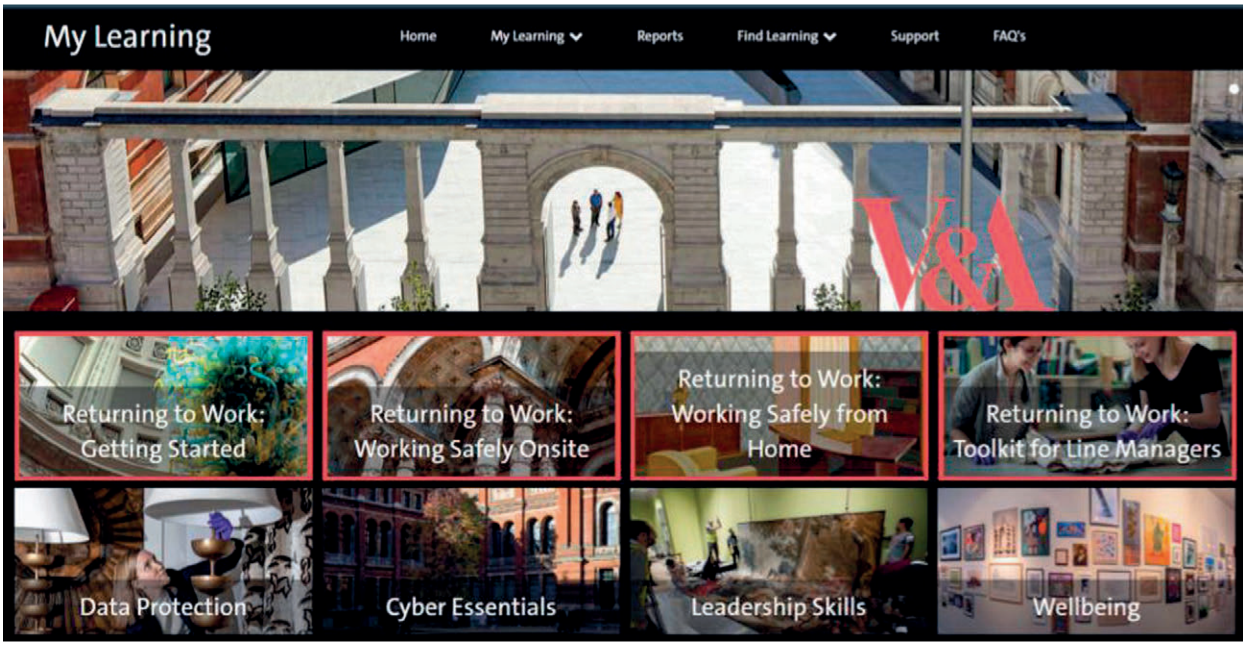


**Figure 2** The training modules offered on the V&A's training platform. An IPM training programme is being developed with the Training Department.

## Going forward

More recently, new software platforms such as Conserve.io[2] have done much of the hard work of establishing online platforms for the conservation community through its online tool. This is being evaluated as a potential solution going forward. Online training groups such as the newly founded ConCode network[3] provide platforms for learning how to develop and utilise data science tools

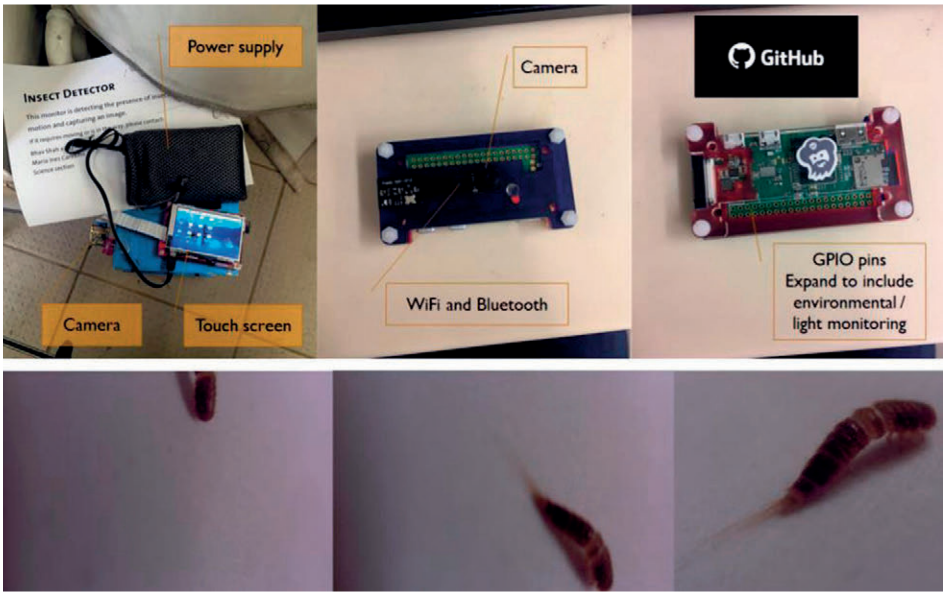


**Figure 3** The Raspberry Pi IPM monitor created with an example of some of the images captured.

in-house by IPM managers in the future. This group will help overcome the barriers that exist to creating these tools.

## Training

Digital training platforms will be the 'new normal' for the foreseeable future. The V&A has moved to place learning modules online that staff can access and register for training (Fig. 2). This platform will be important in a museum where there is increased home working, tightening budgets and a reduction in the ability to facilitate in-person training. Being able to train someone on how to check pest traps in a short space of time will be vital when working across multiple sites that are planned for opening in the near future. Having sufficient numbers of staff available for the urgent inspection of traps will be crucial.

## Technology

The Raspberry Pi Foundation has been producing low-cost programmable computers for the purpose of teaching people how to code. Commercially available sensors and cameras were utilised to develop a product that could capture insect data in real time and alert IPM managers of insect activity in the event of a breakout.[4] During her student placement, Maria Ines Carvalho from the University of Porto used a code available on Github[5] for developing a motion-detecting insect 'security camera' that would activate when motion was detected and record the images. The cost of each Raspberry Pi security camera is about £40 per sensor – almost equivalent to the cost of 1,000 insect traps.

Using a Raspberry Pi connected to the internet provided information in real time without having to wait for the time between checks (Fig. 3). With the development of this method, we are working not only to provide a new form of monitoring, but also towards the development of a technique that can be used in countries where the capture and killing of insects are not acceptable, such as in Buddhist and Jain temples that do not allow techniques to be used that result in the death of insects.[6]

## Conclusions

The future of IPM at the V&A under a newly created preventive conservation team is an exciting opportunity to build on the legacy of previous work conducted by respected colleague Valerie Blyth. For any IPM programme to be effective, it is still critical to develop relationships between those carrying out and managing the tasks, and this can never be replaced by technology: the technology is designed to support and not supplant these roles. The speed at which many people in the museum sector have had to adopt new technology during the lockdown period has provided an opportunity to modernise and integrate new IPM programmes to advance conservation in museums.

## Acknowledgements

We are very grateful for the support of the teams who took on additional responsibilities during the lockdown period including front-of-house, technical services, security, cleaning and housekeeping.

## Notes

1. See https://shiny.rstudio.com/.
2. See https://conserv.io/.
3. See https://www.concode.info/.
4. See https://www.raspberrypi.org/blog/monitoring-insects-at-the-victoria-and-albert-museum/.
5. See https://github.com/pageauc/pi-timolo.
6. See https://www.vam.ac.uk/blog/caring-for-our-collections/making-a-simple-insect-activity-monitor-using-a-raspberry-pi.

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# The use of technology to manage the next generation of house mice

Chris Swindells

**ABSTRACT** Since the conference, *A Pest Odyssey: 10 Years Later* (2011), there has been a proliferation of remote rodent monitoring technologies offered to the pest control market. The possibilities of 24/7 monitoring provision, reductions in costs and time on-site, environmental considerations and perhaps existing treatment failures have seen a slow but gradual uptake of these systems by some pest control companies and their clients. Not all remote monitoring systems operate in the same way: some rely on traps, others on movement sensors, and some a combination of both. When used correctly, and as part of a good integrated pest management (IPM) programme, remote rodent monitoring technology can be extremely useful in identifying activity patterns, areas requiring treatment and measuring the success of a rodent control programme in real time. However, there is still a need for qualified and experienced personnel in the field to analyse the data generated and carry out proactive inspections of vulnerable and high risk environments.

**KEYWORDS** House mice; *Mus musculus*; rodent; integrated pest management (IPM), remote monitoring

## Introduction

For many years, the pest control industry in the UK has traditionally relied on the use of traps and rodenticide bait formulations to both monitor and manage house mouse (*Mus musculus* Linnaeus, 1758) activity. Anecdotally, we are increasingly coming across house mice infestations that are difficult to monitor and control with the use of conventional monitoring baits and traps. There are some very real challenges being experienced on many sites that we visit, often due to the environment, building fabric or simply poor pest control practices – all of which with some effort can be managed and improved. Monitoring and gaining control of some house mice populations is further complicated by behavioural issues such as bait box and trap avoidance, and genetic resistance to specific anticoagulant rodenticides. During a trial, remote monitoring technology (Simmons and Swindells 2017) was used to demonstrate the ineffectiveness of conventional monitoring techniques and the benefits of remote rodent monitoring technology against a population of house mice in a supermarket distribution centre. When deciding to use a remote monitoring system as part of an IPM programme, it should be recognised that 'intelligent' mice that avoid conventional bait boxes and traps are potentially just as likely to avoid remote monitoring technologies housed in conventional bait boxes or those reliant on traps.

## The house mouse

The biology of the house mouse is well documented but perhaps the most pertinent trait worth repeating here is the high reproductive potential. In ideal


**Figure 1** An extreme example of house mice travelling over a bait box and depositing smear marks over a prolonged period (© Chris Swindells/Kiwa 2021).

**Figure 2** Example of 'intelligent' house mice exploiting the design of this protective box (© Chris Swindells/Kiwa 2021).

conditions – availability of harbourage, food with water, stable temperatures and time to reproduce – a large infestation can develop very quickly from just a single pair. When these conditions are met, house mice may breed throughout the year.

## Monitoring and control

Typically, a preventive house mouse monitoring and control programme might consist of eight or more inspections per annum, with intervals of four to six weeks between inspections. For a long time, the monitoring of house mouse activity has been reliant on the use of a control product as the monitor. For example, it is still common to see rodenticide bait or set break back traps deployed as part of the permanent 'preventive' monitoring provision. These monitors may lie undisturbed in the same location, only visited on a six-weekly schedule without being relocated or baits refreshed for prolonged periods of time. It is speculated that this practice has contributed to some of the behavioural issues we now encounter on sites where bait box and trap avoidance is an issue.

### Behavioural issues

We have always been told that house mice are inquisitive, but it is evident on many problem sites that we inspect that there are behavioural issues resulting in bait box and trap avoidance. This is not a new phenomenon but anecdotally we are seeing more evidence of it. 'Not all mice are "curious" toward new objects in their path and may exhibit neophobic responses for varying lengths of time' (Corrigan 2001). Although often referred to as bait box avoidance, in many instances there is evidence that house mice will travel over a bait box (Fig. 1) rather than through it, without necessarily investigating the contents within.

If there is too much reliance on break back traps as the monitoring and control option, there is a risk that activity may go undetected. Subjected to various environmental conditions, some traps lose their sensitivity or are not sensitive enough to trigger an activation when house mice interact with them. Installing break back traps in protective boxes, to prevent unauthorised access or hide captured rodents, also poses a problem as in some populations house mice are avoiding these boxes. Figure 2 illustrates house mice exploiting the opening in the baffles in the roof of a protective box that enclosed the trap. This allowed the mice to go over the back of the trap and access the food used as bait, as indicated by the smear marks on the lower baffles and back of the trap.

### Bait palatability

In many locations it is difficult to find a preparation that some house mice populations will eat. Often this is reported as bait shyness or avoidance, but this problem is certainly exacerbated by the availability of alternative food sources. During the trial of the remote monitoring system (Simmons and Swindells 2017), the presentation of a palatable non-toxic bait formulation outside of a bait box was not sufficient to persuade the house mice population in the distribution centre to eat it. We often find that the lack of bait take does cause one significant issue: it is often interpreted as evidence that there is no house mouse activity occurring even if there are other signs present in the environment or the bait box.

**Figure 3** GTO detector mounted on drain guttering (© Chris Swindells/Kiwa 2021).

### Rodenticide resistance

Past treatment failures and selection of mice with specific gene mutations probably account for the anticoagulant rodenticide resistance found in some house mice populations. Although the available data do not cover all areas of the UK, the pest control industry, in collaboration with other stakeholders, has been able to identify locations of house mice populations that are less susceptible or resistant to two of the routinely used second generation anticoagulant rodenticides: bromadiolone and difenacoum.[1] In the UK, pest controllers and their clients are encouraged to submit tail samples for genetic testing to aid the identification of anticoagulant-resistant populations.[2]

## Remote rodent monitoring technology

In the last 10 years there has been both a proliferation and continued development of remote rodent monitoring options. Technological progress has resulted in equipment becoming smaller with improved connectivity and coverage, and in some instances significant advances in battery life, allowing true 24/7 monitoring capability. Economies of scale have resulted in the gradual decrease in the initial cost of components and systems, many of which now include improved reporting and analysis via a dedicated customer portal.

In 2011, Acheta Consulting Ltd investigated the possibility of using a remote monitoring system as part of its inspection service. The equipment available at the time was inadequate and while initially, but very briefly, we considered developing a system in-house, we soon came across some remote rodent monitoring technology exhibited at PestEx 2011 and manufactured by a Danish company Green Trap OnLine (GTO). The initial trial of the system (Swindells 2012) was very promising. Unlike other systems, it does not rely on a dedicated monitoring box or trap to collect data. Instead, the calibrated heat and motion sensor can be mounted on a bracket which can be fixed to the building fabric or on/in a monitoring box. The flexibility of this sensor appealed because it could be mounted to anything other than a bait box. In fact, we have often mounted the sensor on an upturned length of drain guttering as seen in Figure 3: it does not look like a bait box and allows continuity of the floor surface, both issues we hoped would reduce any bait box avoidance concerns.

In many trials since carried out, we have found this monitoring system to be highly effective at detecting low levels of house mouse activity. One of the biggest obstacles we encounter is from pest control contractors or clients who question its effectiveness and reliability, particularly as there is no capture or kill element to this monitoring system to verify the data it is collecting. Perhaps this is one of the system's advantages: it is truly a monitor that, unlike some conventional control options, is very good at detecting mouse activity. Where the system has reported mouse activity, video footage, tracking in dust or absence of a chocolate button bait have verified the detections recorded and proved the doubters wrong.

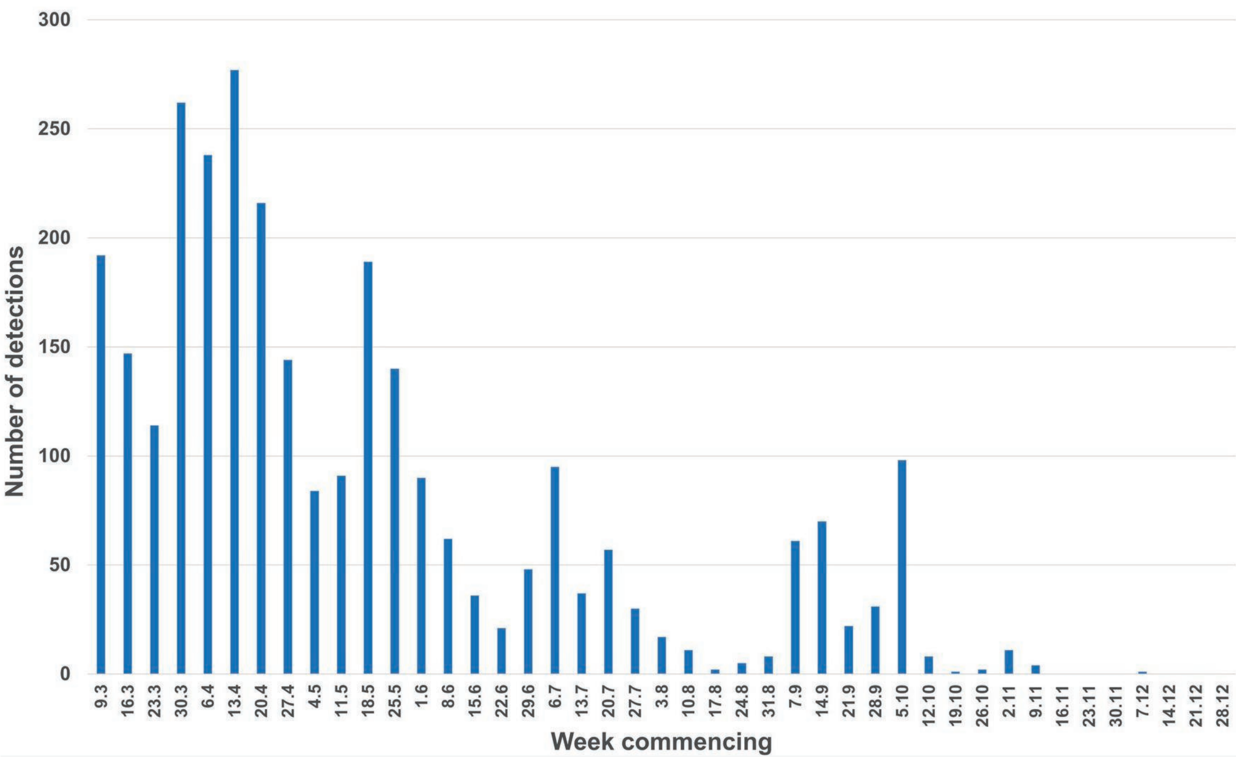


**Figure 4** Trending house mouse detections in a retail environment during the UK COVID-19 lockdown (© Chris Swindells/ Kiwa 2021).

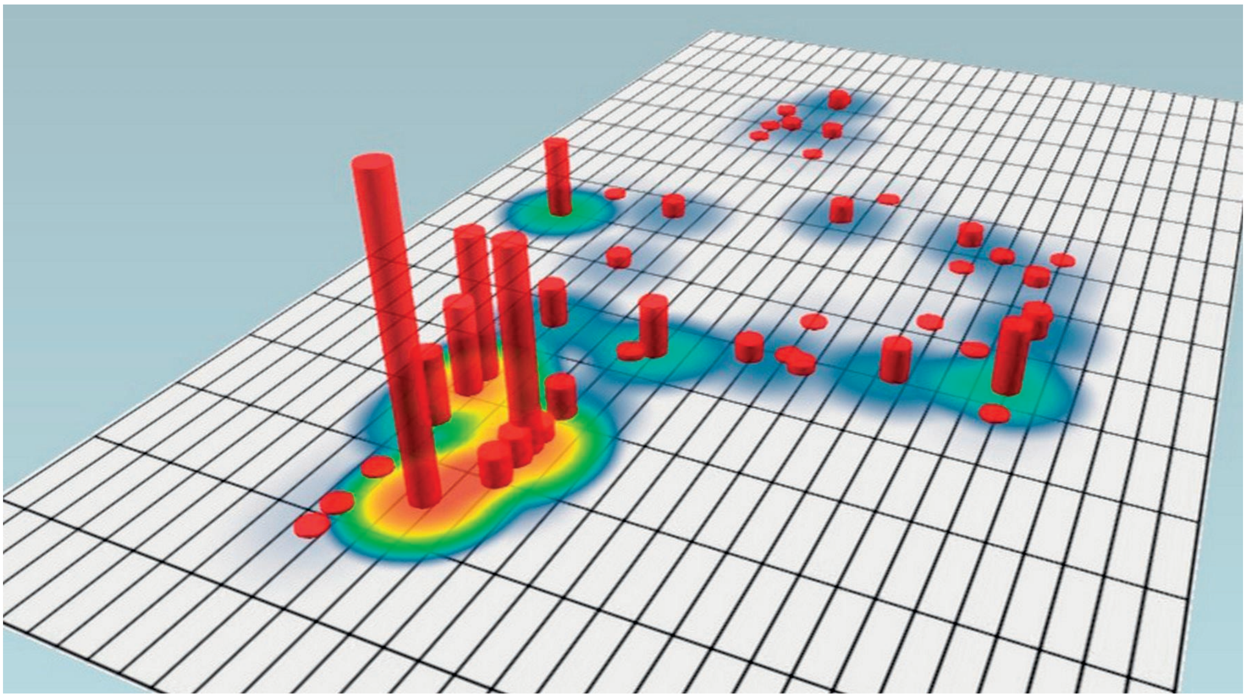

**Figure 5** Visualising detections and areas of house mice activity using a 3D mapping tool in Microsoft Excel (© Chris Swindells/ Kiwa 2021).

While there are many positives to remote monitoring systems there are a few negatives. Not all environments can be monitored, particularly hazardous or extremely wet areas, and there may be issues with connectivity and signal strength on some sites. There is also the initial cost and ongoing maintenance of the system to consider. Finally, who checks the checker? There is still a need for an experienced


**Figure 6** Examples of a dedicated trail camera and alternative home security camera which can be used to monitor rodent activity (© Chris Swindells/Kiwa 2021).

and trained professional to inspect adjoining areas and verify that the equipment is functioning as intended.

## Data analysis

Remote monitoring systems can generate much useful data – the challenge is how to interpret it. During 2020, just prior to the COVID-19 pandemic, a remote monitoring system including over 100 detectors was installed in a large retail environment with an ongoing history of house mouse activity (Simmons 2020). The detectors were placed within the building fabric, some in areas of known activity and others where no evidence existed. To manage the anticipated data that would be created, it was decided that only one detection per detector in every 15 minutes would be counted to offset the possibility of a mouse travelling through a detector multiple times in a short period of time, which could disproportionally skew the data analysis.

The subsequent monitoring exercise recorded some interesting results, not least when the UK was finally in lockdown and the retail centre went quiet. A decrease in alternative food availability and perhaps existing control measures in place meant that the population soon decreased and eventually reached a point where no activity was being reported in the monitored areas. One interesting observation was the approximate six-weekly spikes in activity on the downward weekly trend of detections (Fig. 4). It was speculated that this could have been the emergence of new juveniles into the environment. Using the free 3D mapping tool in Microsoft Excel, it was possible to plot the data collected (Fig. 5) onto a copy of the site plan. This helped to visualise where mouse activity was occurring on the retail estate and direct the incumbent pest control contractor to carry out additional investigations.

## Motion sensing cameras

First developed during the 1980s, motion sensing cameras have advanced enormously since their initial conception and use of 35 mm film technology. In the last decade, there has been a gradual increase in the use of this technology to monitor rodent activity. As with all remote monitoring systems, improvements in digital technology, motion sensing capability, battery life and connectivity mean that these have become a useful tool, especially for problematic house mice infestations. From experience, some wireless motion sensing cameras marketed as home security cameras can be as good as a dedicated trail camera (Fig. 6). Some of the basic cameras only capture photographs and video footage on a memory card that needs to be retrieved, but cameras with suitable connectivity allow alerts to be sent to a computer or phone so the activity can be viewed in real time.

If used correctly, motion sensing cameras can help to identify behavioural issues, levels and times of activity, and identify access points or areas of harbourage. This valuable information allows alternative monitoring and control options to be considered, particularly on sites with ongoing issues. Beneficial in identifying problems, an additional advantage is that they can also be deployed to verify that no rodent activity is occurring undetected by conventional inspection and monitoring practices. This can be useful when monitoring restricted spaces such as wall, floor or ceiling voids that can be difficult to access and inspect.

While there are considerable benefits to the use of this technology there are also some negatives. The cost and maintenance of multiple cameras may mean it is prohibitive to consider this as a long-term monitoring option on many sites. Other considerations might include concerns about privacy or use in sensitive environments. Disturbances or movement in the environment by non-targets, including inquisitive human beings, can result in false activations.

## Conclusions

During the next 10 years into generation 'Alpha', the use of technology may well become the 'new normal' for monitoring and controlling the next generation of house mice. It is inevitable that there will be more challenges with regard to controlling certain house mice populations in the UK, particularly where behavioural issues or anticoagulant rodenticide resistance issues affect conventional monitoring and control strategies. However, there will still be a need for experienced and knowledgeable professionals required to inspect for, identify, interpret data and control house mice infestations. Technology will increasingly become another useful tool at their disposal.

## Notes

1. Further information concerning house mouse anticoagulant resistance maps can be found on the Rodenticide Resistance Action Committee website: https://guide.rrac.info/resistance-maps/house-mouse/europe/united-kingdom.html.
2. The free service is currently provided via the Think Wildlife, Campaign for Responsible Rodenticide Use (CRRU) and further details can be found on their website: https://www.thinkwildlife.org/free-rodenticide-resistance-testing-from-crru/.

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# The attractive qualities of wool and larval frass on wool to the webbing clothes moth (*Tineola bisselliella*)

Patrick Kelley, Rachael Arenstein and James Feston

**ABSTRACT** *Tineola bisselliella* (Hummel, 1823), commonly known as the webbing clothes moth, is a damaging pest in museums and historic houses. The larvae of this species can feed on a wide range of objects that contain natural animal fibres such as wool, feather, fur, hair, hide and skin. Damage has been documented on textiles, skin, taxidermy and entomology collections. The purpose of this study is to determine how larval frass accumulations on wool influence its attractiveness to adult female moths. Data were collected using arena bioassays that incorporated empty sticky traps as a control and sticky traps containing one of two types of wool specimens as a treatment choice. This method allowed quantified response of female moths to un-infested wool and previously infested wool. The results showed that there was no difference in adult female *T. bisselliella* attraction between previously infested wool containing larval frass and clean/un-infested wool with no frass. This work addresses an important topic for both institutions and individuals concerning the risk to wool collections posed by webbing clothes moth. Our results suggest that items that have been previously infested, regardless of cleaning, are not at specific risk of reinfestation by webbing clothes moth.

**KEYWORDS** Webbing clothes moth; *Tineola bisselliella*; frass; wool; cleaning

## Introduction

The webbing clothes moth (*Tineola bisselliella* (Hummel, 1823)) is a cosmopolitan pest of significant economic importance due to damage caused by the larvae of this species feeding on objects that incorporate wool, feather, hair and hide (Krüger-Carstensen and Plarre 2011). One of the most common pests found in museums across the globe, this species of moth causes severe damage to cultural heritage objects (Querner 2014). Clothes moths have found their niche among humans: their textiles and their natural fibre belongings that are used in daily life. This relationship is a particular problem in a museum environment where insects often play a pivotal role in the biodeterioration of museum structures and objects (Pinniger 1994).

The quantification of odour responses in webbing clothes moths is a challenging task. Preliminary tests performed in this study were done in a glass Y-tube olfactometer with a 15 mm inner diameter. Although Y-tube olfactometers worked well when testing the attractiveness of the faeces of drugstore beetle (*Stegobium paniceum* (Linnaeus, 1758)), after they had fed on a collection of books in a library (Kelley *et al*. 2016), it was determined that the Y-tube was not a good means of collecting data for *T. bisselliella* choice tests. The results of the Y-tube study with *T. bisselliella* provided inconclusive evidence of whether adult webbing clothes moths prefer cleaned wool or wool covered with larval frass versus an experimental control. In the majority of tests, the adult moths remained stationary at the onset of the Y-tube observation for longer than the allotted 10


**Figure 1** Webbing clothes moth colony jar with a diet of feather meal and 5% brewer's yeast by weight. Adults were sexed and only females were used in the arenas (© Patrick Kelley).

minutes of each sample run unless prodded into the Y-tube by a small, focused ray of white light. Moths entering the Y-tube after being exposed to this beam often ran immediately into one section of the Y with little to no antennal movement. This seems to indicate that they do not make a decision based on attraction, but instead based on the quickest route to protection from the light.

Considering this previous experience, an arena bioassay was chosen as the experimental testing ground. Arena tests have proved that they collect meaningful data on webbing clothes moth preferences through choice tests offering either dichotomous or single choice preferences. In previous experiments, arena tests have successfully verified the effectiveness of pheromones for webbing clothes moths.[1] For this reason, arena tests were used in this study to answer questions on the attractive qualities of clean wool versus previously infested wool still containing larval frass. In these tests, the released female moths were allowed to make a single preference choice before being captured within a sticky trap.

In natural settings, it is obvious that webbing clothes moth females find woollen materials and oviposit on them, thereby damaging the materials. It is also true that in natural settings, gravid females can land on a multitude of materials before deciding where to oviposit. Ultimately, with this study, we hope to answer the question of whether an institution or individual is putting their wool collections at greater risk of webbing clothes moth infestation if they do not remove or thoroughly clean objects that have previously been infested.

## Materials and methods

### Experimental insects

Insects were collected from colonies of *T. bisselliella* reared at Insects Limited (Westfield, IN, USA). The moths were reared at 23 °C±2 °C on a diet of feather meal and 5% brewer's yeast by weight in glass colony jars (Fig. 1). All test insects were mated female moths. For each arena assay, 10 moths were placed in one-quart glass canning jars containing a single sterile cotton ball to provide traction and a resting place for moths prior to release. Insects were collected two to three hours prior to experimental release.

### Experimental woollen material

The wool material used in this study was a 100% wool sweater acquired from a thrift shop specializing in recycled clothing. The dyed wool sweater had no previous signs of insect activity or damage. No damage or holes were observed penetrating the knitting, and there were no signs of obvious food staining or unusual odors. While no insect activity was observed, the sweater was frozen for two weeks prior to use.

The sleeves of the sweater were cut from the chest and back panels which were then placed back in the freezer to be retained as an un-infested control material (Fig. 2). The sleeves were placed into a plexiglass arena measuring 110 × 47 × 16.5 cm. Two 0.5 liter plastic containers containing live webbing clothes moth colonies (approximately 1000 moths per container in various life stages) were placed into the arena along with the sweater sleeves and sealed off using a fine screen mesh that allowed air to flow in and out of the arena while keeping the moths enclosed. The arena was placed into an environmentally controlled, darkened closet for four months at 23 C°±3 °C and 35±5% RH. During that period, the wool sleeves became increasingly infested with clothes moth larvae: they either crawled out of the colony containers and onto the sleeves, or gravid female moths laid eggs directly onto the wool as they had free access to the entire arena. The larvae feeding on the wool deposited copious amounts of frass onto the textile as they fed (Fig. 3). After four months of exposure, the sleeves were removed from the arena and placed directly into a freezer at –15 °C for a period of two weeks to eliminate all life stages of the live insects on the wool.

**Figure 2** Chest and back panels of the 100% wool sweater were not exposed to clothes moths (© James Feston).

## Wool attraction assay

Both infested and un-infested wool materials were cut into 30 mm squares and placed in odor-proof barrier bags prior to use in the attraction assays. The arena assays were performed using custom-built, 1 × 1 × 0.2 m plexiglass arenas covered in a mesh screen to prevent moths from escaping. The bottom of each arena was cleaned with hexane and lined with Kraft paper prior to introduction of the moths and test materials (Fig. 4). Each arena contained two sticky glue traps (one treatment and one control), placed across from each other 30 mm from the perimeter of the arena. For the un-infested wool assays, one of the two traps in the arena was chosen at random as the treatment trap and contained a 30 mm square of clean un-infested wool attached above the sticky surface in the trap (Fig. 5). For the frass assays, the same procedure was followed using previously infested wool. Control traps contained nothing above the glue surface. The glass jar containing the moths was placed in the center of the arena. One hour prior to release, the room was blackened to allow the moths to acclimatize to the inside of the jar. Under red light, the moths were released by laying the jar on its side, allowing them to leave the jar and move around the arena at their own pace. Each arena assay lasted 63 hours and the number of moths caught in treatment and control traps was recorded. The arena assay was replicated

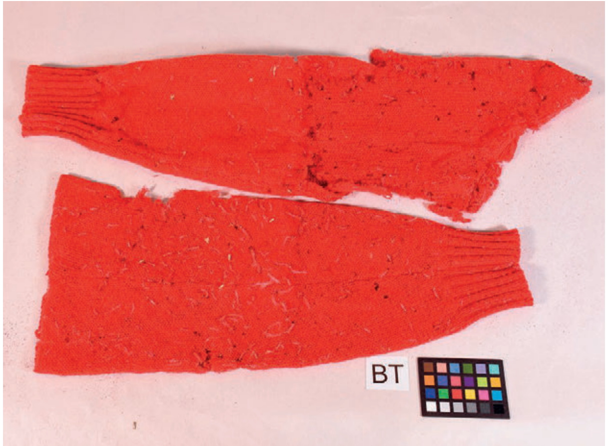


**Figure 3** 100% wool sweater sleeves after being fed on by webbing clothes moths (© Rachael Arenstein).

16 times for the infested wool treatment and 16 times for the un-infested treatment. A chi-squared test ($\chi^2$), which determines the statistical significance between expected and observed frequencies, was used to compare the overall trap catch between control and treatment traps (un-infested vs control, previously infested vs control). Additionally, we observed the total activity level of the moths moving around the arenas by recording the total capture rate for each wool type (un-infested wool + control, previously infested wool + control). These data were analysed with a t-test, which can determine the significance between the mean of two data sets.

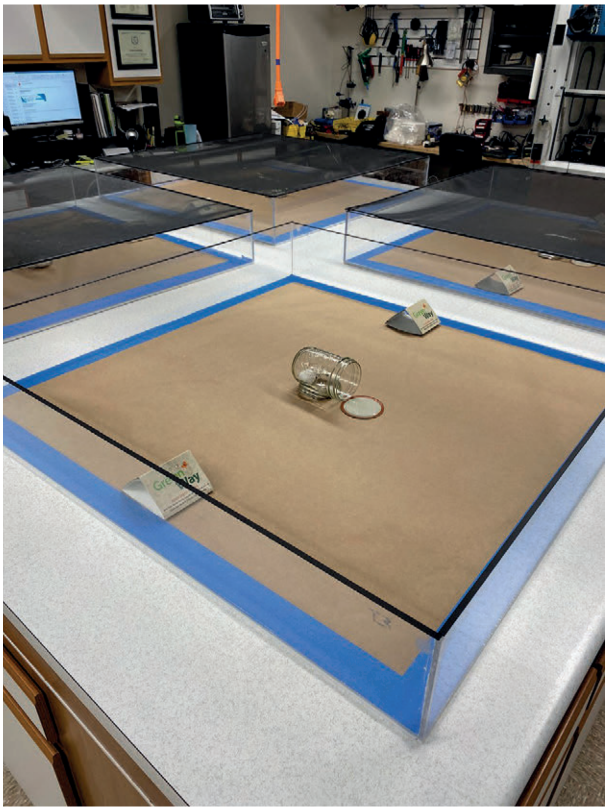


**Figure 4** Assays were performed in mesh-covered 1 m × 1 m × 0.2 m arenas. Moths were released under red light and then held in a blackened room for the duration of the assay (© James Feston).

## Results

The results of the arena bioassays showed no significant difference in trap catches between un-infested wool-baited traps versus control traps ($\chi^2$=1.806, df=1, p-value=0.179). There was also no significant difference in trap catches between previously infested wool-baited traps versus control traps ($\chi^2$=0.13043, df=1, p-value=0.718). In the statistical numbers shown above, a p-value is the probability of an observed result arising by chance. A p-value of zero or 'null' signifies that a hypothesis is accepted. The closer a p-value is to zero, the less likely it is that this outcome was the result of luck. A generally accepted standard in biological sciences is a p-value of 0.05 or below. The chi-squared ($\chi^2$) value is a number that represents the degree of difference between observed data and the data that would be expected. In addition, chi-squared tests factor in degrees of freedom (df), which is based on the number of variables minus 1. In this case, there were two tests performed, each of which only contained two variables: un-infested vs. control and infested vs. control. This means that there is one degree of freedom in each test.

Generally, the lower the chi-square value, the higher the correlation between the data. In order to determine a meaningful chi-squared value, a chi-squared table is used which factors in degrees of freedom and a chosen confidence level (0.05 in this case). The critical value for a confidence level of 0.05 with 1 degree of freedom is 3.84. Both chi-squared values obtained in this study were much lower than the critical value, meaning that the data collected, within each of the two tests, were highly correlated, i.e., not significantly different. For both un-infested wool assays and previously infested wool assays, the total capture rates with each wool type and control combined was 41.8% and 43.1% respectively and were not significantly different (t = –0.211, df=15, p=0.417).

## Discussion

While initially unintuitive that female moths would not appear to be significantly attracted to woollen material, we suggest that initial food resource location in webbing clothes moth may not be mediated primarily by odors. Studies have shown that odor does influence webbing clothes moth female oviposition *after* she lands on an object (Traynier *et al.*1994), but the attractive qualities of wool-based material to *T. bisselliella* females from a distance is not supported by our study. It has been shown that once a resource is located, oviposition behavior of the webbing clothes moth is solicited primarily through tactile stimuli rather than chemical stimuli (Kan and Waku 1985). Sensory hairs located on the ovipositor at the tip of the abdomen probe a substrate to feel if it is a suitable location to lay eggs. Synthetic or plant-based substrates that have a frizzy, fluffy or frayed texture, such as cotton, easily trigger oviposition in gravid females (Kan and Waku 1985). The suggestion that tactile cues play such an important role is supported by research that shows that raw wool, after being stripped of the natural oils and grease produced by sheep, is preferred as an egg-laying site over raw wool that has not been cleaned of these natural by-products (Kan and Waku 1985). It is believed that a scouring process that includes a

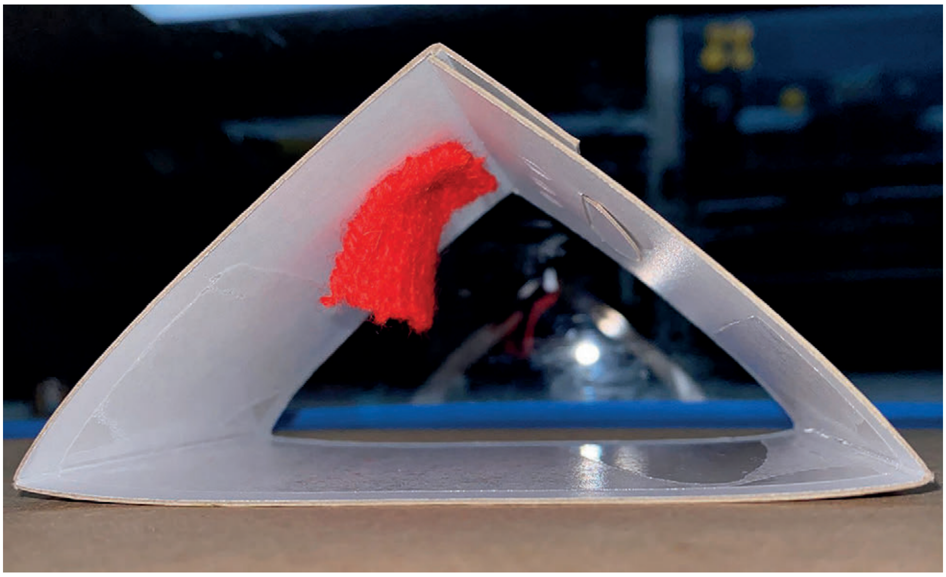

**Figure 5** Example of a treatment trap that contained a 30 mm square of clean, un-infested wool attached above the sticky surface in the trap (© Patrick Kelley).

solvent rinse of the raw wool washes away the oils in the wool and the gravid females prefer the tactile sensation of the processed wool after the acetone rinse. Even cotton is preferred as an oviposition site over raw wool as it lacks the associated oils of wool (Kan and Waku 1985). That study was not a test to see where the female moths would oviposit, but instead a test to determine what material, if any, to which they would first be attracted.

The relationship between humans and webbing clothes moths was explored by Plarre and Krüger-Carstensen (2011) and their results suggest that not only do these moths exist almost exclusively in human habitations, but the larvae have clearly adapted their larval feeding to prefer wool processed by humans. Based on this, we suggest that one reason for a lack of odor-mediated resource location of the different samples of wool in the sweater may be due to webbing clothes moths' tight, synanthropic relationship to humans. This close relationship suggests that webbing clothes moths could rely almost exclusively on humans to supply them with viable food sources in close proximity, rather than needing to search for them in outdoor environments through odors absorbed via sensilla in the antennae. A lack of necessity by *T. bisselliella* to use an expenditure of energy to locate odor-mediated food sources could possibly be an evolutionary result of their synanthropic relationship. Tactile cues received through the female ovipositor seem to be the greater influence on the number of eggs laid on viable food sources in a human environment. Further studies into the attractive qualities of food sources other than wool should be explored. These future studies may shed more light on the importance of food odors and resource location in *T. bisselliella*.

Research on oviposition preference provides useful information for managers of cultural heritage collections. *T. bisselliella* is seen as a scourge of proteinaceous collections so it is important to note that prior research has shown that cotton can be attractive for egg-laying females. Although *T. bisselliella* does not receive the necessary nutrients to survive on clean cotton beyond the 1st instar larval stage, larvae living on cotton that is in direct contact with wool or other natural animal fibers can transfer to these materials and cause significant damage. When inspecting collections for evidence of infestation, cultural heritage professionals should ensure that they are not giving short shrift to examining non-wool collections. Cleaning textiles and artifacts made with hair and fur to remove frass and other evidence of infestation can be slow and time consuming. The results of this study suggest that if there is no preference in attraction to previously infested wool over clean, collection managers and conservators do not need to rush cleaning treatments in an effort to prevent reinfestation. 'Frassy' items can be isolated and cleaned as time allows. The initial focus of staff time should be ensuring that an infestation is fully treated.

## Materials and suppliers

- Y-tube olfactometer: 15 mm inner diameter manufactured by Sigma Scientific, LLC., Micanopy, FL. USA
- Odor-proof barrier bags: manufactured by Uline, Pleasant Prairie, WI, USA
- Screen mesh to cover arena: 48” x 25’ Charcoal Fiberglass Replacement Screen manufactured by ADFORS SAINT-GOBAIN, Courbevoie, France
- Red Lights used over the arena: XGYA19-D-R-DIM 120 V- 60 Hz, distributed by Home Depot, Atlanta, GA USA, made in China
- Sticky traps: GreenWay Clothes Moth Trap manufactured by Insects Limited, Inc., Westfield, IN, USA

## Note

1. Unpublished Insects Limited in-house data on pheromone preference in *Tineola bisselliella*, 2015–2021.

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# The detection of grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) in the Museum of Applied Art, Frankfurt/Main

Christian Dressen

**ABSTRACT** Since the first detection of grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) in December 2017 in the Museum of Applied Art in Frankfurt/Main, a wide range of measures has been undertaken to reduce the number of specimens in the building. Live catch traps and custom-made sticky traps were set up to identify the infected areas. This paper describes the maintenance of these traps and the change interval of baits. Different bait materials were tested for the highest attraction to the target *C. longicaudatum.*

**KEYWORDS** *Ctenolepisma longicaudatum*; museum; traps; baits; pest-free display

## Introduction: the museum buildings

The extension of the Museum of Applied Art in Frankfurt/Main was designed by Richard Meier in 1985 and is connected to the neoclassical Villa (1804) by a bridge. Further workshops and administrative buildings are situated on the property on the river. In addition, the museum operates an outdoor storage facility and a warehouse for temporary exhibition materials. Since 2013, the museum has been pursuing a new exhibition concept in which the ratio of permanent to temporary exhibitions has been reversed in terms of space. This change in the use of space has a strong influence on the volume and number of potentially infested materials such as loans and their packaging brought in for each temporary exhibition, as well as the materials needed for the adaptation of the exhibition architecture.

**Figure 1** Morphology of *Ctenolepisma longicaudatum* in instars 8 to 13 (© Christian Dressen).

## Insect pest species found

Integrated pest management (IPM) at the museum has to deal with well-known museum pests from time to time. The appearance of the almost unknown grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) on 4 December 2017 (on the wall on the first floor facing the freight elevator in building section 2) needed action to correctly identify the species, as well

**Figure 2** *Ctenolepisma longicaudatum* in moist corrugated cardboard with protruding cerci (© Christian Dressen).


**Figure 3** Upper plastic lid of cardboard tube trap with bait (dry food for cats) and caught *Ctenolepisma longicaudatum* (© Christian Dressen).

as to conduct further studies on its distribution and living conditions (Fig. 1). We believe that the potential source of the infestation were items loaned from other institutions for an exhibition on the fashion designer Jil Sander, held 4 November 2017–6 May 2018. During the construction phase before the opening, figurine boxes made from corrugated cardboard were unpacked in the adjacent exhibition space.

## Pest entry

The ingress of pests can occur in a variety of ways including regular mail deliveries and goods as well as loans for temporary exhibitions including their packaging (Fig. 2). Goods are delivered (and stored) almost exclusively on wooden Euro exchange pallets, which are transported from room to room in the building, with the exception of the art depots. Materials and objects stored in this way are not protected from infestation or contamination: *C. longicaudatum* can easily crawl up the pallets, which also provide a good refuge in terms of hiding place, microclimate, food and reproduction (Biebl and Querner 2021).

A thorough inspection of all items entering the building on a daily basis has not yet been possible. For this purpose, a second quarantine line would have to be opened, as is the case with incoming art objects. Furthermore, the required material supplies would have to be treated against pests as a preventive measure more quickly than is required with art objects.

Therefore, in order to improve the control of pest infestation in the museum, the main focus must be on pest-free transport and subsequent storage or display of the art objects as well as the other objects brought into the museum.

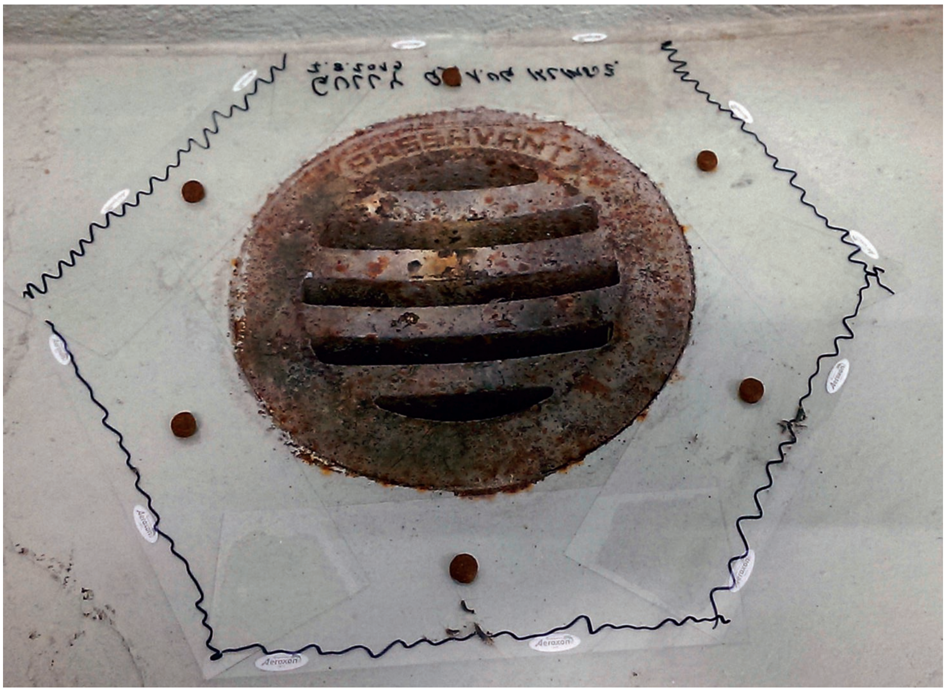


**Figure 4** Circular arranged adhesive traps on hard plastic foil to indicate the direction of infestation of drains (© Christian Dressen).

## Infestation survey

In order to obtain a first impression of the pest's distribution in the buildings, 100 live catch traps were placed in the following rooms: offices, conservation and educational departments, all storage rooms (for art objects, museum shop, maintenance and sanitary facilities) quarantine rooms, archives, exhibition and public spaces, air conditioning ducts and ventilation systems and the warehouse.

## Traps

Live catch traps, adhesive traps on hard plastic foil and capsuled sticky traps were tested for monitoring *C. longicaudatum* over a period of three years. Experience was gained in the effectiveness, applicability and maintenance of these traps. Live catch traps (industrial paper tubes TM) have proved effective for trapping *C. longicaudatum* alive, as they allow for quick inspection during routine inspections. The tubular design and vertical setup of the 20 cm long traps make them less likely to collect dust due to the greater distance from the floor. In addition, the tubular trap, which has plastic lids pressed into both side openings, offers good stability with a diameter of 16 cm. The ideal locations for these traps are along walls or in corners (Fig. 3). In brightly lit rooms, the traps should be placed in darker areas. Initially, it can take one or two months until the traps are accepted and the first catches recorded. If after this time the traps remain empty, a change in placement location will usually result in success provided *C. longicaudatum* are nearby. As these traps keep *C. longicaudatum* alive for some time, an increased number of captures is possible due to the distribution of pheromones from the live insects remaining in the traps (Woodbury 2008). The live traps should be equipped with a ruler or similar that can later be used to measure the size of the individual insect using a photo editing programme. This helps to assign the individuals to their four developmental stages: nymphs without scales, nymphs with scales up to 5 mm, youths from 5 to 10 mm, and sexually mature adults from 10 mm (Mattsson and Jenssen 2019).

In the selection of the adhesive trap, the high adhesive strength and modular assembly of individual traps into novel traps are important. Window fly traps (Aeroxon TM) with a trapping area of 117.6 cm² at a circumference of 53.2 cm were selected for monitoring. The *C. longicaudatum* get caught in the trap from all sides but a disadvantage is that, depending on the dust load in the room, dust will accumulate on the adhesive surface after some time. If the cleaner is careless, the trap will be picked up by the cleaning mop and need to be replaced. Visibility can be improved by marking the traps from below with a felt-tip pen.

This type of trap can be adapted to the requirements of the room (e.g. placement next to drains, penetrations of wiring, baseboards, under furniture). Six traps can be arranged in a circle to secure drains, allowing the direction of infestation to be determined (Fig. 4). Due to the flat design, adhesive traps can also be placed under skirting boards to catch insects that might be missed with conventional blunder traps. Capsuled sticky traps (Panko TM) were tested in different areas. An attracting effect of the supplied bait was not detectable over a period of more than a month, although there was known pest activity in this area.

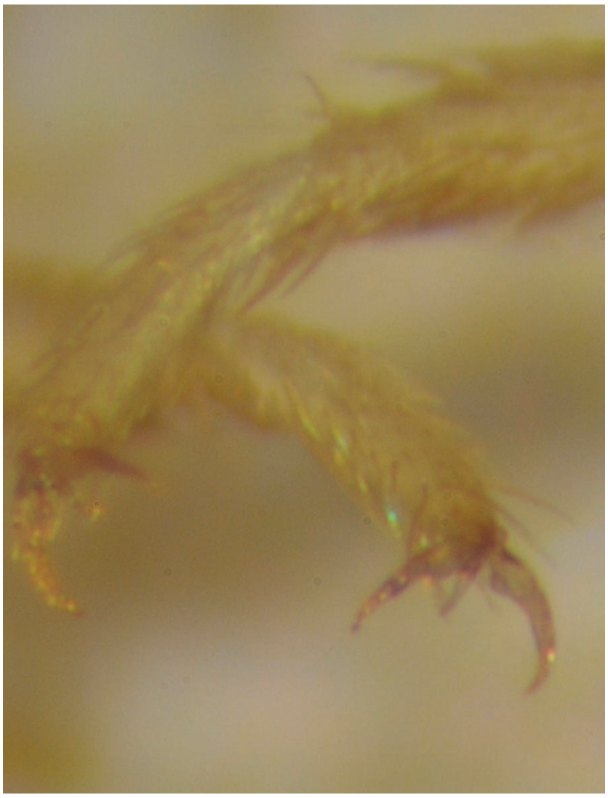

**Figure 5** Tarsi of *Ctenolepisma longicaudatum* (© Christian Dressen).

## Bait

Different baits were then tested to increase the catch success. Initially, no specifications were drawn up for the bait selection so that standard baits from regular suppliers were tested under actual conditions. The baits used (common silverfish trap plus bait traps for ants and against vermin) were stuck directly onto the transparent window flytrap for better evaluation. An increased attraction effect could not be determined. Subsequently, dry food for fish was tested and after only a few weeks a visible attraction effect was observed. The small size and layer thickness of the flakes that could be attached on the adhesive trap, however, quickly caused the bait to lose its scent, hence its attractiveness quickly faded. A good alternative in the form of tablets was found in the Tetra Fun Tips (Tetra TM). After detailed literature research on suitable baits for *C. longicaudatum*, a reference to turkey meat in the form of dog/cat food was found (Cayia and Baldwin 2012). Unfortunately, the new bait, initially procured in the form of turkey necks, presented a strong odour nuisance during the tests, so alternatives were sought. Suitable bait was finally found in 'CRAVE Adult Dry Food with Turkey and Chicken' (Mars TM), a dry food for cats that has so far proved to be the most enticing in use, with equally good dosage and low odour.

## Maintenance of the traps

Live catch traps should be cleaned every two to four weeks by simply wet cleaning the recessed part of the plastic lid. Each cleaning process roughens the plastic surface, which could allow *C. longicaudatum* to climb over the edge of the lid if the inner edge area is also cleaned. Spiders' webs should be removed from both the trap and its surroundings to prevent the *C. longicaudatum* from escaping from the plastic lid. Sticky traps should be replaced if the surface is clogged with specimens or dust. Bait should be replaced every two to four weeks to maintain the highest level of attraction to the targeted *C. longicaudatum*. If a trap is found without the bait, this may be a sign of rodent presence in which case immediate rodent control should be put in place and all bait removed from the affected area until the rodent activity is under control.


**Figure 6** Surface damage on a business card caused by *Ctenolepisma longicaudatum* in transmitted light (© Christian Dressen).

## Recommendations for display cases and wall-mounted artwork

*C. longicaudatum* are unable to climb smooth surfaces, such as baked enamel metal or polyethylene, with their tarsi (Fig. 5), therefore display cases should be made of either enamelled steel construction or very smooth melamine-coated panels. These panels can be adapted to architectural design requirements as long as the underside remains untreated, protrudes, and is positioned with adequate clearance from the wall. During the testing phase of this research, no damage was observed to objects in display cases constructed in this manner despite some limited pest activity in this area (Fig. 6).

When displaying framed artworks, a baked enamel metal sleeve encasing the screw thread of the hook provides good protection against *C. longicaudatum*. When mounting, care should be taken to ensure that there is sufficient clearance between the wall and the back of the frame. This can be achieved by adding stove-enamelled spacer sleeves at the bottom edge of the frame. Conventionally built pedestals used for displaying objects, which touch the floor with their side walls, can be raised slightly from the floor by using adjustable feet thereby preventing pests from crawling up the pedestal or display case. For this purpose, a stove-enamelled washer must be threaded to allow it to be screwed onto the thread of the adjustable foot. Since *C. longicaudatum* slide off the smooth underside of the body washer, they are effectively stopped from reaching any object that is placed on such adjusted pedestals.

## Conclusions

In the course of the preliminary evaluation of the traps for the control of grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) over a period of more than three years, it was determined that a containment of *C. longicaudatum* is only possible to a limited extent for a number of reasons. It is difficult to guarantee permanent freedom from infestation due to the constant influx of merchandise, exhibition materials and loans into the museum as this insect is not restricted to a specific material as food. It can certainly survive with a sufficient degree of contamination (dust, hair, etc.) and with the possibility of retreat into areas that create a microclimate of higher humidity.

During this research it became apparent that the concept for protection against *C. longicaudatum* should focus primarily on the safe storage and presentation of the art objects, which must be supplemented by a functioning quarantine and comprehensive monitoring programme in the entire building as well as the external buildings/warehouses/depots. Mass spreading can only be prevented by adopting a holistic approach. It requires the development of new protective measures in the form of barriers and polyethylene boxes or pallets, secure display cases, pedestals and mounting devices, as well as further research into the effectiveness of bait gels in use in the museum context (Aak *et al*. 2020).

## Acknowledgements

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# Preserving Peruvian organic cultural heritage using Andean lupin (*Lupinus mutabilis*) extracts

Angélica Isa, Carolina Parada, Marilyn Palomino and Eliana Quispitupac

**ABSTRACT** This study hypothesises that Andean traditional knowledge of the use of plants as dissuasive agents against agricultural pests can be repurposed to protect organic cultural heritage in Peru. Andean lupin (*Lupinus mutabilis* Sweet), known locally as tarwi, contains secondary plant metabolites, such as quinolizidine alkaloids, that act as defensive chemical compounds against predators. This investigation extracts the active compounds responsible for pest repellence in tarwi and tests them directly on the beetle *Tricorynus herbarius* (Gorham, 1883), which the project entomologists sampled, identified and reared for this purpose. Semi-quantitative experiments were carried out to test the repellent effect of hydroalcoholic extracts from tarwi leaves and seeds. Spectral scan analyses on tarwi effluents tested positive for alkaloid presence. Results suggest that tarwi leaf hydroalcoholic extracts are effective repelling agents against *T. herbarius.* This paper proposes that the extrapolation of these results would enable the creation of a patented, safe and sustainable organic repellent through a circular economy scheme that uses waste effluent from the food industry.

**KEYWORDS** Sustainable; preventive conservation; *Lagenaria siceraris*; *Tricorynus*; *Lupinus mutabilis* natural repellent

## Introduction

The beetle studied here is a common species found in Peru. Until now, it had not been taxonomically identified as Peru does not have a glossary of local museum pests. Regardless of identification or lack thereof, whenever insects are found, it has been common local practice to apply commercial insecticides and repellents, often directly onto objects, causing visible darkening in archaeological gourds and a distinct chemical odour that allows treated objects to be identified many years later despite a lack of documentation. Unfortunately, active *Tricorynus herbarius* (Gorham, 1883) beetles have been found on gourds smelling strongly of previous pesticide treatments.

**Figure 1** Archaeological gourd destroyed by *Tricorynus herbarius* (© 2021 Pachacamac Museum/Ministry of Culture of Peru).

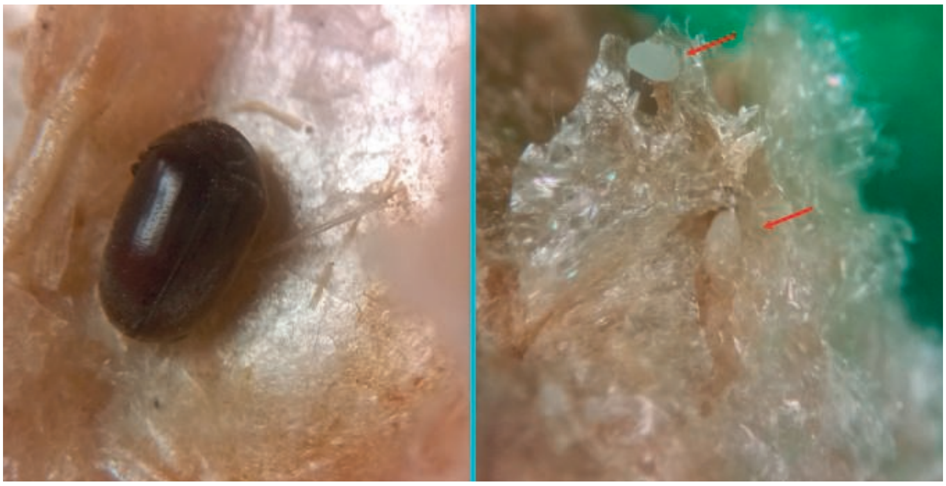

**Figure 2** Adult *Tricorynus herbarius* laying eggs (*left*) and two eggs nested in the folds of the substrate (*right*) (© 2021 Marilyn Palomino).

Given this background, a lack of accurate identification of a very destructive beetle (Fig. 1) and the liberal application of commercial biocides, this study[1] aimed to highlight opportunities in reutilising natural products from plants endemic to the region to protect cultural organic materials. We are aware of the use of similar natural products such as neem (*Azadirachta indica* Juss, 1830) and *Citronella* Don, 1832 (Perumal and Wheeler 1997), but these plants are neither native nor easily available in Peru.

Locally known as tarwi, this endemic Andean plant has been used by Peruvian rural communities since pre-Hispanic times for the control of agricultural pests and as a natural anti-parasitic in animals (Tapia and Fries 2007; Atchison *et al.* 2016). Tarwi produces quinolizidinic alkaloids and other metabolites distributed in its leaves, flowers and seeds (Otterbach *et al.* 2019). Although the role of alkaloids is still debated, research suggests that they protect the plant against both herbivores and pathogenic microorganisms (Wink 1992; Waller and Nowacki 1978). This paper proposes the use of alkaloids extracted from tarwi to repel *T. herbarius* and avoid the use of toxic substances which could affect museum staff and organic collections.

## Biological study of beetle specimen

The beetle was initially identified by photograph only by entomologist Tony Irwin through the 'pestlist' Google group.[2] To ensure an accurate identification, larva, pupae and adult individuals were collected by hand by entomologists from infested material at Museo Pachacamac, located 30 km south of Lima, for mass rearing. The larvae were fed with dried fragments of the same gourds found in local museum collections: *Lagenaria siceraria* (Molina) Standley. The new generation that emerged from this base group was used for the chemical tests. The beetles were identified according to the taxonomic keys from White (1963), Ceruti *et al.* (2010) and Luer and Honour (2019), and the male genitalia were extracted to confirm the identification.

The findings regarding beetle biology thus far may be summarised as follows. The entire cycle from egg to adult in artificial rearing conditions lasts approximately 146 days. After copulation, the gravid females place their eggs one by one among the folds of the substrate (Fig. 2). The eggs do not adhere to the surfaces, causing them to move and roll around easily. Incubation lasts around 18 days, after which actively feeding larvae spend roughly 100–107 days creating internal galleries in the substrate and preparing the inner chamber, where they will spend 25 days as pupae until the emergence of sexually mature adults.

## Extract preparation and effluent characterisation

The following procedures were carried out to obtain hydroalcoholic tarwi extracts and confirm the presence of alkaloids in the tarwi aqueous effluents.

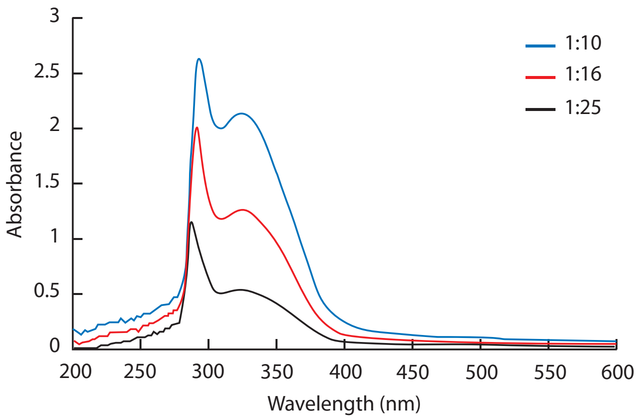


**Figure 3** Spectral graph and absorbance results for filtered and centrifuged aqueous effluent at dilution ratios 1:10, 1:16 and 1:25 (© 2021 Carolina Parada).

## Leaf preparation

Fresh tarwi leaves (65 g) from the Ancash region were selected, washed and macerated for three days in 500 ml of 96% alcohol in total darkness. The extract was filtered, placed in a glass bottle protected from light and stored at 4 °C.

**Table 1** Maximum absorbance values for different dilutions with a slit width of 2. A constant value of 325nm is observed.

| Dilution | Absorbance (nm) |
|---|---|
| 01:10 | 293 and 325 |
| 01:16 | 262 and 325 |
| 01:25 | 288 and 325 |
| 01:30 | 290 and 325 |

## Seed preparation

Seeds were dried in an oven at 40 °C for two days, ground and then pulverised. One gram of seed powder was macerated in 25 ml of absolute ethanol in darkness and at room temperature. The mix was filtered and stored at 4 °C for later use in bioassays.

## Commercial aqueous effluents

Fresh aqueous effluents from tarwi seed washing were provided by TARWIcorp.[3] The jars of waste effluent remained sealed and refrigerated in darkness after the company's donation until experimental use. The effluent was characterised by measuring pH, density and conductivity.

## Extract evaluation and alkaloid detection

The leaf and seed hydroalcoholic extracts were tested on both termites *Cryptotermes brevis* (Walker, 1853) and *T. herbarius*, while the aqueous effluent was used for alkaloid detection analysis. Future studies will complete spectral scans for alkaloid detection on the hydroalcoholic extracts and carry out bioassays with the aqueous effluent. Analysis of the aqueous effluent with Dragendorff's Reagent (DR) was carried out following the methodology reported by Sreevidya and Mehrotra (2003). The appearance of an orange precipitate verified the presence of alkaloids. The treated effluent was scanned at different dilutions with wavelengths between 800 and 200 nm using a UV-Vis spectrophotometer (Shimadzu, model UV-2600), versus a control sample. Figure 3 shows the spectra obtained for the aqueous effluent diluted to 1:10, 1:16 and 1:25. The maximum absorbance values in the samples of tarwi seed washing effluent are all within the 280–325nm range, indicating the presence of alkaloids such as lupanine and sparteine (Table 1).

## Evaluation of antifeedant activity

Having confirmed the presence of alkaloids in the aqueous effluent and assuming higher

**Table 2** Antifeedant index (%) shown by *C. brevis* on filter paper treated with tarwi extract and 96° ethanol.

| Repetition | Consumed weight in C discs (g) | Consumed weight in Tw discs (g) | Consumed weight in OH discs (g) | Feeding Inhibition (FI) Tx % | Feeding Inhibition (FI) OH % |
|---|---|---|---|---|---|
| 1 | 0.08 | 0.02 | 0.04 | 60.0 | 33.3 |
| 2 | 0.10 | 0.02 | 0.06 | 66.7 | 25.0 |
| 3 | 0.08 | 0.02 | 0.02 | 60.0 | 60.0 |
| 4 | 0.10 | 0.00 | 0.02 | 100.0 | 66.7 |
| 5 | 0.07 | 0.02 | 0.02 | 55.6 | 55.6 |
| **Mean** | **0.086** | **0.016** | **0.032** | **68.4** | **48.1** |

**Figure 4** Setup for repellence and antifeedant tests on termites (© 2021 Eliana Quispitupac).

concentrations in the hydroalcoholic extracts, biological experiments on dry wood termites (*Cryptotermes brevis* (Walker, 1853)) selected from a pine wood breeding nucleus were carried out in unmodified environmental conditions. Termites were chosen due to their ample availability. The Sharma and Raina (1998) methodology on repellent and antifeedant activity was slightly modified for this experiment.

Fifteen 9 cm diameter disks of No. 2 Whatman filter paper were cut and separated into three groups. Two groups received 1 ml of either hydroalcoholic tarwi leaf extract (Tw group) or 96° ethanol (OH group) and were allowed to dry for 48 hours. The third group was not modified and served as a control (C group). After drying, each disk was placed in a petri dish with 30 specimens of *C. brevis* workers and their behaviour observed for 30 days in a permanently darkened 1 $m^3$ plastic breeding chamber. Temperature and humidity were recorded throughout with a digital thermohygrometer (Fig. 4).

To determine the Feeding Inhibition (FI) index of the tarwi extract, consumption was evaluated by weighing the filter paper every three days for 30 days. The total consumed weight allowed the calculation of the FI index as a percentage (Simmonds *et al.* 1990) where:

$$FI\% = \frac{\text{consumed weight of control disk} - \text{consumed weight of treated disk}}{\text{consumed weight of control disk} + \text{consumed weight of treated disk}} \times 100$$

The FI % yielded the highest results with the Tw group at 68.40% while it only reached 48.10% with the OH group (Table 2). These results of antifeedant behaviour are demonstrated visually in Figure 5,

**Table 3** Mean repellence (%) of tarwi extracts on *C. brevis*.

| | **Group statistics** | | | | | |
|---|---|---|---|---|---|---|
| | Treatment | N | Mean | Std. Deviation | Std. Error Mean | Significance t-test |
| **RP (% repellency)** | OH | 45 | 84.8378 | 16.49422 | 2.45881 | 0.001 |
| | Tw | 45 | 94.3218 | 8.88592 | 1.32464 | 0.001 |

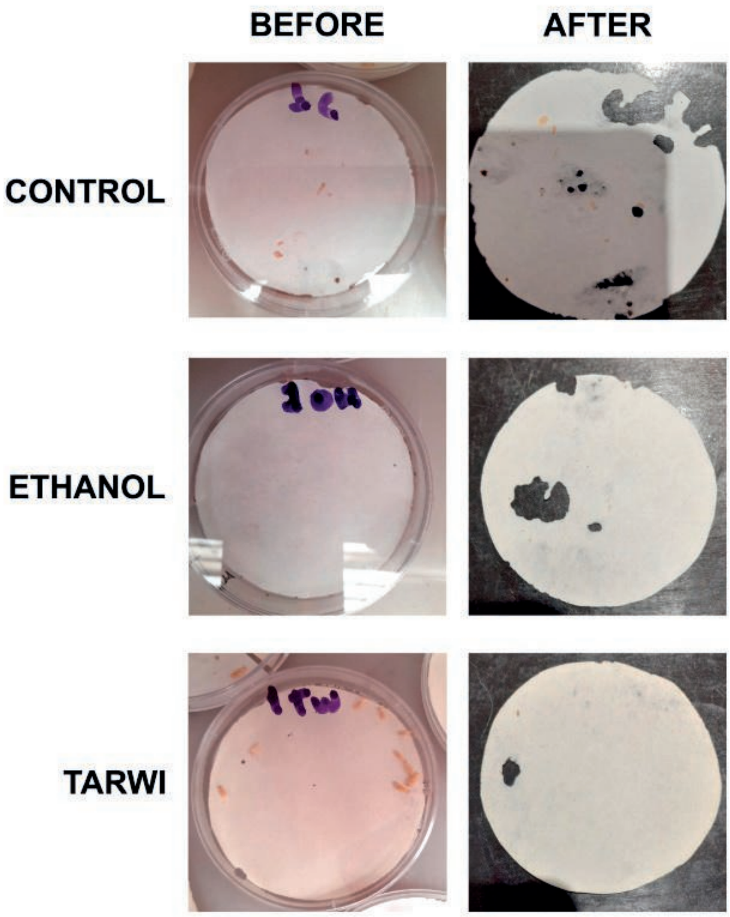


**Figure 5** Antifeedant evaluation results on termites (© 2021 Eliana Quispitupac).

showing the amount of filter paper consumed in all three groups.

## Repellence evaluation with termites and *Tricorynus herbarius*

Repellence was evaluated based on feeding activity and mobility on paper with or without two different treatments: tarwi leaf hydroalcoholic extract or 96° ethanol in distilled water. This experiment was modelled on Rech-Cainelli *et al*. (2015). Filter paper was cut into 9 cm diameter disks and then in half. Some halves received 1 ml of treatment and were air dried for an hour, while the others were left clean as control. One untreated and one treated half were set side-by-side in petri dishes and 30 adult worker termites (*C. brevis*) placed in the middle of each dish. Their location was counted every four days for 30 days with minimal perturbation. Each experiment was repeated five times. The dishes were kept in a darkened breeding chamber, and temperature and relative humidity were measured throughout. Repellence percentage (RP) was calculated using the formula:

$$RP = \frac{Ca - Ta}{Ca + Ta} \times 100$$

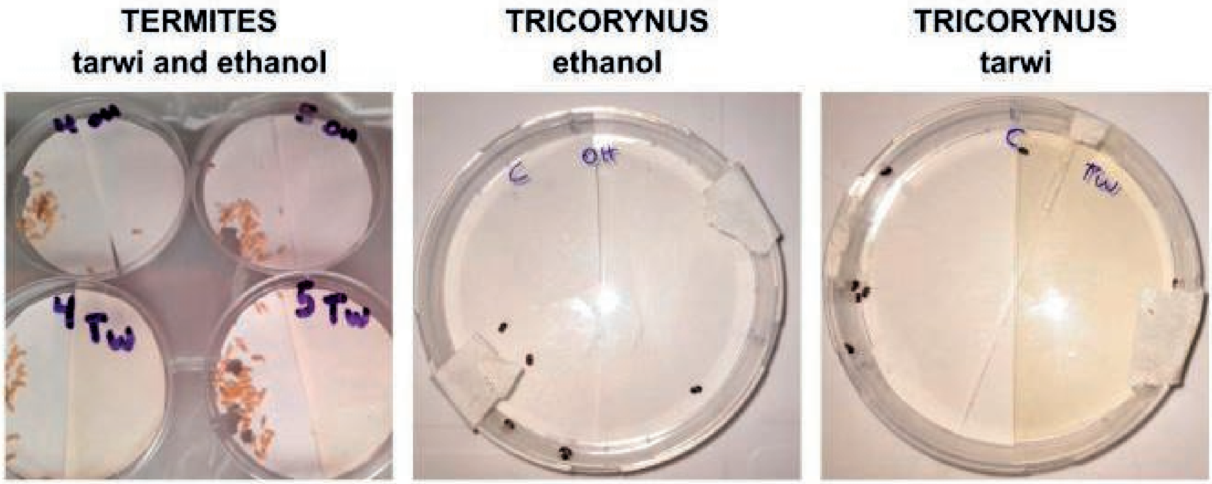


**Figure 6** Repellence tests on termites (*left*) and *T. herbarius* (*middle and right*) showing control filter paper against ethanol (OH) and hydroalcoholic tarwi extract (TW) (© 2021 Eliana Quispitupac).

where Ca is the number of termites present in the control area and Ta is the number of termites present in the treated area (McDonald *et al.* 1970). A student's t-test was used to determine the significant difference between the treatment and control means for the termite RP test. The RP was also carried out with 20 specimens of *T. herbarius* and hydroalcoholic seed extract in March and April 2021. It was not possible to increase repetitions with the beetle due to the low number of adult individuals available. The RP in termites showed a significant difference between treatments, with a higher repellence displayed by the tarwi extract ($p<0.05$; Table 3). The mean RP for tarwi extract was 94.3% and 84.4% for ethanol. Repellence tests on *T. herbarius* presented both greater distancing behaviour (Fig. 6) and a higher index for tarwi extract (RP = 70%) than for 70% aqueous ethanol (RP = 10%). Although only qualitative analysis could be done because COVID-19 restrictions affected the number of repetitions possible, the tarwi extract is evidently capable of a meaningful repellent effect.

## Conclusions and future plans

This research has shown that sufficient alkaloids can be obtained from the leaves and seeds of the *L. mutabilis* plant to encourage significant antifeedant and repellent behaviour on both *T. herbarius* and *C. brevis.* Characterisation tests on the hydroalcoholic extracts and direct bioassays with the aqueous effluent are ongoing and could be published within the next year. The mass production of waste tarwi effluent from the food industry could supply a cheap, effective and sustainable substance for the large-scale availability of a safe repellent in both the Peruvian and global heritage markets. A patent may lead to the commercialisation of a cultural heritage-friendly product whose revenues could be reinvested into further research.

We are also currently researching a bio-polymeric substrate to hold the extract based on tarwi pods, which might further enhance repellent properties. Resulting extracts and substrates will be Oddy-tested to evaluate suitability for museum use, and the mode of use for the extract will be determined in the future based on further experimentation.

## Acknowledgements

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## Notes

1. This investigation was carried out during significant COVID-19 restrictions in Peru.
2. Tony Irwin, personal communication, 2018.
3. TARWIcorp, suppliers of Andean food and medicinal plants, is a biotechnology-based company (Lima, Peru).

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# Screening of two plant-derived extracts from Sri Lanka for their potential to control the subterranean termite *Coptotermes formosanus*

Rudy Plarre, Udaya Cabral and Pascal Querner

**ABSTRACT** The tropical environment of Sri Lanka accelerates biodeterioration of cultural objects. Termites are one of the most damaging insect pests, destroying the cellulose components of historical artefacts. Herbal extracts obtained from resin of *Vateria copallifera* (Retzius) Alston and seeds of *Madhuca longifolia* (Konig) Macbride have been used for centuries to preserve, for example, palm leaf manuscripts from insect attack. Herbal extractions of these traditional products for palm leaf manuscript were tested for their efficacy against the termite species *Coptotermes formosanus* Shiraki, 1909. Naturally and artificially aged herbal extractions were tested to obtain a repellent index. Resin oil of *V. copallifera* caused slightly higher repellencies than *M. longifolia.* Artificially aged samples produced lower repellencies than naturally aged samples. The results indicate that the active ingredients are volatile. The potential for barrier treatment was tested only with *V. copallifera*. The tunnelling behaviour of *C. formosanus* workers through sand in the presence of *V. copallifera* resin oil was largely reduced.

**KEYWORDS** Termite control; essential oils; library pests; IPM in museums

## Introduction

Sri Lanka is an island near the equator with a typical tropical climate. The hot and humid environmental conditions accelerate the biodeterioration of cultural objects, especially organic materials such as paper and wood. Microorganisms, fungi, insects and rodents represent the majority of pests affecting paper-based cultural heritage in Sri Lankan libraries. Pests feed and harbour inside books, on wooden shelves and other organic materials. A recent survey has revealed that *Lepisma saccharinum* Linnaeus, 1758, *Liposcelis divinatorius* (Müller, 1776), *Lasioderma serricorne* (Fabricius, 1792), *Gastrallus indicus* Reitter, 1913, *Periplaneta americana* (Linnaeus, 1758), and subterranean termites such as *Coptotermes formosanus* Shiraki, 1909 cause most of the serious damage to books in Sri Lanka (Cabral and Querner 2017). The Sri Lankan insect pest community thus varies slightly from that of Europe (Gallo 1985; Querner *et al*. 2013; Pinniger 2015; Fizialetti *et al*. 2017). Although Sri Lankan museums and libraries are attempting to apply the concept of integrated pest management (IPM), effective preventive pest control measures and good quarantine/housekeeping are lacking (Cabral and Querner 2017).

Besides books, documents and other ‘modern’ paper materials, Sri Lankan libraries hold large collections of the ancient traditional Sinhala writings in the form of the famous Ola leaf (palm leaf) manuscripts (Fig. 1). These manuscripts contain traditional knowledge gained and collected by the ancestral people of Sri Lanka and other Asian countries (Freeman 2005; Udaya Kumar *et al.* 2009). Regrettably, many of these surviving Ola leaf manuscripts are brittle and have been damaged by insect and microorganism activity, but some – even those that are many hundreds of years old – are better preserved than others due to herbal extractions that were traditionally used to preserve the ancient manuscripts from attack by pests (Fig. 2). Unfortunately, the origins, compositions and recipes of these plant extracts seemed to have been lost over time.

However, in 1997 the National Library of Sri Lanka was given a formula by a traditional manuscript writer (Gunawardana 1997). The formula, now believed to be one that was widely utilised in the past to preserve Ola leaf manuscripts, was a heavily guarded secret and handed down the generations. Today, the plant sources have been identified and the ratio of each ingredient of the recipe is known. Surprisingly, although written in the Imperial Sinhalese language with a native coding system, the formula is not complicated. We were the first to test two species for their insecticidal effects, in particular to determine the potential of two plant extracts of local Sinhalese origin for the control of the subterranean termite species *C. formosanus*. We also wished to observe some signs of their mode of action and discover whether the extracts function as repellents (allomonal allelo-chemicals) or as herbal contact insecticides.

**Figure 1** Palm leaf manuscript in Sri Lanka.

**Figure 2** The traditional application of natural oils.

## Materials and methods

### Herbal extracts

Pure oil obtained from *Vateria copallifera* (Retzius) Alston resin (Malvales, Dipterocarpaceae) and *Madhuca longifolia* (Konig) Macbride seed oil (Ericales, Sapotacea) were used for all experiments. The oils were extracted at the National Library in Sri Lanka: 5 kg pure resin excreted from *V. copallifera* was placed in a distillation tank to which 5 L tap water was added. The distillation machine operated at approximately 270 °C for 2 hours. Resin vapour passed through the copper tube inside a cooling water tunnel and the oil that condensed at the lower end of the machine was collected. *M. longifolia* seed oil was obtained from the plant seeds (by machine pressing) and transported to Germany for laboratory experiments.

### Termite cultivation

The founder colony of *C. formosanus*, which originated from Louisiana (USA) in 1972, has since been reared at the Federal Institute for Materials Research and Testing in Berlin (BAM). The stock culture was kept in a metal tank with a volume of approximately 2 $m^3$ at 29 °C±2 °C and 75%±5% RH (Fig. 3) and the termites were regularly fed with pine sap wood at libitum. Termites used for bioassays were lured out of the culturing tank in larger groups with moistened cardboard. Only healthy and active termites were used.

**Figure 3** Metal rearing tank (approx. 2 $m^3$) with termite species *C. formosanus*.

**Figure 4** Example of experimental setup for testing the avoidance effect of plant extracts. One half of treated cellulose pad (*V. copallifera* resin oil), dark brown in colour on one side on top of a moistened untreated cellulose pad covering the entire bottom of the dish (diameter approx. 45 mm, height approx. 35 mm). A total of 30 healthy termite workers (*C. formosanus*) were released for 24 hours and their position in the dish recorded.

## Bioassay procedures

### Avoidance test, mortality rate and repellent index

Absorbent cellulose pads (Media Pad AP 10, 45 mm diameter and 0.9 mm thick) were treated with 1 ml pure oil derived from *V. copallifera* resin or *M. longifolia* seeds, respectively, resulting in a retention of approximately 0.06 ml per $cm^2$. After drying for 24 hours, treated pads were cut in half and aged for one, two and five days, respectively before exposure to termites (henceforth referred to as naturally aged samples). In addition, treated pads prepared in the same way as above were inserted into a wind tunnel (model STK-SV 90 Schulz Verfahrenstechnik GmbH), which was operated for two days at a wind speed of 1 $ms^{-1}$ and a temperature of 40 °C±1 °C (henceforth referred to as artificially aged samples). Treated samples were stored under two different conditions until required for use in bioassays: in petri dishes, one open and the other with a closed cover.

Avoidance experiments were designed to determine potential repellent effects. A dual choice test was set up in petri dishes. Each replicate consisted of a plastic dish of 45 mm in diameter and 35 mm in height. One piece of untreated cellulose pad as described above was placed into each dish, covering the bottom entirely, and moistened with 1 ml tap water which was repeated every 12 hours. Immediately thereafter one half of previously treated and conditioned cellulose pad was placed on one side of the dish, lining one half of the area; the other half of the dish remained unexposed to treatments. Following this, 30 worker termites of *C. formosanus* were released into each dish (Fig. 4). Untreated controls were set up in the same way but using one half of an untreated pad to line one side of the dish. All setups were kept at controlled conditions of 27 °C±1 °C and 70%±5% RH. Each of the dual choice combinations (Table 1: resin vs untreated) were repeated 10 times. Controls for correction factor calculation (Table 1: control vs. control) were repeated three times.

The number of termites on either side of the dish were recorded 120 minutes after exposure. After 24 hours all termites (dead and alive) were removed and 30 new termites introduced into the dishes; this was repeated after 48 and 120 hours. We calculated a repellent index for treated pads aged for 24 hours,

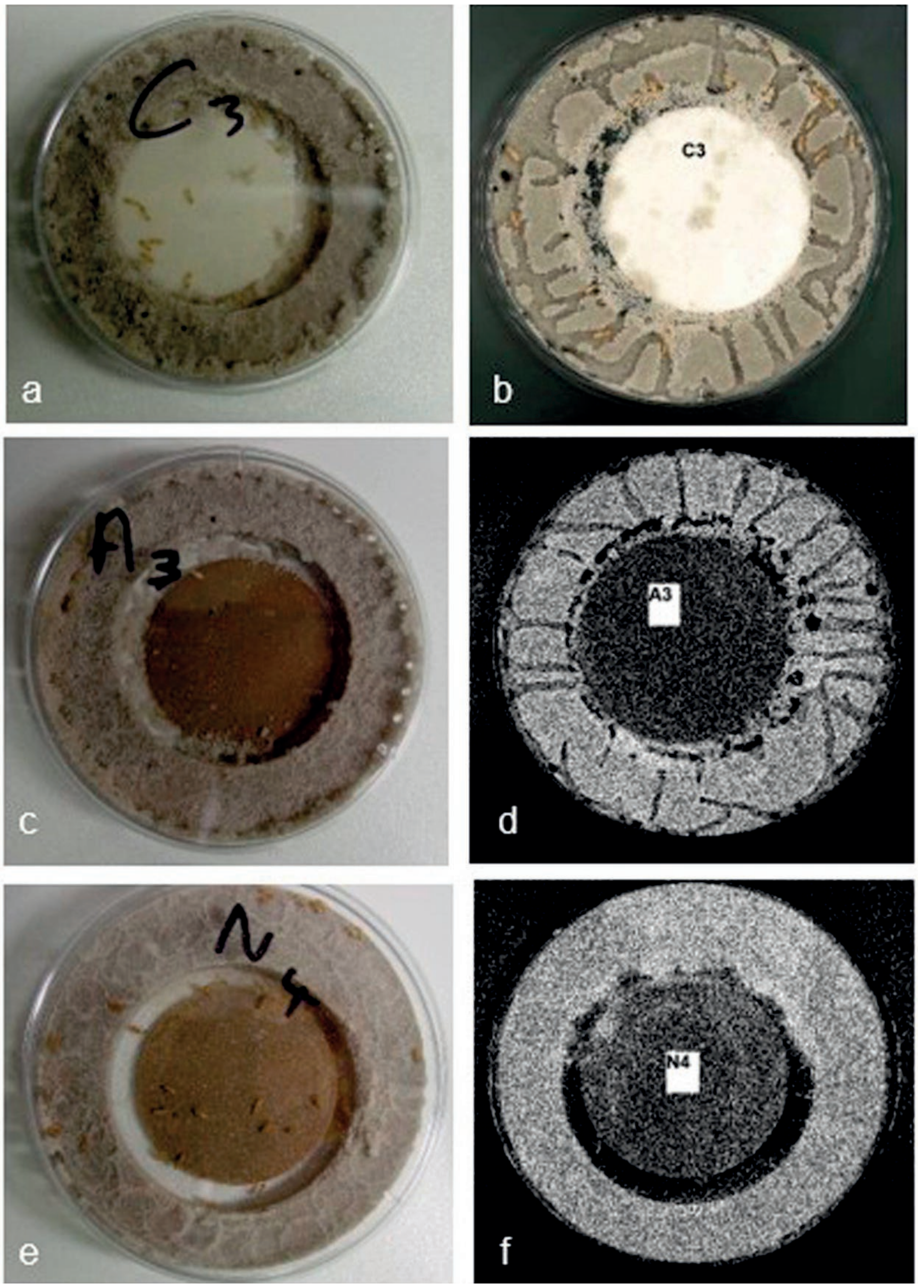


**Figure 5** Examples of tunnelling behaviour in the presence of treated (*V. copallifera* resin oil) and moistened cellulose pad (45 mm in diameter) after one week. Top view (*left*) and copy machine scan from underneath (*right*). (a) and (b) untreated control; (c) and (d) treatment and artificial ageing; (e) and (f) treatment and natural ageing.

48 hours and 120 hours to gain an insight of the percentage of termites repelled. The repellent index was calculated by first determining the repellent correction factor, and as a second step, the repellent index:

Repellent index in % = [(untreated side × repellent correction factor) – treated side] × 100% / 30

The repellent correction factor, derived from untreated controls, takes experimental artefacts into account because one side of the petri dish was wet and the other dry.

## Tunnelling test

Tunnelling behaviour was observed in round bioassay arenas of 90 mm in diameter and 15 mm in height. The centre circle area of the arena (approx. 50 mm in diameter) was spaced out using a cylindrical spacer.

**Table 1** Mean and Standard Error (SE) in % on treated and untreated side, with *V. copallifera* resin oil, *M. longifolia* seed oil and the respective untreated controls, depending on ageing and storage procedures for samples aged for 24 hours, 48 hours and 120 hours. Values under 5% are marked in bold (N / a = natural ageing; A / a = artificial ageing).

| Ageing | storing | Dual choice Resin/untreated (respective control) | % of termites (n=30) on the treated side / untreated after 120 min of exposure 24 h | | 48 h | | 120 h | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean in % | SE in % | Mean in % | SE in % | Mean in % | SE in % |
| N / a | closed lid | *V. copallifera*/untreated | **0.3/99.7** | 1.1 | **0/100** | 0 | **0/100** | 0 |
| | | (control/control) | 50/50 | 9.4 | 51.7/48.3 | 2.4 | 25/75 | 2.4 |
| | | *M. longifolia*/untreated | **1/99** | 3.2 | 7/93 | 4.8 | **1.7/98.3** | 2.4 |
| | | (control/control) | 26.7/73.3 | 28.3 | 26.7/73.3 | 28.3 | 30/70 | 33 |
| A / a | | *V. copallifera*/untreated | **1.7/98.3** | 2.4 | **0.7/99.3** | 2.11 | **2.3/97.7** | 3.2 |
| | | *(control/control)* | 50/50 | 9.4 | 51.7/48.3 | 2.4 | 23.3/76.7 | 0 |
| | | *M. longifolia*/untreated | **1.7/98.3** | 2.4 | 5.3/94.7 | 4.8 | **1.7/98.3** | 2.4 |
| | | (control/control) | 28.3/71.7 | 11.8 | 28.3/71.7 | 11.8 | 31.7/68.3 | 25.9 |
| N / a | open lid | *V. copallifera*/untreated | **4/96** | 3.4 | 5.7/94.3 | 6.3 | **6.3/93.7** | 4.6 |
| | | (control/control) | 50/50 | 42.4 | 50/50 | 42.4 | 50/50 | 42.4 |
| | | *M. longifolia*/untreated | **4.3/95.7** | 5.2 | 7/93 | 4.8 | **1.7/98.3** | 2.4 |
| | | (control/control) | 36.7/63.3 | 14.1 | 36.7/63.3 | 14.1 | 41.7/58.3 | 16.5 |
| A / a | | *V. copallifera*/untreated | **4/96** | 3.4 | 5.7/94.3 | 6.30 | 6.3/93.7 | 4.5 |
| | | (control/control) | 50/50 | 42.4 | 50/50 | 42.4 | 50/50 | 42.4 |
| | | *M. longifolia*/untreated | **4.3/95.7** | 5.22 | 7/93 | 4.83 | **1.7/98.3** | 2.36 |
| | | (control/control) | 36.7/63.3 | 14.1 | 36.7/63.3 | 14.1 | 41.7/58.3 | 16.5 |

**Table 2** Repellent indices after treatment with *V. copallifera* resin oil and *M. longifolia* seed oil depending on ageing and storage procedures. The repellent index was calculated for samples aged for 24 hours, 48 hours and 120 hours.

| Ageing | Method of storing | Resin | Repellent index % after 120 min of exposure 24 h | 48 h | 120 h |
|---|---|---|---|---|---|
| Natural ageing | Petri dish with closed lid | *V. copallifera* | **99.33** | **93.54** | **90.00** |
| | | *M. longifolia* | **80.67** | 69.72 | 67.16 |
| Artificial ageing | | *V. copallifera* | **96.66** | **92.25** | **91.84** |
| | | *M. longifolia* | 72.95 | 66.50 | 61.99 |
| Natural ageing | Petri dish with open lid | *V. copallifera* | **92.00** | **88.66** | **87.33** |
| | | *M. longifolia* | 74.59 | 69.72 | 67.16 |
| Artificial ageing | | *V. copallifera* | **92.00** | **88.66** | **87.33** |
| | | *M. longifolia* | 74.59 | 69.72 | 67,16 |

The rest of the arena was filled with approximately 30 ml white sand (standardised sand: Normensand IEC59F WG 3) of 0.09–0.2 mm particle size, creating an outer circular rim of suitable tunnelling matrix for termites, approximately 7 mm in height and approximately 20 mm in width. The sand was moistened with tap water to the point of saturation. The spacer was then removed and replaced by a cellulose pad treated with *V. copallifera* resin oil which had been either artificially or naturally aged. The respective pad was then moistened with 1 ml of tap water before 30 active worker termites of *C. formosanus* were released into the arena (Fig. 5). The experimental setups were repeated five times. Untreated controls were set up with untreated pads in the same way and number. The numbers and tunnel extensions made by the termites were checked daily by placing the arenas onto a RICOH MP C 3504 copier and taking scans from below.

## Results

### Avoidance test and repellent index

The choice of behaviour by the termites between the treated and untreated side in the experiments is given as mean percent values in Table 1. Respective untreated control values when both choice options were untreated are given directly below. These values were used to calculate the correction factors. The resulting repellent indices are presented in Table 2.

Treatments with *V. copallifera* resulted in higher repellent indices than treatments with *M. longifolia* (Table 2). Repellent effects declined over time with *M. longifolia* declining faster. Artificial ageing resulted in loss of repellent effects when compared to natural ageing: again, the loss was greater with *M. longifolia.* Within the respective ageing procedure and treatment (type of resin), corresponding initial repellent indices were lower when treated cellulose pads had been stored in open petri dishes as compared to those in closed dishes.

### Tunnelling behaviour

Termite tunnelling behaviour was only tested in the presence of *V. copallifera* resin oil. In the untreated controls, termites constructed elaborate systems of tunnels large in number and volume to forage for food and water (Fig. 5a,b). In the presence of treated and artificially aged samples, tunnelling behaviour was severely reduced (Fig. 5c,d), and in the presence of naturally aged samples, tunnels were completely absent (Fig. 5e,f). Low to no tunnelling behaviour corresponded with high rates of mortality compared to untreated controls.

## Discussion

Natural products from plants (seed oil, resin oil, plant leaves etc.) can help to prevent infestations or damage by termites and have been used for centuries worldwide (Turchen *et al.* 2020). Herbal insecticides usually have a lower mammalian toxicity (Murray 2000), but their potential negative side effects on different materials such as discoloration, as well to the health of practitioners applying them, have to be considered. There is currently an increasing interest in these substances in order to reduce the application of synthetic insecticides and for the control of termites. The focus, however, is on termites as building pests (Wilkins 1992; Verma *et al.* 2009) and less as museum and library pests (Murray 2000).

Our results show that the traditional oils used in the preservation of palm leaf documents in Sri Lanka have an effect on *C. formosanus*. We are aware that their use was tested only on one colony of *C. formosanus* termites in the laboratory and that testing on further colonies and also in the field is needed to verify the results. Of the two plant products tested, *V. copallifera* gave good results in repelling and even killing this species. Accelerated ageing in a wind tunnel and open-lid storage caused evaporation of the product after treatment and reduced the efficacy compared to non-aged treatments in closed storage. If *V. copallifera* resin is used, a higher efficiency can be achieved by treating objects in a closed space, resulting in a higher concentration of the volatile compounds with improved repellent characteristics against termites.

Although our results have shown a high potential to prevent termite attack, at least for *V. copallifera* resin oil, field application still needs to be investigated. Different modes of application may be replicated from experiences with other oils derived from peppermint, basil, lemon and orange (Reda *et al.* 2010), including a variety of plants indigenous to Sri Lanka such as lemongrass, citronella grass, cinnamon and the rhizome of snap ginger (Paranagama *et al.* 2004). Senadeera *et al.* (2011) investigated *V. copallifera* for antibacterial and insecticidal activities and found that the seed extract killed mosquito larvae. In our experiment, we tested the resin oil only therefore our results cannot be compared directly, but both results show that this plant has insecticidal effects.

Our screening needs to be continued in order to determine the necessary dosages for long-term protection. Finally, although natural products, plant extracts also require to be tested rigorously with respect to their impact on both the environment and human health.

## Conclusions

We were able to demonstrate that plant oils traditionally used in Sri Lanka can be used as repellents for the control of the subterranean termite *Coptotermes* *formosanus*. The two natural plant extracts tested, *Vateria copallifera* resin oil and *Madhuca longifolia* seed oil both affected tunnelling activity and resulted in different levels of repellency, with *Vateria copallifera* showing the better results.

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# Preliminary trials with reduced temperatures in humidity controlled warm-air treatment: a gentler and more efficient way to disinfest artworks and cultural heritage objects

Thomas Kolling, Eva-Maria Fennert, Thomas Schmitt and Nikolaus Wilke

**ABSTRACT** Controlled humidity warm-air treatment is an eco-friendly option for treating artworks and cultural heritage objects infested by insects. Generally applied treatment temperatures of 50–55 °C ensure complete mortality of all insect pest individuals. However, lower treatment temperatures are desirable for some objects and materials. This paper therefore introduces the results of lethal temperature trials. For determining lethal temperatures, an accepted approach is to identify the temperature needed so that the insect dies when exposed to that temperature for one hour. In this trial, the approach is reversed because the intention was to identify how long various species need to be exposed to 43 °C and 46 °C, respectively, to achieve 100% mortality. The trials were performed at 60% relative humidity with four different and frequently occurring pest insect species: *Anobium punctatum* De Geer 1774, *Lyctus brunneus* (Stephens, 1830), *Ctenolepisma longicaudatum* Escherich, 1905, and *Tineola bisselliella* (Hummel, 1823). While an exposure time of 6 hours at 46 °C was sufficient to control all four species, reaching a full mortality needed 32 hours at 43 °C. The implications of the results are discussed in relation to possible lower temperature treatment protocols for artworks and cultural heritage objects.

**KEYWORDS** Humidity-regulated heat treatment; insect pest control in collections; ecological insect control; pest control in museums

## Introduction

Thermal control of insect pests in artworks and other cultural heritage properties by means of heating or freezing is firmly established in museums and collections worldwide, and the humidity-controlled heat treatment has been applied for more than three decades. The broad spectrum of objects which are treated regularly ranges from old master paintings on canvas or wood to contemporary paintings and art installations. It is in the nature of the subject that art collectors rely on discretion; this is why many treatment projects cannot be discussed publicly. Textiles, furniture, polychrome objects, taxidermy and natural history specimens have also been successfully disinfested with this method.

Published temperature recommendations range from 48 °C (*Anobium punctatum* De Geer, 1774) to 56 °C (*Hylotrupes bajulus* (Linnaeus, 1758)) and 58 °C (*Lyctus brunneus* (Stephens, 1830)) (Strang

1992). Additionally, Strang previously reported temperatures for the control and extermination of 46 museum insect pests. For example, three different conditions for the treatment of *Anobium* larvae are mentioned: 48 °C for 150 minutes; 54 °C for 30 minutes; and 58 °C for 20 minutes. Strang (1992, 2014) also observed that some of the published values are contradictory. Exemplifying this observation, Stengaard Hansen and Vagn Jensen's 1996 study on *A. punctatum* eggs, larvae and adult thermal mortality showed a 5-minute exposure of *Anobium* larvae to 52 °C led to 100% mortality, with the larvae being the most heat tolerant of *Anobium* life stages.

Some contradictions might also result from the fact that heat treatments against insect infestations originated partly from the control of wood borers in architectural timber such as roof trusses. Reaching the necessary kill temperature in a building is much more difficult to achieve (and requires a far greater energy input) than in a highly insulated treatment chamber for moveable objects. In a building there are sometimes huge volumes to treat and the lack of proper insulation can result in cold spots where the necessary temperature is hard to reach. Hence the temperature recommendations for building treatments may have been determined to compensate for this risk of surviving insects. Consequently, the simple transfer of conditions to the treatment of artworks is problematic and one of the reasons why protocols are in need of optimisation for some museum and collection materials and items.

Although almost all types of materials and objects have been safely treated at temperatures of 52–55 °C, it would be useful to know whether these temperatures are really necessary to achieve 100% mortality among the most common museum pests. However, if applying lower temperatures, it is crucial to know how long the insects have to be exposed to them for sufficient mortality. This paper summarises the preliminary findings of a longer research project planned for the coming years. We subjected different stages of four pest insect species to relatively low temperatures of 43 °C and 46 °C and analysed mortality rates. The trials were performed at 60% relative humidity (RH) as this is a realistic value for museum collection storage conditions. Additionally, it is likely to be more difficult to kill insects in an ambient higher RH as low humidity will have an additional drying-out effect on the organisms and hence kill them more quickly. The results obtained are discussed in light of future applications of the treatment for sensitive collection items.

## Material and methods

We analysed the thermo-sensitivity of four insect pest species: *Anobium punctatum*, *Lyctus brunneus*, *Ctenolepisma longicaudatum*, Escherich, 1905 and *Tineola bisselliella* (Hummel, 1823). *L. brunneus* and *A. punctatum* were reared in the facilities of Materialprüfungsanstalt Eberswalde (MPA) on a mixture of oak wood powder, starch and brewer's yeast; the two other species were provided by other institutions (*T. bisselliella* from BAM Bundesanstalt für Materialforschung und -prüfung, Berlin and *C. longicaudatum* from the Rathgen Institut, Berlin). The trials were carried out between 3 February and 21 May 2021.

Two thermal test series were performed: one at 43 °C/60% RH and the other at 46 °C/60% RH. Together with temperature, the exposure time is the second essential parameter. A step-down approach was adopted starting with long exposure times and gradually lowering them. For instance, when finding no surviving specimens at 46 °C after 16 hours, we tried 12, 10, 6 and 4 hours (with another 16-hour trial as an additional control). Each temperature/exposure time/species combination was based on 5–10 larvae and 5–10 adults; only the combination 46 °C with 8-hour exposure for *C. longicaudatum* was based on three larvae and three adults. For eggs, we used at least one uncounted batch – eggs were only counted for *A. punctatum*. For *C. longicaudatum*, data were only obtained for larvae and adults, but not for eggs. For the individual treatments, *L. brunneus* and *A. punctatum* larvae and adults (five of each stage) were placed in plastic containers filled partly with a mixture of oak wood powder, starch and brewer's yeast on which they were bred. Five *T. bisselliella* larvae and five adults were put into plastic tubes together with their original substrate (feathers), which also contained *T. bisselliella* eggs (Fig. 1).

*C. longicaudatum* were placed in plastic boxes with 100% cellulose filter paper. *A. punctatum* and *L. brunneus* eggs were laid on oak wood blocks or in the wood grain, respectively (Fig. 2). All control samples

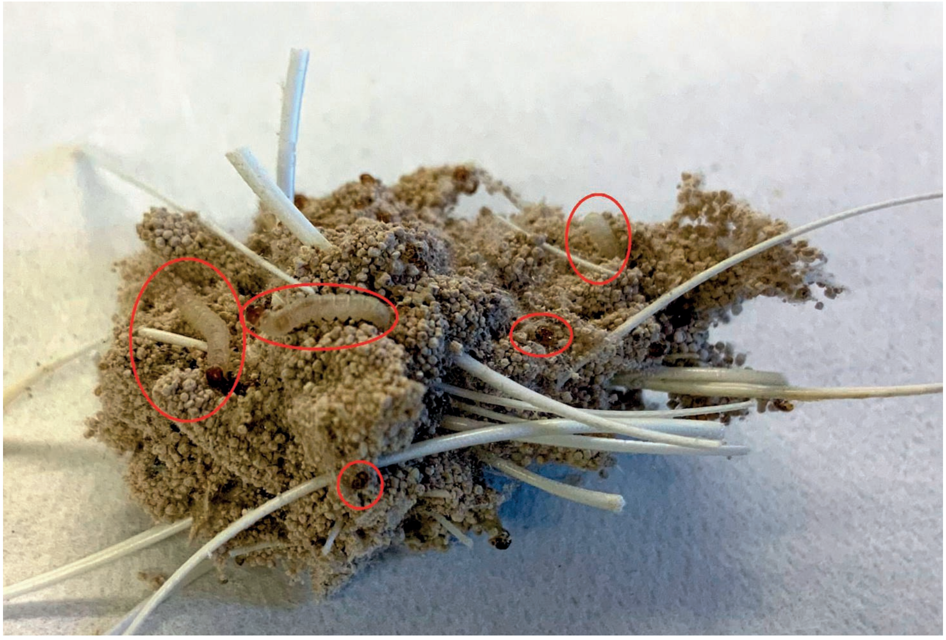

**Figure 1** *T. bisselliella* larvae on feather substrate and excrement (© Nikolaus Wilke/ICM).

were kept in the MPA breeding rooms (*A. punctatum* and *C. longicaudatum* at 22 °C/70% RH, and *L. brunneus* and *T. bisselliella* at 26 °C/70% RH). The plastic containers with the insect samples were put into a desiccator inside a Heraeus UT 6200 heating cabinet (Fig. 3). Individual plastic containers were removed at different time intervals: after 8/ 16/ 24/ 32/ 40/ 48 hours at 43 °C/60% RH and after 4/ 6/ 10/ 12/ 16/ 24/ 32/ 40/ 48 hours at 46 °C/60% RH. One temperature sensor is part of, and measured the temperature in, the cabinet. The second temperature sensor (TESTO 176T4) was positioned inside the desiccator together with the humidity sensor (Bosch BME 280) in the immediate vicinity of the insect samples (Figs 2 and 3). All the sensors were calibrated. The humidification inside the cabinet and desiccator was achieved with a saturated sodium nitrite ($NaNO_2$) solution (101 g per 100 ml water) to keep the RH constant at 60% (Fig. 4). Preliminary tests were carried out to check the time it took for the RH to return to 60% after opening the climatic chamber and/or desiccator. After opening the desiccator, it took on average 5 minutes to reach 55% RH and 18 minutes to reach 60%. Obviously, the temperature in the test cabinet also dropped briefly when the samples were removed, but this can be considered either negligible or favourable for the insect's survival chances.

Mortality was checked visually. The larvae and beetles were assessed no earlier than 24 hours post-treatment to exclude a possible heat strain from which they might recover. They were examined under a microscope and touched lightly to provoke possible movement of the feet and/or mandibles. If there was any doubt the specimens were checked again at a later point. The assessment of possible egg hatching was first done visually after about 4 weeks for *A. punctatum* and *L. brunneus*, and after 2–4

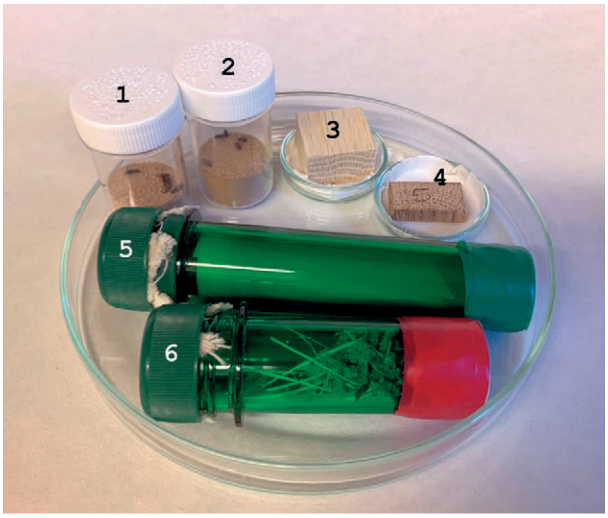


**Figure 2** Insect samples on glass tray. 1: *L. brunneus* larvae inside the substrate, *L. brunneus* adults on substrate; 2: *A. punctatum* larvae inside substrate, *A. punctatum* adults on substrate; 3: *A. punctatum* eggs on oak wood; 4: *L. brunneus* eggs on oak wood; 5: Biotest tube with *C. longicaudatum* larvae and adults; 6: Biotest tube with clothes, *T. bisselliella* larvae and adults (© Nikolaus Wilke/ICM).

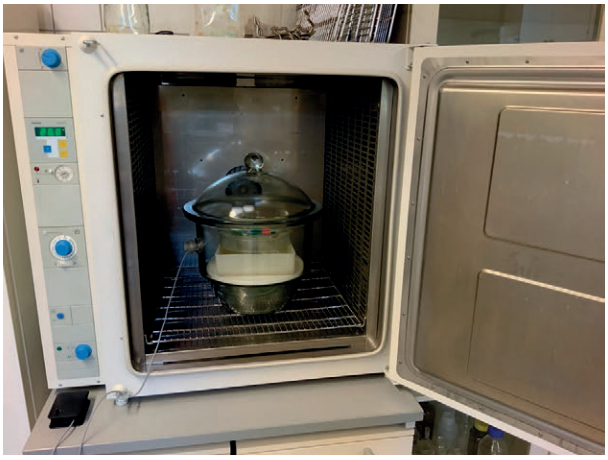

**Figure 3** Heraeus UT 6200 heating test cabinet with desiccator containing the test samples. Note the cable of the temperature and humidity sensor on the left-hand side going into the desiccator (© Nikolaus Wilke/ICM).

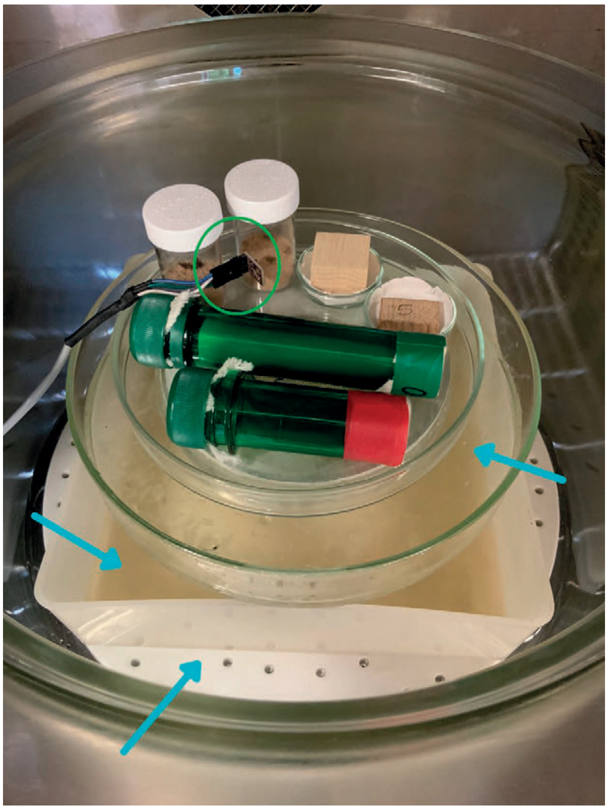

**Figure 4** Samples in a petri dish inside the desiccator. The blue arrows point at four bowls (two invisible under a ceramic disk) with saturated sodium nitrate solution. The humidity sensor is inside the green circle and the temperature sensor was placed about 1 cm away from it. During the trials there was an additional perforated ceramic plate in the desiccator which could accommodate five petri dishes with the sample containers (© Nikolaus Wilke/ICM).

weeks for *T. bisselliella*. In the case of *T. bisselliella*, the young larvae can easily be spotted after about 4–6 weeks. With *A. punctatum* the waiting time is about 6 months to ensure that larval galleries and possibly larvae are visible after splitting the wood on which the eggs were laid. With *L. brunneus* this would be visible after 2 months at most.

## Results

All pest species could be killed successfully at 43 °C (Table 1) and 46 °C (Table 2), however the necessary exposure times were considerably shorter at the higher temperature. Thus, to guarantee a full elimination of all pest species at 43 °C, 32 hours are required. When using the moderately higher temperature of 46 °C, this goal was reached after 6 hours for *A. punctatum*, *L. brunneus* and *C. longicaudatum*.[1]

## Discussion

Our data support the idea that 100% mortality is achieved after 6 hours for three of the tested species at 46 C. Until 13 December no surviving eggs were found in the wood blocks with *A. punctatum* and *L. brunneus* eggs. Only some eggs in the moth samples survived at 46 °C after 10, 12 and 16 hours exposure time.

There is a considerable difference in the time–efficacy ratio between 43 °C and 46 °C (Tables 1 and 2). Thus, a temperature of 43 °C needs to be maintained for much longer than 46 °C to achieve the same efficacy. Furthermore, a surprising outlier was obtained at 43 °C with a *T. bisselliella* egg hatching after 24 hours. Nonetheless, even treatments at 43 °C should be sufficiently effective if this temperature is held for 32 hours as no surviving specimens were reported after that exposure time. This is still quicker than freezing, which takes at least three days at –30 °C, seven days at –25 °C and 14 days at –18 °C. In addition, an anoxic treatment requires between two and five weeks, depending on temperature (Pinniger 2015: 85–8).

While *L. brunneus* is the most heat resistant of the four tested species, a fact also confirmed in Strang's review (1992), *H. bajulus* larvae are reported to be even more resilient. This was supported by an additional,

**Table 1** Killing efficiency of different exposure times at 43 °C on four different insect pest species. The table gives the numbers of surviving adults, larvae or eggs, respectively, with the number of tested individuals in parentheses. For eggs, uncounted egg clutches (abbreviation cl.) were used for three of the species. The control groups were kept in parallel to the treatments in suitable conditions.

| **Number of surviving insects** | | **7** | **8** | **1** | **0** | **0** | **0** | **>89** |
|---|---|---|---|---|---|---|---|---|
| | | **8 h** | **16 h** | **24 h** | **32 h** | **40 h** | **48 h** | **Contr.** |
| *L. brunneus* | adults | 0 (5) | 0 (10) | 0 (10) | 0 (10) | 0 (10) | 0 (5) | 10 (10) |
| | larvae | 4 (5) | 8 (10) | 0 (10) | 0 (10) | 0 (10) | 0 (5) | 10 (10) |
| | eggs | 1 (1ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | hatched |
| *A. punctatum* | adults | 0 (5) | 0 (10) | 0 (10) | 0 (10) | 0 (10) | 0 (5) | 10 (10) |
| | larvae | 0 (5) | 0 (10) | 0 (10) | 0 (10) | 0 (10) | 0 (5) | 10 (10) |
| | eggs | 1 (>33) | 0 (>26) | 0 (>48) | 0 (>40) | 0 (>27) | 0 (>10) | >18 (>42) |
| *C. longicaudatum* | adults | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | – | 4 (5) |
| | larvae | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | – | 4 (5) |
| | eggs | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | – | 0 (1 ba.) |
| *T. bisselliella* | adults | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | – | 3 (5) |
| | larvae | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | – | 5 (5) |
| | eggs | 1 (1ba.) | 0 (1 ba.) | 1 (1ba.) | 0 (1 ba.) | 0 (1 ba.) | – | 15 (1 ba.) |

**Table 2** Killing efficiency of different exposure times at 46 °C on four different insect pest species. The table gives the numbers of surviving adults, larvae or eggs, respectively, with the number of tested individuals in parentheses. For eggs, uncounted egg clutches (abbreviation cl.) were used for three of the species. The control groups were kept in parallel to the treatments in suitable conditions.

| **Number of surviving insects** | | **6** | **0** | **0** | **2** | **3** | **4** | **0** | **0** | **0** | **0** | **>168** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **4 h** | **6h** | **8 h** | **10 h** | **12 h** | **16 h** | **24 h** | **32 h** | **40 h** | **48 h** | **Contr.** |
| *L. brunneus* | adults | 0 (10) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 15 (15) |
| | larvae | 6 (10) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 15 (15) |
| | eggs | 0 (2 ba.) | 0 (2 ba.) | 0 (1 ba.) | 0 (2 ba.) | 0 (1 ba.) | 0 (2 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | hatched |
| *A. punctatum* | adults | 0 (10) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 12 (15) |
| | larvae | 0 (10) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 15 (15) |
| | eggs | 0 (>69) | 0 (>35) | 0 (>30) | 0 (>92) | 0 (>17) | 0 (38) | 0 (>9) | 0 (>7) | 0 (>11) | 0 (>175) | >22 (>123) |
| *C. longicaudatum* | adults | 0 (8) | 0 (8) | 0 (3) | 0 (8) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 13 (13) |
| | larvae | 0 (8) | 0 (8) | 0 (3) | 0 (8) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 11 (13) |
| | eggs | 0 (2 ba.) | 0 (2 ba.) | 0 (1 ba.) | 0 (2 ba.) | 0 (1 ba.) | 0 (2 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (3 ba.) |
| *T. bisselliella* | adults | 0 (10) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 13 (15) |
| | larvae | 0 (10) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (10) | 0 (5) | 0 (5) | 0 (5) | 0 (5) | 15 (15) |
| | eggs | 3 (2 ba.) | 0 (2 ba.) | 0 (1 ba.) | 2 (2 ba.) | 3 (1 ba.) | 4 (2 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 0 (1 ba.) | 40 (3 ba.) |

short experiment with this species (data not shown) proving that this insect is extremely heat tolerant. Therefore, when treating at temperatures of around 46 °C, this species must not be present in the infestation otherwise the treatment will fail. Fortunately, *H. bajulus* is very rare in museum collections and only attacks coniferous wood, so its radius of action is limited. However, Biebl and Querner (2021) found that *H. bajulus* is occasionally present in museums in wooden pallets so a careful inspection and identification is necessary prior to each treatment.

If applying heat treatments for disinfestation, it is vital that the kill temperature reaches the core of all of the treated objects: only once the core temperature has been reached can the counting of the necessary exposure time start. Therefore, the exposure times to be used in practical treatments are necessarily longer than those obtained by experimental designs such as in this trial. Furthermore, the treatment chamber must provide a very even distribution of the temperature and humidity conditions. The results of our trials are very encouraging as successful treatments will be possible at lower temperatures than hitherto considered necessary. Even if temperatures of around 52–55 °C can be considered safe for the treatment of the vast majority of collection objects, the option of treating at lower temperatures is clearly an advantage in some cases for more heat-sensitive items. The development of evolving heat resistance in insects, as well as a generally higher heat tolerance in insects from hotter regions, should be taken into account in future trials.

## Note

1. It was only after the presentation of the paper during the Pest Odyssey conference presentation that surviving specimens were found in the moth egg samples; Table 2 has been updated accordingly.

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# Efficacy of a low-cost simple solar heating box to eradicate insect pests in Sri Lankan libraries

Udaya Cabral, Deepika Amarasinghe and Pascal Querner

**ABSTRACT** Insect pest infestation is a severe problem in libraries in Sri Lanka. The recommended chemical control measures against these pests are not sufficient to eradicate them. This paper describes a simple, low-cost method using a solar heating box suitable for the control of insect pests in libraries and archives in Sri Lanka.

## Introduction

The preservation and conservation programme is a crucial element in the whole operating system in a library to prolong the usable life span of library materials by minimising the risk of damage from insect pests and rates of deterioration. This paper proposes accomplishing this goal by selecting high quality materials, providing a suitable storage environment and introducing safe handling procedures while identifying and minimising the use of valuable originals (Roper and Millar 1999). Paper-based materials are the most common library materials stored in the National Library and Documentation Services Board (NLDSB) of Sri Lanka that are likely to be vulnerable to chemical, physical and biological deterioration processes. The biological degradation of paper is the decomposition of the material by pests including bacteria, fungi, invertebrates and vertebrates (Ahmed *et al*. 2018). Paper and associated binding materials provide nutrients for such biological agents and become attractive when materials are stored in unsuitable conditions, such as humid and warm microenvironments and dark and dusty conditions (Havermans 1995; Daniels 1988; Dean 2002). Biological agents also include several taxa of invertebrates, including insects, mites and vertebrates such as rodents, bats and birds. The book collections of the NLDSB suffer from pest infestations mainly due to climatic circumstances: high temperature and relative humidity (RH) play a major role in accelerating the rate of biological degradation of the paper-based collection and provide a conducive atmosphere for the proliferation of insect pest populations.

Many arthropod pest species thrive and multiply very rapidly in tropical climatic conditions in Sri Lankan libraries with termites, bookworms (beetles), silverfish, cockroaches and booklice being some of the most common insect pests encountered (Cabral 2013). In addition, other common household insects are also to be found in libraries. The immature stages, larvae or nymphs, and adult insects damage books and paper materials. Specific species of bookworms (Coleoptera) are predominant in tropical regions: their larvae feed mainly on paper, leather, spices, dried vegetable matter and herbarium collections, and often tunnel through the leaves of the book, emerging through the cover or spine (Khan 2011). Silverfish (Thysanura) is the most common insect pest recorded as well as cockroaches (Blattodea). Termites (Isoptera) are frequently found in libraries located in the hot, humid regions in the country, especially in the wet zone which receives an annual rainfall above 5000 mm, and in the intermediate zone where the annual rainfall measures between 2500 and 5000 mm. Their infestation, rapid growth and damage cause very severe issues for many

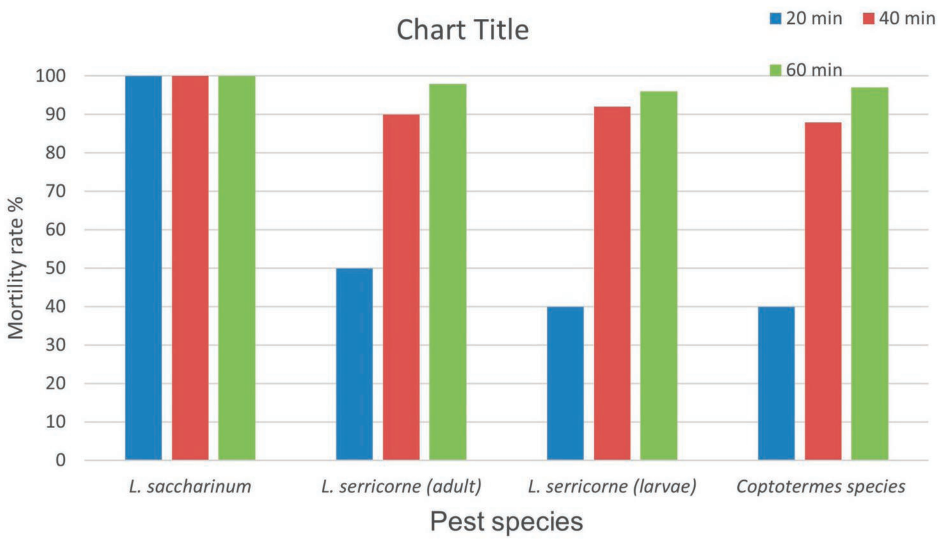


**Figure 1** The experimental setup was kept in the courtyard under sunshine (© Udaya Cabral).

types of collections in libraries and museums as well as in private homes (Cabral 2013).

Pest infestation caused by the high humidity and temperature resulted in conservation problems with respect to the durability of paper material stored in the NLDSB. The climatic conditions combined with poor maintenance of the central air-conditioning of library buildings exacerbated the problem. A new central air-conditioning system was installed in 2018 in an attempt to overcome this issue but after an in-depth study of the insect pest situation showed high activities of different pest species, it was decided that a practical treatment method was needed. A simple, user/environmentally friendly and economically feasible control measure was therefore developed.

## Material and methods

### Testing solar heating against insect pests

A thermal insulated rigifoam box (470 × 405 × 362 mm$^3$) with a lid was used for this experiment. The outer surface of the box was painted with water-based black paint. A data logger to record temperature and humidity was fixed to the outer surface and internal probes were placed in the centre of the box (Fig. 1). Thirty books infested with most common insect pests, namely *Lepisma saccharinum* (Linnaeus, 1758), *Lasioderma serricorne* (Fabricius, 1792) and *Coptotermes* spp., were used for this study. The insect pests, obtained from cultures maintained at the NLDSB, were introduced equally into the books. Five of each of these infested books were wrapped separately with blotting paper to create six replicas, used as experimental samples.

The experimental setup was placed in the courtyard of the NLDSB on a sunny day for one hour. When the temperature inside the box reached 45 °C, six replica wrapped book samples were placed in it (in a 3 × 2 layout arrangement). One sheet each of two types of papers – 70 gsm chemically produced wood pulp photocopy paper (210 × 297 mm$^2$) and 40 gsm mechanically produced wood pulp newspaper (449 × 597 mm$^2$) (2004 TAPPI, T 529 om-04 method) – were placed inside the rigifoam box, and the lid closed tightly, to determine the changes to pH during the thermal process. The temperature and humidity levels inside the box were monitored at 20, 40 and 60 minutes. An identical control sample was made as above and kept in ambient conditions (30 °C±2 °C and RH 80%±10%). The pH was measured using an acid-based indicator dye method. Insect mortality was recorded after each experiment and calculated according to Abbott (1925).

## Results

*Lepisma saccharinum* showed 100% mortality after 20 minutes exposure to 45 °C±1 °C and RH 45% ±5%. When the exposure time was increased to 40 minutes, the mortality rates of both adult and larvae of

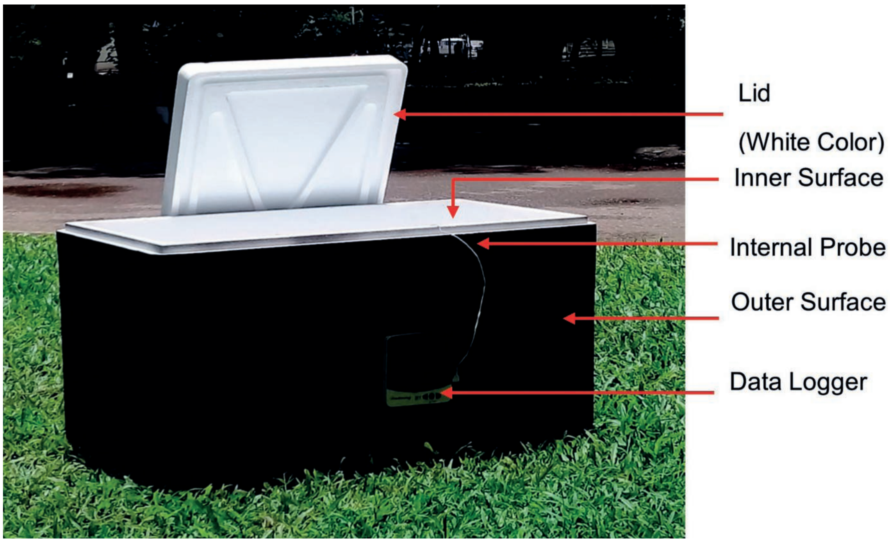


**Figure 2** Percentage mortality of different insect pests after 20, 40 and 60 minutes exposure to solar heat (© Udaya Cabral).

*Lasioderma serricorne* and *Coptotermes* spp. also increased. The maximum mortality rate observed was 93%–96% after 60 minutes (Fig. 2). Test results reveal that the experimental level of thermal increase did not cause pH changes in the paper material.

## Discussion

Insects can survive in temperatures as high as 60 °C (Strang 1992) as they are able to adapt to slowly changing temperatures. The success of thermal pest eradication relies on rapidly reaching killing temperature to prevent them from having time to adapt. Recommended methods of thermal pest eradication involve a rise from room temperature to 52 °C within one to four hours (Child 1994; Nicholson and von Rotberg 1996; Pinniger 1996). Heat treatment for infested collections of books is an effective method for ensuring 100% efficacy in killing insect pests. In addition, it is a method that can be used *in situ*. Strang (1992) pointed out that a short exposure at 55 °C was sufficient for the eradication of all life stages of insects. The thermal solution technique conducted by Pinniger (1996) was the technically refined version of the heat treatment in this study. A chamber was designed in which infested books could be placed and the environment monitored precisely by a digital data logger. The RH inside the chamber, during both the warming and cooling down phases, was controlled to ensure that the humidity balance was maintained. As a result, no dehydration of the objects occurred using this method. The humidity-regulated heat treatment has been evaluated as a possible practical option to control museum insect pests (Pinniger 1996; Ackery *et al*. 2005). This treatment is a method of eliminating insects using a climate-controlled heating chamber which controls moisture content during heating and cooling. This process is currently being used commercially to treat a variety of organic items such as furniture, textiles, herbaria, books, manuscripts, silks and leathers; it is also suitable for antiques and museum exhibits (Pinniger 1996). Blotting paper sheets used to wrap test books in the solar heating method helped to buffer the moisture fluctuation and prevent moisture loss in this study. Using the tight-fitting lid of the rigifoam box helped to maximise the interior temperature and screen out UV and visible light, which is harmful to paper materials.

## Conclusions

Using the solar heating chamber, within 20 minutes the mortality rate of *Lepisma saccharinum* reached 100%, and in 40 minutes the mortality rate of both larvae and adults of *Lasioderma serricorne* and *Coptotermes* spp. increased with a maximum of 93–96% being reached after 60 minutes. Since the energy source is free and the operation simple, the solar heating method described in this study can be used in libraries (both personal and public) in rural areas of Sri Lanka during the dry season on clear, sunny days.

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# From discovery to recovery: managing a webbing clothes moth infestation at the Peabody Museum of Archaeology and Ethnology

Cassy Cutulle, Matthew Vigneau, Molly Richmond, Khanh Nguyen, Lindsay Koso and Mollie Denhard

**ABSTRACT** In 2016, staff at the Peabody Museum of Archaeology and Ethnology at the University of Harvard discovered an infestation of webbing clothes moths (*Tineola bisselliella* (Hummel, 1823)) in the largest storeroom for ethnographic objects. In an effort to quickly control the infestation, emergency response actions were successfully executed which prompted the creation of a mitigation protocol, devoted to combating the webbing clothes moth infestation, in conjunction with the Museum's pre-existing pest management program. In this paper, the emergency response steps and long-term mitigation protocol are detailed, alongside recommendations for assisting the setting up of an effective mitigation program. The decrease in moth activity over the period of 2017—2021 reflects the successes of both the emergency response and post-discovery mitigation protocol for the storage room as well as two other contexts.

**KEYWORDS** Webbing clothes moths; integrated pest management; mitigation; disinfestation

## Introduction

In 2016, an infestation of webbing clothes moths (*Tineola bisselliella* (Hummel, 1823)) was discovered in the largest storage room for ethnographic objects at the Peabody Museum of Archaeology and Ethnology at the University of Harvard (hereafter Peabody Museum), which measures 509 m$^2$ and contains approximately 40,000 objects. The initial discovery was located in a corner alcove of the storage room on a pair of caribou fur leggings. These bays contain primarily arctic and sub-arctic organic objects including dressed historic mannequins, large furs and hides, wool textiles, feather work, as well as hair, and quill. It was immediately clear that an infestation had started, as the moths were seen fluttering on garments without the aid of magnification tools. Upon further inspection, the moths were visible in this alcove and beyond, which classified it as an emergency.

Prior to this discovery, a previous monitoring program had an extended trap inspection cycle during a transition in staff appointments, which unfortunately allowed the moths to go unnoticed. The integrated pest monitoring (IPM) program was then adjusted accordingly to identify areas of elevated activity. Such an infestation presented a serious concern that required both immediate and long-term attention (Fig. 1).

## Emergency response

Staff acted quickly by executing an emergency response aimed at containing the moths *in situ* and

**Figure 1** Detail photograph of webbing clothes moths (*Tineola bisselliella*) in a polyethylene bag at the Peabody Museum of Archaeology and Ethnology (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

preventing their spread to other areas throughout the room and wider Museum. Emergency actions included: quarantining the space, monitoring, containing objects, and disinfesting the objects with ultra-cool freezers.

## Quarantine and containment

The alcove was immediately sealed with polyethylene sheeting secured to the ceiling, walls, and floor with Scotch 3M packaging tape, Scotch blue 3M painter's tape, and ceramic magnets to prevent the rapid spread of moths. The fur objects, as well as any other objects at risk within the alcove, were bagged and sealed as quickly as possible, followed by the containment of any protein-containing objects in bays throughout the rest of the storage room.

## Low-temperature disinfestation

The Peabody Museum quickly reached out for aid in low-temperature, or freezing, disinfestation of the objects during the emergency response. Thanks to a collaboration with the Harvard Museum of the Ancient Near East, Harvard Museum of Comparative Zoology, and the Harvard University Herbaria & Libraries, the Peabody Museum was able to gain access to multiple freezer spaces almost immediately. These freezers were all capable of reaching –20 °C in 24 hours, which provided effective extermination of the moths (Strang 1992, 1997).

# Post-discovery mitigation protocol 2017–2021

In 2017, the trap data and visual inspections of objects indicated that the infestation had been caught early and that the emergency response was successful, having halted the spread within and outside of the storage room (Table 1). Post-discovery, a moth mitigation protocol was drafted, which directed the actions to be carried out in the future. These actions included adjusted monitoring, containment, low-temperature disinfesting, and assessing, cleaning, and treating affected objects.

## Adjusted monitoring

While the pre-existing monitoring program included approximately 320 traps, it was adjusted to 350 sticky blunder traps in the whole Museum, with 27 sticky blunder traps situated in the affected storage room (Fig. 2). These traps were placed strategically at floor level near areas of egress and were collected every two months during the emergency response and 2–3 months thereafter. Each trap was labeled with the date it was placed, its location, and a code that was utilized in collecting data during the inspection process.

**Table 1** Emergency response steps and post-discovery mitigation protocol (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

| **Emergency response steps** |
| --- |
| Quarantine spaces |
| Contain objects at risk |
| Monitor spaces |
| Disinfestation at low temperatures |
| **Post-discovery mitigation protocol steps** |
| Creation of protocol/long-term mitigation program |
| Monitor spaces, adjust traps accordingly |
| Continue to contain objects at risk and not at risk |
| Continue disinfestation at low temperatures |
| Examine, assess, and clean objects |
| Maintain mitigation protocol tasks over time |

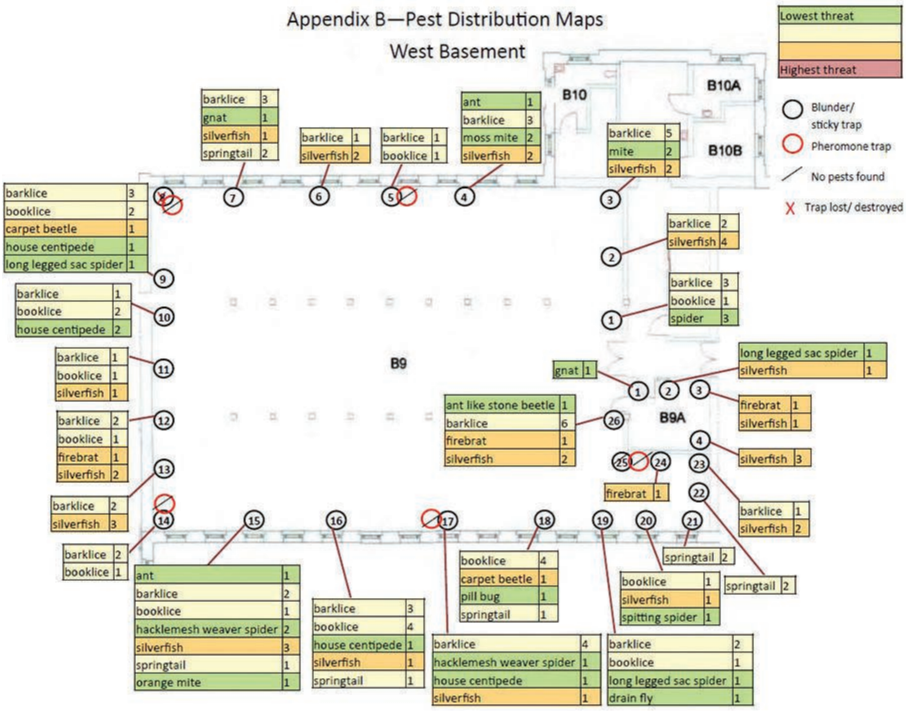


**Figure 2** West Basement floor plan showing trap placements in the storage room (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

In response to the webbing clothes moth infestation, the Peabody Museum introduced the use of 27 sex pheromone traps throughout all object storage rooms and five in the affected room. This monitored the possible spread of moths and also targeted areas of activity (Fig. 3). This pheromone was synthesized and contained in a capsule secured within a sticky blunder trap, marketed for use in attracting male moths (Trematerrra and Fontana 1996). For the needs of this longer-term project, pheromone traps with a shelf-life of six months were chosen, and visually inspected each day. With a radius of approximately 7.5 m, traps were placed at distanced intervals for complete coverage in each area.

At the end of the sticky blunder or pheromone trap cycle, each one was brought to the Conservation Department, where it was closely inspected under magnification by Associate Conservator, Morgan Nau. The identifications and counts were entered into The Museums System (TMS) database and reported on quarterly. New traps were set immediately upon collecting the previous ones.

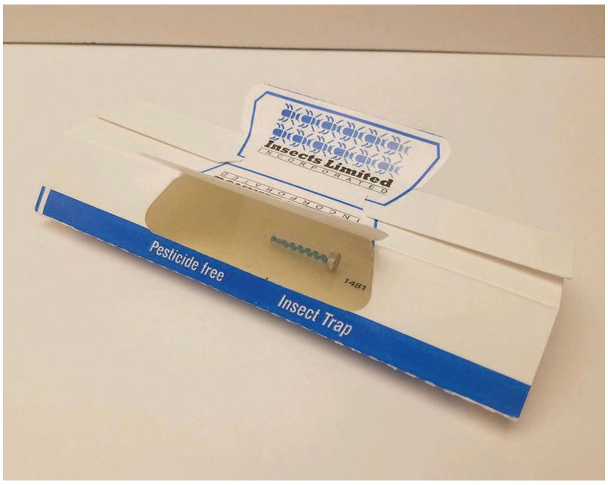


**Figure 3** Sex pheromone trap for female webbing clothes moths (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

**Figure 4** Walk-in freezer at the Peabody Museum displaying the organization of rolled textiles on metal racks (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

## Continued containment

At the onset of the mitigation process, staff immediately contained objects at the highest risk of damage such as fur, feather, hair, wool, and quill. This was continued into the post-discovery phase, and both proteinaceous and non-proteinaceous objects were contained throughout the rest of the storage room. A series of sealable and open-ended polyethylene bags in (2–4 mm thick) was employed to create custom enclosures that safely accommodated objects of all sizes, shapes, and structural integrities. The continued containment of the objects protected the materials from moths and prevented the spread of moths during object transport, and damage during low-temperature disinfestation.

## Freezing

No pesticides or other pest extermination of the space was allowed due to potential risks to the objects and staff, and state laws which prohibit the use of such materials. The use of a $CO_2$ bubble was also explored as an option as other institutions have utilized this method with great success (Historic New England 2018). As this is also prohibited by law it was not pursued. As a result, freezing was the only method of disinfestation that was considered both safe and effective for most materials (Carrlee 2003).

Due to the freeze tolerance exhibited by *T. bisselliella*, freezers that reached –20 °C in less than 24 hours were selected for use (Strang 1992, 1997). At the Peabody Museum, freezer scheduling limitations as well as the high quantity of large and dense objects ultimately determined a two-week freezing cycle at –20 °C. Following the emergency response, two chest freezers, each measuring 2 m$^2$, were purchased which allowed objects to be frozen in large quantities. Use of the freezers utilized during the emergency response also continued. As of July 2021, 5,900 objects had been successfully contained and disinfested.

In 2020, the Peabody Museum's mission to freeze all potentially infested objects in the affected storage room was made exponentially easier with the installation of a long-awaited 18.5 m$^2$, –40 °C walk-in freezer (Fig. 4). This new ability to freeze large objects in-house enabled staff to address entire categories of objects which were on hold due to their size or difficulty of movement. After removal from the freezer, objects acclimatized to room temperature, still contained, for at least 24 hours. Since object materials became temporarily brittle

**Figure 5** Photographs of a remedial treatment on a fur cap: (*left*) before treatment and (*right*) after treatment (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology, PMAE 69-30-10/2109).

**Table 2** Webbing clothes moth numbers in the Peabody Museum buildings and the affected storage room from the period of 2017–2021 (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

| | December 2016–January 2017 | February–March 2017 | April–May 2017 | June–July 2017 | April–May 2018 | October–December 2019 | June–July 2020 | November 2020–January 2021 |
|---|---|---|---|---|---|---|---|---|
| Peabody museum building | 18 | 7 | 12 | 22 | 52 | 2 | 2 | 0 |
| Affected storage room | 10 | 1 | 0 | 2 | 0 | 0 | 0 | 0 |

at such low temperatures, post-freezing handling was minimized until the objects returned to room temperature.

## Assessment, cleaning, rehousing, and interventive treatments

After an object had been examined and its condition assessed, a cleaning approach was devised and conducted. When damage caused by webbing clothes moths was observed, dry, mechanical cleaning of adult moths, larvae and larval casings, feeding tubes, eggs, and frass was typically necessary. Cleaning required carefully parting the fur with flat, metal tweezers and a micro-spatula, and debris removal with either tweezers or a brush and vacuum. Objects were vacuumed on low-suction with a variable speed vacuum. The small, focused nozzles used were capable of reaching tight spaces and were netted to prevent accidental suction of object construction materials. Some objects received additional treatments and were rehoused, which prevented further pest damage and ensured a safe environment for long-term storage (Fig. 5).

## Observations and conclusions

Webbing clothes moths presented a high risk of damage to the proteinaceous, ethnographic collections. In 2016, we were faced with a serious moth infestation. Professionals at the Peabody Museum swiftly enacted an emergency response, which led to the creation of a long-term mitigation protocol that detailed steps to be maintained to prevent pest infestations. The emergency response steps, and post-discovery protocol were successful, with a drastic decrease in moths noted from 2017 to 2021 throughout all Peabody Museum buildings and the affected storage room (Table 2). The correlation between the 5,900 objects contained and frozen over the past four years and the subsequent decrease in moths indicated that these methods were effective.

In 2018–2019, this protocol was largely successful in the remediation of two additional moth infestations in a Zooarchaeology Laboratory and exhibit space at the Harvard Museum of the Ancient Near East. The large number of moths present in 2018 is reflective of the webbing clothes moth outbreak in the Zooarchaeology Laboratory, which happened to be situated within the Peabody Museum building

**Figure 6** Image of a live larvae moving through a cavity in the lower right section of a zooarchaeology specimen (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

(Fig. 6). The same steps used in the mitigation of moths in the original affected storage room were employed in this pest event and were observed to be effective. In total, more than 600 trays and plastic bins full of zooarchaeology specimens were contained, frozen, examined, cleaned, and rehoused. Additionally, the entire lab was thoroughly cleaned by the same staff assigned to the original affected storage room mitigation project. Moths decreased instantly after completion of emergency activities and since the beginning of the infestation in 2016, no moths have been observed in the space.

The drafting of a mitigation protocol was crucial in prioritizing and outlining the tasks, deliverables, resources, and deadlines for the mitigation project. This was considered vital in planning and understanding the project in a broader sense. It was also realized that the mitigation approach used was only as good as its maintenance in the long term, therefore activities such as continued containment of objects, preventive freezing, monitoring, continued examinations and cleaning of objects, quick reporting of pest sightings, and regular cleaning of spaces were critical in preventing additional infestations. The success of this mitigation protocol has resulted in its continuation into 2021 and beyond.

Some considerations to keep in mind in advance of undertaking a mitigation project such as this include the resources necessary and respective costs, the staffing needs and associated training, the availability of dedicated workspaces, the prioritization and efficient coordination of activities, and also awareness of any cultural sensitivities in order to ensure that the most appropriate methods of handling and care are used. This work prompted a recognition of the importance of addressing insect and pest issues on both a museum and university-wide scale, particularly as the Peabody Museum shares a building with university offices, laboratories and classrooms. The training efforts extended far beyond the mitigation staff and included colleagues in all departments. While this pest event was incredibly unfortunate, it provided useful opportunities for long-term care and preservation. Should another situation arise, staff at the Peabody Museum are now ready and able to address such an issue.

## Materials and suppliers

- Blueboard, twill tape, abaca tissue, unbuffered tissue, Mylar, tweezers, microspatulas, Coroplast, OptiVisor DA-7, Volara, bone folders: TALAS Conservation, Archival, and Bookbinding Supplies, Brooklyn, NY, USA (https://www.talasonline.com/)
- Chest freezers (20 cu. ft. 115V –34 °C, key lock, digital controller, locking casters: Industrial Freezer Sales, Agoura Hills, CA, USA (https://www.freezerlink.com/)
- Heat gun: All-Spec, Wilmington, NC, USA (https://www.all-spec.com/)

- Knives, 3M 415 double-coated transparent tape, blueboard boxes, polyethylene sheeting/bags (2–4 mmm thickness), and Ethafoam: University Products Inc., Holyoke, MA, USA (https://www.universityproducts.com/)
- Polyester batting: Test Fabrics, West Pittston, PA, USA (https://www.testfabrics.com/)
- Polyethylene containers: Iris USA, Inc., Pleasant Prairie, WI, USA (https://www.irisusainc.com/)
- Polyethylene foam planks: Index Packaging Inc., Milton, NH, USA (https://www.indexpackaging.com/)
- Polyethylene foam rings (custom), polyethylene foam sheeting: United Foam Plastics (UFP Technologies), Georgetown, MA, USA (https://www.ufpt.com/)
- Sticky blunder traps and pheromone traps: Insects Limited, Westfield, IN, USA (https://www.insectslimited.com/)
- Tyvek (softwrap): MasterPak, New York, NY, USA (https://masterpak-usa.com/)
- Vacuum, Nilfisk GM 80 HEPA filter: Nilfisk Inc., Pittsburgh, PA, USA (https://www.nilfisk.com/)
- Walk-in freezer (–40 °C): Minus-Eleven, Inc., Weymouth, MA, USA (https://www.minuseleven.com/)
- Wheeled racks: Nexel Shelving USA, Inc., Curtis Bay, MD 21226 (https://nexelshelvingusa.com/)

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# Infestation stations! A novel full-cycle approach to webbing clothes moth (*Tineola bisselliella*) eradication at Blickling Hall, Norfolk

Hilary Jarvis, Nigel Blades, Ellie Hobbs and David Loughlin

**ABSTRACT** Webbing clothes moth (*Tineola bisselliella* (Hummel, 1823)) is one of the top two insect pests found in National Trust properties, increasingly manifesting itself in hard-to-control infestations at a small number of houses. *T. bisselliella* caught in traps at Blickling Hall, a 17th-century mansion in Norfolk, tripled in 2016, and have since accounted for 15% of the average annual *T. bisselliella* catch across the Trust. At Blickling, the authors are investigating a new methodology to systematically and simultaneously target different stages of the *T. bisselliella* life cycle. This involves enhancements to the existing approach plus the parallel use of two new treatments: electrostatically charged pheromone dispersal to disrupt adult mating encounters and parasitoid wasps (*Trichogramma evanescens* Westwood, 1833) to destroy moth eggs. The aim is to devise an effective and swift response where entrenched infestations pose a threat to vulnerable and significant collections. This paper presents the methodology and early insights on its practical application.

**KEYWORDS** Integrated pest management; biological insect pest control; insect pest infestation; country house; collections care; cultural heritage collections; webbing clothes moth; pheromone; *Tineola bisselliella*; *Trichogramma evanescens*

## Introduction: National Trust insect pest profile

*Tineola bisselliella* (Hummel, 1823) is one of the National Trust's leading species of insect pest (Fig. 1). The Trust's collection of about 1.5 million accessioned objects includes 100,000 textile items, most on open display. As such, *T. bisselliella* poses a significant risk, particularly since populations can develop rapidly if unrestrained (Pinniger 1994).

The number of insects caught across Trust properties each year has risen by 81% since 2015, for reasons not explored in this paper, with a 93% increase in three moth species (*Tinea pellionella* Linnaeus, 1758), *Hofmannophila pseudospretella* (Stainton, 1849) and *Endrosis sarcitrella* (Linnaeus, 1758)) and a 125% increase in *T. bisselliella* (Table 1).

In 2020, about 46% of the total *T. bisselliella* catch related to an 'infestation', the balance pertaining to what might be deemed typical populations in historic buildings supporting visitor activity. The definition of an infestation by the National Trust is when the total catch of any species exceeds 450 in at least one quarter of the year, for a minimum of two consecutive years. Table 2, which lists those properties with a *T. bisselliella* infestation since 2015, shows that the highest numbers have consistently been reported at Blicking Hall, which accounted for 15% of all *T. bisselliella* caught across 173 properties reporting in 2020.

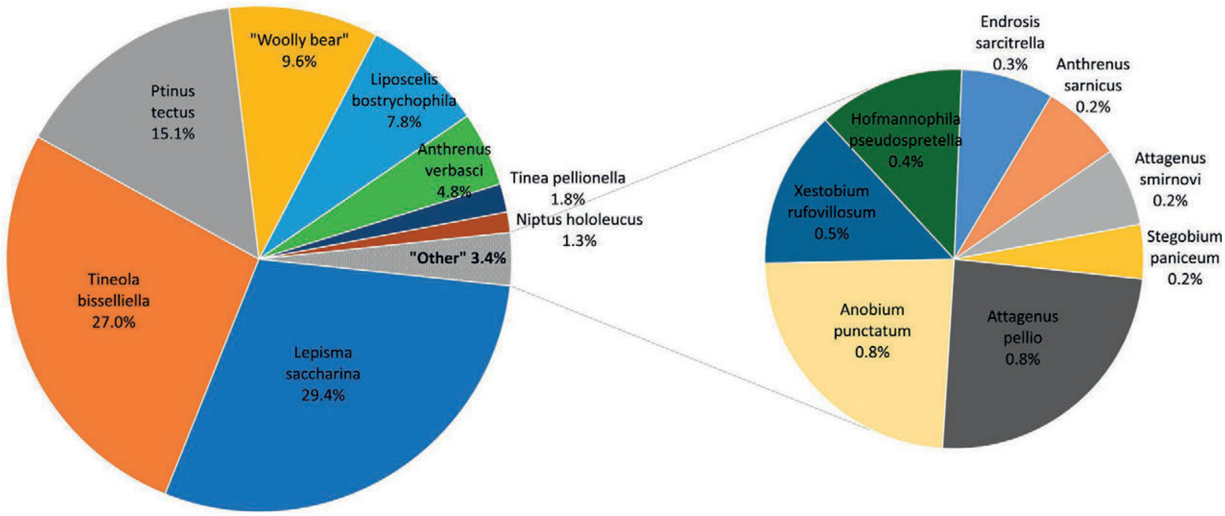


**Figure 1** Insect pest species as percentages of the total insect pest catch on blunder and pheromone traps in 2020, aggregated for all National Trust properties.

**Table 1** National Trust annual total insect pest catch, normalised to insects caught per 50 traps deployed, to enable year-on-year comparison.

| **Year** | **Nine principal insect pest species** | **Four moth species** | T. bisselliella |
|---|---|---|---|
| 2015 | 249 | 69 | 54 |
| 2016 | 380 | 129 | 117 |
| 2017 | 361 | 134 | 127 |
| 2018 | 356 | 127 | 117 |
| 2019 | 408 | 141 | 125 |
| 2020 | 450 | 133 | 121 |
| **5-year growth (%)** | **81%** | **93%** | **125%** |

**Table 2** Total *T. bisselliella* catch at NT 'infested' properties, 2015–2020.

| **Property** | **Total 2020** | % of total 2020 | **Total 2019** | **Total 2018** | **Total 2017** | **Total 2016** | **Total 2015** |
|---|---|---|---|---|---|---|---|
| Blickling Hall, Norfolk | 2,455 | *15%* | 2,950 | 1,822 | 3,394 | 2,508 | 755 |
| Castle Drogo, Devon | 609 | *4%* | 423 | 878 | 1,408 | 2,441 | 2,361 |
| Claydon House, Bucks | 1,468 | *9%* | 1,258 | 1,555 | 553 | 382 | 255 |
| Hanbury Hall, Worcs | 1,218 | *7%* | 626 | 664 | 1,455 | 1,117 | 3 |
| Sizergh Castle, Cumbria | 763 | *5%* | 505 | No data | 1,544 | 1,049 | 156 |
| Tyntesfield, Bristol | 1,594 | *10%* | 1,370 | 1,481 | 944 | 364 | 149 |
| **All properties (total)** | **16,458** | 46% | **15,297** | **14,703** | **16,438** | **13,228** | **5,975** |
| **All properties (normalised to per 50 traps)** | **120** | | **122** | **116** | **125** | **116** | **52** |

## Blickling Hall

Blickling Hall, a substantial Jacobean mansion in Norfolk (Fig. 2), is one of the Trust's leading properties, with 13,000 accessioned items including an array of historic and internationally significant carpets, tapestries and wall hangings, as well as a library of exceptional national and international significance. According to the Association of Leading Visitor Attractions (ALVA), Blickling attracted approximately 225,000 visitors in 2019.

House staff have been assiduous in their integrated pest management (IPM) approach. Bob Child, the Trust's former external IPM adviser, facilitated

**Figure 2** Blickling Hall, Norfolk (© National Trust Images/John Millar).

**Figure 3** Close-up of *T. bisselliella* larvae damage to the State Bedroom carpet at Blickling Hall (© National Trust/Ellie Hobbs).

multiple chemical treatments. He also arranged a small (undocumented) trial of *Trichogramma evanescens* Westwood, 1833 in 2018, although any efficacy was not long lasting, as is evident in Table 2. Although modern-day moth damage is rare, it has been recorded, for example, in the late 18th-century Axminster carpet in the State Bedroom (Fig. 3). With the numbers of *T. bisselliella* consistently above 2,000, the threat posed by seemingly uncontrollable larvae was deemed sufficient to justify a departure from the Trust's usual approach.

## Concept and methodology

In autumn 2019, the decision was taken to investigate more drastic measures to quickly reduce if not eradicate the infestation. Historyonics, a leading UK-based pest product supplier and consultancy, suggested trialling similar methods to those used in horticulture, where beneficial insects (predators, pathogens and parasitoids) are commonly used to control pests in glasshouse crops. Since the 1980s, pheromones have replaced chemical sprays

**Table 3** Blickling Hall: *T. bisselliella* treatment regime initiated in March 2021.

| Change from existing | **Treatment** | **Timing** | **Location** |
|---|---|---|---|
| *Increased* | Monitoring with 44 pheromone traps | Year-round with monthly counting (was quarterly) | 41 spaces |
| | Insecticide spray (Constrain) | Once a month and on signs of activity | Around all carpet edges and where required |
| | Total Release aerosol insecticide foggers | June (spring breeding cycle); repeated in August (summer) | House staff apartments and Attic room 5 only |
| | Housekeeping | Throughout project | All spaces |
| *Novel* | Passive insecticide release devices (wardrobe hangers and drawer liners with transfluthrin) | Constant, for duration of project | 6 rooms in 2 house staff apartments |
| | Biological control: *Trichogramma evanescens* x 40 dispensers | March to end November; replaced every 2 weeks | 15 rooms on first floor, plus 1 ground-floor meeting room |
| | Pheromone mating disruption: Insectrac CL Tabs x 69 | March to end October; replaced every 12 weeks | Entire ground floor (16 rooms); + 15 rooms on first floor |

**Table 4** Blickling Hall: *T. bisselliella* catch by room, 2020.

| | | **Moth count** | **Percentage of infestation** | **Cumulative percentage** |
|---|---|---|---|---|
| High-risk rooms | Long Gallery | 485 | 20% | 20% |
| | Chinese Bedroom | 284 | 11% | 31% |
| | House staff Flat B | 275 | 11% | 42% |
| | Attic 5 (textile store) | 220 | 9% | 51% |
| | Brown Room | 207 | 8% | 59% |
| | Sewing Room | 144 | 6% | 65% |
| | 'O' Bedroom | 133 | 5% | 70% |
| | Linen store | 93 | 4% | 74% |
| | Syndicate Room | 67 | 3% | 77% |
| | Peter the Great Room | 56 | 2% | 79% |
| | House staff Flat C | 49 | 2% | 81% |
| Low-risk rooms | 13 Medium risk | 347 | 14% | 95% |
| | 35 Low risk | 124 | 5% | 100% |
| | **Total 2020** | **2,483** | | |

in orchards, olive groves and vineyards to manage moth pests through a process known as mating disruption (Howse *et al*. 1998). The concept is that populations can be reduced to an acceptable level by using a combination of two biological control approaches: pheromones (Insectrac CL Tab)[1] to first disrupt moth mating and reduce egg laying, complemented by the introduction of *T. evanescens* wasps to parasitise any eggs that may still be laid.

The onset of the 2020 COVID-19 pandemic kept the project at concept stage until early autumn 2020, when the decision was taken to initiate it regardless because moth numbers remained high and we were able to adapt our research design to work within the confines of the national UK lockdown. The project was based on the following priorities:

1. To systematically and simultaneously target different stages of the *T. bisselliella* life cycle.
2. To continue the treatments for at least a year to cover the full breeding season, and potentially two years, depending on efficacy.
3. To enhance the monitoring regime to assess the efficacy of the treatments.

The treatment and monitoring programme is summarised in Table 3.


**Figure 4** Dead *T. evanescens* near a wasp dispenser card on a bookshelf in the Long Gallery at Blickling Hall (© National Trust/Ellie Hobbs).

How and where to deploy the different treatments required detailed planning, not least because of the pandemic: Blickling Hall has about 60 rooms and is usually cared for by four senior house staff and four part-time collections assistants, supported by 18 conservation volunteers. The 2020 lockdown left only four individuals on-site to deal with all the essential tasks for the mansion and estate. Our trial therefore had to be simple and easy to oversee, while still generating meaningful results.

Analysis of the 2020 Blickling pest catch suggested that 81% of adult moths were caught in 11 rooms (Table 4) with a further 14% confined to another 13. The priority was therefore these 24 high- and medium-risk spaces, plus a sufficient number of nearby low-risk rooms to ensure a viable but still practicable attack; 41 rooms were eventually treated.

## Novel elements of the approach

The novel element of the trial is the use of two biological control techniques in tandem: specifically parasitoid wasps in combination with pheromone mating disruption. Conventional chemical treatments have been limited to the upper floor and staff apartments as a comparison. The experimental design was to measure the effect of all treatments, both individually and in combination, as outlined in Table 3. Pheromone lure sticky traps were placed in all rooms, at least 2 m away from any Insectrac CL Tabs to minimise disruption to tab efficacy. The moth catch was counted each month.

## Biological control

### *Trichogramma evanescens*

Parasitoid wasps have been used to combat webbing cloths moth in cultural heritage settings (Querner and Biebl 2011), but not widely and with varying success. On hatching, the wasps mate and the female seeks out *T. bisselliella* eggs, which she locates by smell and into which she then oviposits her eggs. The developing wasp larvae will consume the moth host. The adult wasps both fly and crawl. A key question in relation to their application in a historic house is the female's ability to find moth eggs in collection items in large, open rooms (Querner and

Biebl 2011). The wasps are 0.3–0.5 mm long and, as egg parasitoids, are among the most important and best-studied natural enemies worldwide (Romeis *et al*. 2005). The distances they can cover vary widely for a range of reasons, but particularly if they need to traverse a large space and forage across non-smooth surfaces, such as textiles (Schöller and Prozell 2013).

The first batch of *T. evanescens* was released at Blickling on 4 March 2021 at an approximate rate of one card per 25 m²: 40 card dispensers, each containing about 2,400 parasitoid wasp eggs, were distributed across the 15 first-floor show rooms and one ground-floor meeting room. Thereafter they were replaced every two weeks, meaning up to 864,000 wasps had been released by the end of May 2021. Continuous *T. evanescens* introduction is planned until December, because *T. bisselliella* in the UK typically have two life cycles per year, with adult flights in the spring and autumn, although overlapping generations mean precise dates for egg-laying availability are unknown. The aim of the continuous introductions is to ensure sustained parasitoid wasp availability whenever moth eggs are likely to appear.

In orchards, the wasps are released within the tree canopy in the vicinity of the fruit to maximise the chances of the females smelling the moth eggs. After landing on a plant, the female wasp begins a random search for hosts, sensing host kairomones such as moth scales and sex pheromones, stimulating an arrestment behaviour in the vicinity of eggs. At Blickling, the wasps have generally been released close to ground level or from shelves, as near as possible to void or underfloor harbourages where we believe the moth eggs are being laid. It will be interesting to note whether the data suggest deployment positioning is critical. This warrants further research.

Staff have reported dead wasps around some dispensers (Fig. 4). This could be due to a range of factors, including potentially contaminated surfaces (Schöller and Prozell 2013) and will need investigation. The requirement to regularly clean areas around the dispensers is an unforeseen consequence of the treatment and will need to be factored into any future use.

## *Tineola bisselliella pheromone tabs*

The second element to our novel combination was mating disruption using Insectrac CL Tabs

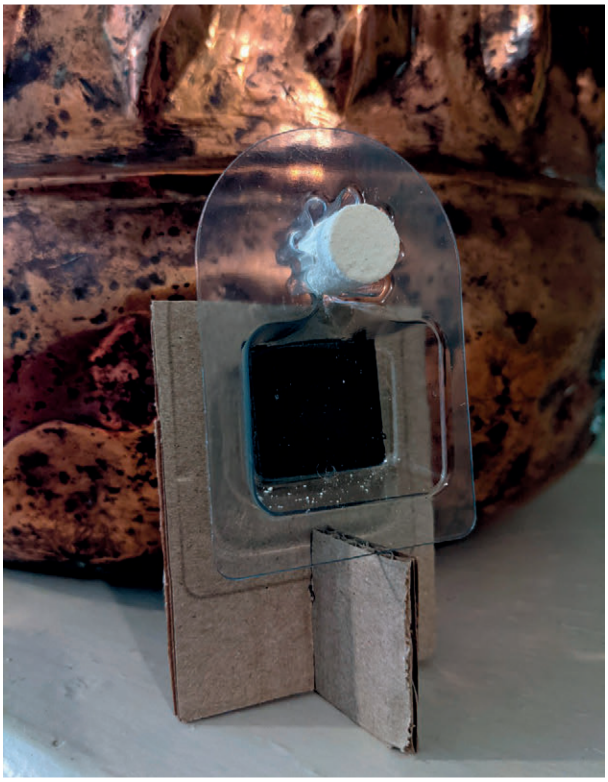

**Figure 5** Insectrac CL Tab pheromone tab in plastic dispenser and cardboard holder (© National Trust/Ellie Hobbs).

containing *T. bisselliella* pheromone. Male moths are drawn to the tabs and pick up wax particles on their antennae and body (due to the electrostatic properties of the formulation) before taking off. The close proximity of the pheromone on their body renders them incapable of seeking females, a process known as auto-confusion, with the treated males in turn becoming mobile pheromone distributors.

The pheromone system has been available as a monitoring trap-enhancement treatment for *T. bisselliella* for some years, and deployed in trials at cultural heritage sites such as Marble Hill House in London (Lauder 2009). Regarded as a long-term population-suppression approach, the number of breeding cycles it takes for an entrenched infestation to recede remains unclear, with multiple years alluded to in that trial and another at the Natural History Museum (Ryder *et al*. 2014). The authors are conducting separate trials on solo auto-confusion efficacy at three other National Trust properties and will report on these in due course.

The Insectrac CL Tab is supplied with clear plastic holders with clicklock backing, but for the Blickling study, cardboard stands were made to ensure that no holder was directly attached to a historic surface

(Fig. 5). The application rate is one tab per 25 m² and positioning was based on staff knowledge of the rooms and regular moth sightings.

On 26 March 2021, 69 tabs were introduced, generally 5 m apart, in 31 rooms. Dual treatments were carried out in 15 of the 41 spaces, again with 5 m between the tabs and wasp cards. The ground floor was left exclusively for pheromone mating disruption to facilitate the comparison of efficacy with and without other treatments. Conventional insecticide treatments were limited to the third-floor attic rooms and staff apartments. The tabs remain effective for three months and will be replaced at the end of each quarter. They will be deployed throughout spring and summer to ensure a sustained mating-disruption effect.

## Conclusions and future work

At the time of writing, there were insufficient data to provide meaningful conclusions on the success of the project, let alone the relative efficacy of the different life-cycle treatments. We will report on these in due course, as well as on any varying outcomes in our chosen locations for the different approaches, positioning of the tabs and the wasp cards, the proportion of *T. evanescens* dying close to their release point and any other practicalities or unforeseen consequences.

## Note

1. Insectrac CL Tabs manufactured by IPS Ltd (previously known as Exosex CL Tabs) and supplied by Historyonics (www.historyonics.com).

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# Over 10+ years using parasitoid wasps in integrated pest management for cultural heritage in Germany

Stephan Biebl

**ABSTRACT** This paper presents a historical overview of biological control against cultural heritage insect pests and the use of parasitoid wasps in museums and historic buildings today. The use of natural enemies in wood preservation has been established practice for many years as part of integrated pest management (IPM). Various types of wasps can be used and commercially sourced. Natural counterparts (antagonists) have been considered an integral part of technical standards and rules in conventional pest control for some years now, and also in terms of a European standard for IPM for the protection of cultural heritage. A practical example is given to describe the successful use of parasitoid wasps to control clothes moths in the exhibition rooms of the Deutsches Museum Verkehrszentrum (Transport Museum) in Munich from 2007 to 2020. Experience of the practical use of different beneficial insects within the last 10 years, as well as the application of accompanying methods such as the moth confusion system, is discussed.

**KEYWORDS** Integrated pest management; IPM; biological pest control; museum pests; parasitoid wasps; natural enemies

## Introduction: history and development of biological control

Biological pest control can be described as the use of living organisms to limit the population of harmful animals and plants. In 1888, the ladybird (*Rodolia cardinalis* (Mulsant, 1850)) was brought to California by Charles Valentine Riley to fight an Australian scale insect infestation in orange orchards. Due to successful pest control, about 500 million ladybirds of this species have been bred and released in California to date.[1]

Biological control of insect pests using natural enemies was reported by DeBach (1974) in crop protection to reduce the use of toxic and environmentally harmful chemicals. The egg parasitoids of the genus *Trichogramma* were originally used for biological control in field crops (maize and apple). They accept the eggs of many lepidopterans, including the clothes moth: *Trichogramma evanescens* Westwood, 1833, parasitises the eggs of the clothes moth particularly well (Zimmermann 2010). According to the Technical Rules and Standards for Pest Control (TRNS),[2] biological methods in pest control are listed as the targeted use of suitable living organisms (e.g. natural enemies). In addition to predatory bugs and nematodes, parasitoid wasps are considered natural enemies of certain insect pests according to the TRNS. Annex E of the European standard DIN EN 16790 2016, *Conservation of Cultural Heritage – Integrated Pest Management (IPM) for the Protection of Cultural Heritage*, describes treatments for the release of parasitoids.

## Use of parasitoid wasps today

In the last 10 years in the cultural heritage sector, the regular application of parasitoid wasps over an


**Figure 1** Deutsches Museum Verkehrszentrum (© Stephan Biebl 2021).


**Figure 2** Cars in Exhibition Hall 3 (© Stephan Biebl 2021).

extended period of time has been reported in the literature (Querner and Biebl 2011, 2013; Dummer and Prozell 2013; Schöller and Prozell 2013). The use of beneficial insects in integrated pest control against insect pests is part of everyday life in many museums and collections in Germany and Austria. For example, since 2011, wasps of the species *T. evanescens* and *Baryscapus tineivorus* (Ferrière, 1941) have been used regularly in various museums and collections in Germany and Austria as a preventive measure against clothes moth infestations. Parasitoid wasps and other beneficial insects are now an integral part of the IPM for the protection of cultural heritage in Germany.[3] Evidence gained from several years of experience confirms that the regular and long-term use of biological antagonists can lead to a significant reduction of moth or beetle infestations in an exhibition area or on objects (Biebl 2013). In sacred buildings, such as churches with historically valuable wood furnishings, the use of the braconid wasp *Spathius exarator* (Linnaeus, 1758) as an antagonist of the common furniture beetle (*Anobium punctatum* De Geer 1774) has been one of the alternative methods used in integrated wood protection for more than seven years (Biebl and Auer 2017).

## Parasitoid wasps used as a control against textile moths

Different species of parasitoid wasps can be used to control textile moths: the egg parasitoids *Trichogramma* spp. (Trichogrammatidae) and the two larval parasitoids *Apanteles carpatus* (Say, 1836) (Braconidae) and *Baryscapus tineivorus* (Eulophidae). In the past, other members of the Braconidae, such as *Habrobracon hebetor* (Say, 1836) have also been described by scientists as effective parasitoids against moth larvae such as the webbing clothes or case-bearing clothes moth (Zimmermann and Wührer 2010). The application of *Trichogramma* wasps is carried out using cardboard capsules as a release unit. The juvenile stages hatch continuously over 3 or 4 weeks and can walk up to about 15 m on smooth surfaces. The flight-capable wasp *Baryscapus tineivorus* is delivered in small plastic tubes and released on-site.

## Parasitoid wasps and predatory bugs against material-damaging beetles

To control biscuit beetles, tobacco beetles and spider beetle species such as *Niptus hololeucus* (Faldermann, 1836), the parasitoid wasp *Lariophagus distinguendus* (Förster, 1841) is used in museums (Biebl 2010; Schöller and Prozell 2013). For Berlin beetles (*Trogoderma angustum* Solier, 1849) or varied carpet beetles (*Anthrenus verbasci* (Linnaeus, 1767)), *Laelius pedatus* (Say, 1836), a Hymenopteran parasitoid in the family Bethylidae, has been described as an effective control agent (Notton 2016; Schöller and Prozell 2013). The warehouse bug *Xylocoris flavipes* (Reuter, 1875) forages in eggs and early larvae of insects of different insect orders and can decimate,

**Figure 3** Furnishings inside the vintage car (© Stephan Biebl 2021).

according to Jay *et al*. (1968), the black carpet beetle (*Attagenus unicolor* (Brahm, 1971)), the brown carpet beetle or vodka beetle (*Attagenus smirnovi* Zhantiev, 1973), and the Australian carpet beetle (*Anthrenocerus australis* (Hope, 1843)).

## IPM at the Deutsches Museum Verkehrszentrum

In three structurally connected exhibition halls dating from 1907 in the Deutsches Museum Verkehrszentrum (Transport Museum), many different historical objects such as railways, cars, motorbikes, bicycles and carriages are displayed in an area totalling 12,000 m$^2$ (Figs 1 and 2). A special exhibit is Carl Benz's first automobile with a petrol engine from 1886 in Exhibition Hall 3. How vintage cars made of metal can be infested by clothes moths may sound surprising, but many of the old vehicles and carriages contain furnishings made of wool, silk, felt and horsehair, which was used in covers, floor mats and upholstery (Fig. 3). In addition, there are also objects containing animal hair (felt boots, ski skins, etc.) as well as textiles presented in special exhibitions from time to time.

The first infestation of clothes moths appeared in 2007 on 33 inspected vehicles in Exhibition Halls 1 and 2. After monitoring, a more severe infestation was detected on a Mercedes Simplex: the vehicle was treated with anoxia (Biebl 2013) shown in Figure 4. After assessing the moth infestation and calculating

**Figure 4** Anoxia treatment in Exhibition Hall 2 (© Stephan Biebl 2021).

**Figure 5** A *Trichogramma* card and pheromone trap placed in the trunk of a car (© Stephan Biebl 2021).

the high cost for a complete anoxia treatment of all vehicles, experimental use of *Trichogramma* wasps and accompanying monitoring was suggested by the present author. The cost of the annual use of beneficial insects is approximately equivalent to the treatment costs of anoxia for one vehicle in the exhibition. Another reason for employing parasitoid wasps was to avoid the use of chemicals for the protection of objects, staff and visitors, as well as the risk of introducing pests via new arrivals or changes of vehicles from two sites in the museum.

According to the monitoring results in the first year (2007), in total 789 clothes moths were found in the deployed pheromone traps in Halls 1 and 2. Evaluation in the second year (2008) showed only 311 clothes moths on the pheromone traps, with an extension of the monitoring to 70 vehicles in three halls. The moth population was reduced from an average of 10–15 moths to 2–3 per vehicle within three years through the monthly use of *Trichogramma* cards in each vehicle (Fig. 5). Monitoring in the fifth year (2012) resulted in 117 trapped clothes moths. In the following years (2013–2020), individual vehicles were permanently free of moths and the population was kept at a very low level. In 2020, only 65 clothes moths were documented in the three exhibition halls with 77 vehicles monitored (for a comparison of webbing clothes moths trapped 2007–2020 see Fig. 6). The use of parasitoid wasps will be continued on a monthly basis as this method has proved successful to the museum in the long term.

Successful integrated pest management at the Deutsches Museum Verkehrszentrum also includes regular cleaning of vehicles and showrooms, monitoring with monitoring traps, climate control, control for harmful rodents, compliance with quarantine and staff training. Flanking measures with additional parasitoid wasps and the use of auto-confusion

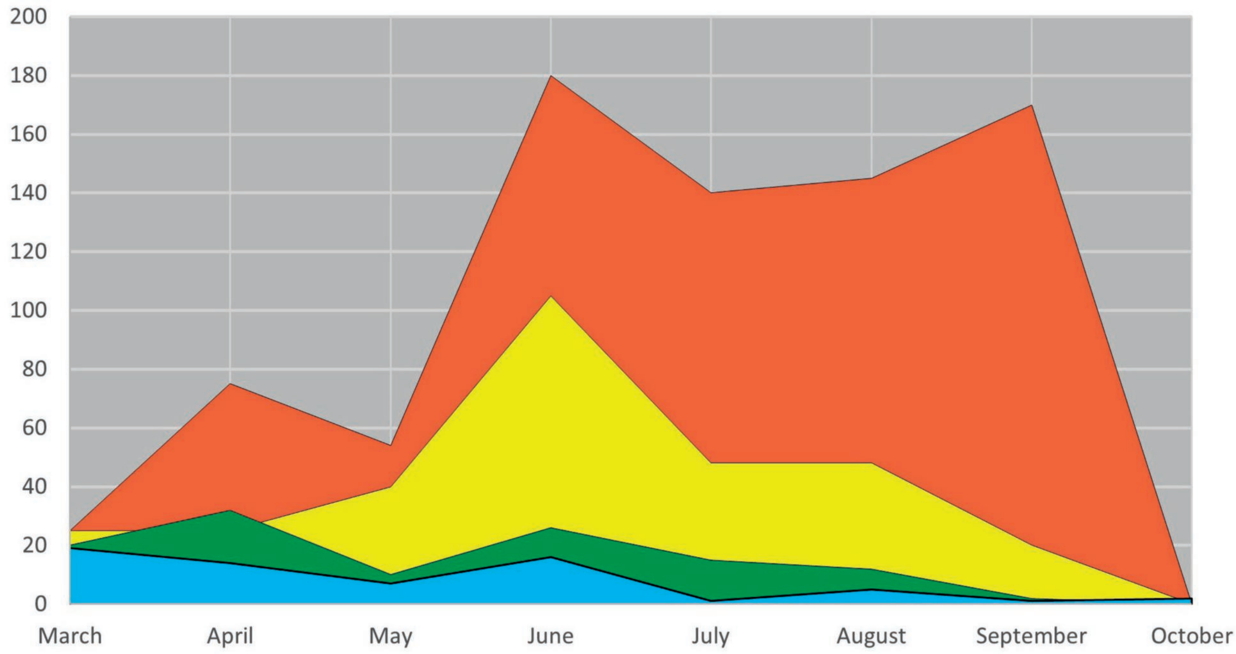


**Figure 6** Webbing clothes moths trapped annually 2007/2008, 2012 and 2020 respectively (© Stephan Biebl 2021).

technology have not proved successful, as described below.

## Accompanying practical trials on the use of parasitoid wasps

In the first year (2007), an attempt was made to trap the male clothes moths outside the infested vehicles with additional pheromone traps placed on the tyres as a confusion technique (Karg 2006) in an attempt to deter them from accessing the interior of the vehicles. However, this flanking measure was discontinued after one year as the sticky traps were disturbed during cleaning. In 2008, the larval parasitoid *Habrobracon hebetor* was distributed on an experimental basis in addition to the *Trichogramma* cards, with 50 tubes each containing 50 braconid wasps in the affected vehicles. Due to the wasps' body size of up to 4 mm and the cost of delivery from a beneficial insect manufacturer in Switzerland, this trial was discontinued.

The Exosex Auto-confusion system (Higgs *et al.* 2011), which came onto the European market in 2011, supplemented the continuous use of *Trichogramma* wasps with the confusion technique on a trial basis in Hall 3 (Biebl 2013). The costs for the SP-Tab system, durability of the pheromones, the large floor area, the problem of cross-connection to pheromones of the sticky traps and lack of long-term experience led to the discontinuation of the ExoSex system after six months.

In addition to the clothes moth infestation, there were also isolated problems with the brown carpet beetle (*Attagenus smirnovi*), which was discovered on one occasion on a carriage in 2007 and controlled locally in 2019 to 2020 in a vintage vehicle with textile furnishings using the storage pirate bug *Xylocoris flavipes*.

## Practical experiences and problems with the use of beneficial organisms

- Dispatch during periods of very extreme temperatures (winter/summer) can lead to weakening or death of beneficial organisms during shipment.
- Delay in the mail (e.g. during holiday periods) leads to weakening of beneficials or a time shift in the rhythm of application.
- Shipping across national borders can be problematic if there are delays due to customs regulations or with the contracted transport services (e.g. during strikes or public holidays).

- Delays in application are possible in larger museums due to internal post distribution and passing on to staff, or application in external depots.
- The application temperatures in museum warehouses should be at least +15 °C in the museum stores.
- If the planned number of beneficial insects is too low, the quantity may have to be adjusted during the year.
- The use of beneficial insects in cases of heavy pest infestation cannot replace control by fumigation or equivalent methods.
- The regular application of beneficial insects in the case of a low infestation of insect pests such as clothes moths avoids emergencies or costly control measures.
- The preventive application of parasitoid wasps in museums with special or travelling exhibitions with textiles has so far proved positive.
- Chemical residues of pollutants on textiles and wooden surfaces can jeopardise the use of parasitoid wasps or render them ineffective.
- Improper use of long-term chemical pesticides prevents the use of beneficial insects.
- Proper use of short-term chemical pesticides, such as pyrethrum, allows emergency measures to be taken to reduce clothes moth indoors and the continued use of parasitoids.
- In addition to infestations on textiles, problems with clothes moth infestations on dead rodents have also been treated with wasps in the past.

## Conclusions

The use of parasitoid wasps against insect pests has become an integral part of integrated pest management as a preventive and biological measure for more than 10 years in Germany. The regular use of various parasitoid wasps can keep a population of clothes moths permanently low and thus prevent damage to museum objects. The advantages of using parasitoid wasps are that they are inexpensive and easy to release in limited areas (Querner and Biebl 2011). In the case of an acute active moth or beetle infestation, parasitoid wasps can provide supportive assistance as part of integrated pest management if other effective measures such as cleaning, monitoring and quarantine are also used. However, the use of beneficial insects cannot replace control by fumigation or equivalent methods in cases of heavy pest infestation. Complete eradication of an insect pest population is not possible, even with the long-term use of parasitoid wasps. Incorrect assessment or lack of information on pesticide residues on objects can lead to failures of biological control. Since 2016, the release of parasitoids has also been part of the European standard (DIN EN 16790) as a method for reducing and controlling pest populations in the context of integrated pest management.

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## Notes

1. See https://de.wikipedia.org/wiki/Australische Wollschildlaus (accessed 5 July 2021).
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# Pest comparison of three treatment methods for archival materials against grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905): re-evaluation of the efficacy limits of freezing, heating and anoxic treatment with oxygen absorbers

Judith Wagner, Pascal Querner and Andrea Pataki-Hundt

**ABSTRACT** The museum pest *Ctenolepisma longicaudatum* Escherich, 1905 (long-tailed silverfish, grey silverfish) has been spreading rapidly in Europe for years and endangers the collections of archives, libraries and museums. Therefore, there is an urgent need of recommendations for curative and preventive control strategies, which can be implemented in a way that is gentle to the object, rapid and cost-effective. In the study conducted as part of a Masters project in conservation sciences, the efficacy of three non-chemical treatment methods – freezing, heating and oxygen deprivation – and the lethal effects for *C. longicaudatum* was evaluated under laboratory conditions. Standardised test samples (archival boxes 40 × 28.2 × 11 cm) were prepared and an infestation situation was simulated, in which all developmental stages were examined: adults, nymphs and eggs. Mortality rates were determined by controlling time, temperature and oxygen levels. The results show that freezing at –20 °C without first reaching core temperature required only 12 hours to kill all stages. The anoxic treatment was successful in 48 hours at 22 °C, 50% RH and 0.1% residual oxygen. In the heat treatment studied, 47.5 °C held for one hour was already sufficient.

**KEYWORDS** *Ctenolepisma longicaudatum*; paper; archive; library; non-chemical treatment; freezing; heating; anoxic treatment; oxygen absorbers

## Introduction

With the detection of the grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) in Europe, a new threat to collections of written cultural property and works of art on paper has been identified. In Germany, the first finding was detected and published by Udo Sellenschlo in 2007. It is suspected that the international trade in goods has favoured the massive spread and for this reason it is also increasingly found in art and cultural heritage institutions. The pest enters libraries, archives and museums through new acquisitions, object loans, infested packaging materials, paper tissues or toilet paper. Often the quantity of these potentially contaminated objects or packaging materials exceeds the capacity for quarantine. The damage caused by the insect is noticeable as abrasions on the surface of the affected paper and even pitting. If an infestation is not detected or treated, there is a risk of severe


**Figure 1** Different stages of *C. longicaudatum* in a live trap (in cm). (© Judith Wagner).

**Table 1** Methods of non-chemical insect pest treatments in museums.

| Method | Equipment | Temperature | RH | Residual oxygen | Time of treatment | References |
|---|---|---|---|---|---|---|
| Freezing | freeze chamber, freeze container, household freezer, chest freezer | −18 °C | ~50% | – | 14 days | Strang 1992; Pinniger *et al.* 2016; Lauder and Pinniger 2019; Strang and Kigawa 2009 |
| | | −25 °C | | – | 7 days | |
| | | −30 °C | | – | 3 days | |
| Heating/ humidified warm air | heating chamber, heat bubble | Mind. 55 °C | 45–55% | – | 24 hours | Xavier-Rowe *et al.* 2000; Pinniger *et al.* 2016; Strang 1992, 2001 |
| Anoxic treatment | nitrogen chamber, nitrogen bubble, bags with scavengers | 27 °C | ~50% | 0.5% $O_2$ 1.0% $O_2$ | 21 days | Selwitz and Maekawa 1998; Landsberger *et al.* 2019 |
| | | 24 °C | ~50% | 0.5% $O_2$ | 21 days | |

loss of substance or irreversible insect damage. Therefore, the solution appears to be the application of curative and preventive control measures that are targeted to control the grey silverfish.

## Aim of the study

The grey silverfish is a synanthropic species and considered a material pest for paper and cardboard because it prefers to feed on carbohydrates, such as cellulose, starch and sugars (Lindsay 1940). The grey silverfish reaches a maximum length of 18 mm without antennae (Beijne Nierop and Hakbijl 2002; Sellenschlo and Weidner 2019). Reproduction is continuous, regardless of season, with about 60 eggs laid per year (Aak *et al.* 2019). These hatch into nymphs, which reach sexual maturity at the 14th instar and a body size of approximately 9.5 mm (Fig. 1). A temperature of 22–26 °C and a relative humidity (RH) of 55% or above is ideal for its development. According

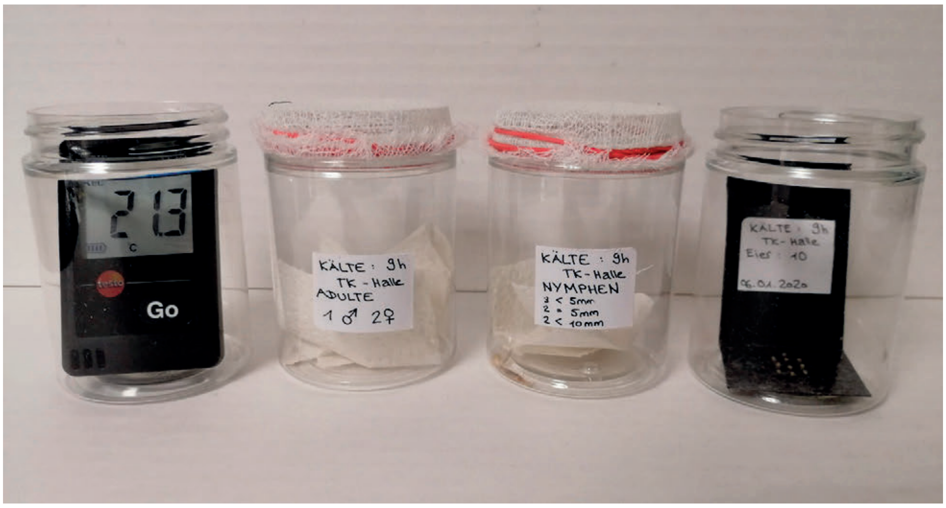


**Figure 2** Plastic test container with *C. longicaudatum* – separated into adult, nymph and egg stages – and a climate data logger (© Judith Wagner).

to Lindsay (1940), temperature values below 0 °C and above 41.5 °C have a lethal effect, although adults can survive and recover after brief exposure.

The established system of integrated pest management (IPM) provides a comprehensive strategy of prevention, detection and appropriate control of a pest infestation (Brokerhof *et al.* 2007; Pinniger *et al.* 2016). For preventive or curative control, the chosen treatment methods should be compatible with the principles of conservation of cultural heritage property (Florian 1997). This means the condition of the treated objects should not be affected in any way. In addition, the chosen methods must be residue-free in application to protect humans, the environment and the object. Physical pest control using high and low temperatures or anoxic treatment by creating a modified atmosphere via nitrogen enrichment or oxygen removal fulfill all these requirements (Querner and Kjerulff 2013). An overview of the common guidelines for assured treatment success applied to pests is summarised in Table 1, which also gives the effective values of the parameters' temperature, RH, time of treatment and residual oxygen.

Based on the proven recommendations for the three non-toxic treatment methods, the aim of this study was to adapt the different parameters of the methods to the biology of this particular pest species by reducing the temperature gradient or the time of exposure. There should still be a 100% mortality rate of all the different developmental stages of *C. longicaudatum.*

In collection repositories containing paper and cardboard objects, the climate is ideally adjusted to their needs (~18 °C and 50% RH). Exposure to climatic changes leads to physical stress of the objects: even if an immediate damaging effect cannot be confirmed for most materials (Beiner and Ogilvie 2005), long-term damage cannot be ruled out. In addition to saving financial resources, the shortening of the time of exposure also increases productivity as treatments can be better integrated into the daily routine of institutions.

## Material and methods

### Preparation

*C. longicaudatum* was cultivated to ensure the presence of enough test individuals in all developmental stages – adult females and males, nymphs and eggs. Breeding at temperatures between 18 °C and 30 °C with an average RH of 50–60% resulted in sufficient individuals for the experiments. To exclude increased stress to the insects, they were prepared at least three days before the experiment. The individuals were differentiated into adult and nymphal stage based on body length, and for each experimental run 10 specimens of both sizes were placed in separate 100 ml plastic containers. Ten eggs per experiment were mounted on black sample cards specially prepared with double-sided tape (using a magnifier) before being transferred to the containers. The containers were sealed with a gauze and placed back in

**Figure 3** Five archival boxes prepared for the experiment, filled with telephone directories and four milled round recesses per box (© Judith Wagner).

the breeding container until immediately before the experiments.

For freezing and anoxia treatment, archival A4 format boxes (external dimensions 400 × 282 × 110 mm) were filled with six layers of telephone directories. Four cylindrical recesses were milled into the stacks at even intervals, into each of which the plastic containers with test insects and a data logger were inserted (Figs 2 and 3). To create comparable baseline conditions, the archival boxes were pre-conditioned at 18±2 °C and 46%±3% RH for two weeks prior to the experimental runs.

## Freezing

The tests were carried out in a Liebherr GGPv 6570 ProfiLine freezer cooled to −20 °C. The test specimens were wrapped with polyethylene (PE) film in accordance with the process recommendations. The time parameter was investigated by setting the treatment intervals to 4, 6, 12 and 24 hours (without reaching core temperature). After the end of the treatment period, a thawing phase of 24 hours took place.

## Heating

The experiments were carried out in an ATMOS MTH-4100 Temp/Humidity Stress Chamber. The lowest temperature selected was 40 °C which was increased by 2.5 °C to 50 °C at systematic intervals. The RH was set at 50% but was subject to slight fluctuations owing to the equipment. Due to a lack of a control sensor, the time intervals needed to be adjusted and finally programmed based upon prior experiments. Using the knowledge of the length of the heating phase, the climatic chamber was then programmed to ensure a gradual heating phase was followed by a one-hour holding phase before the temperature was slowly lowered again. The plastic containers containing the insects were placed directly in the chamber.

## Anoxic treatment

Mortality of *C. longicaudatum* was studied at a residual oxygen concentration of 0.1% and a temperature of 22 °C. The time intervals to be tested were set at 12, 24, 48 and 168 hours. An oxygen-free atmosphere was created in 42 × 68 cm bags (ceramic-coated PET on one side and aluminium composite film A 30T on the other) by adding 10 ATCO FTM 1000 oxygen absorbers. A RH of 50% was controlled by PROSorb silica gel. The residual oxygen content was monitored with a GOX 100 oxygen meter and the treatment intervals started as soon as the desired concentration of 0.1% residual oxygen was reached, after about 20 hours.

## Data collection

During each test run, temperature and humidity values were recorded using the data logger

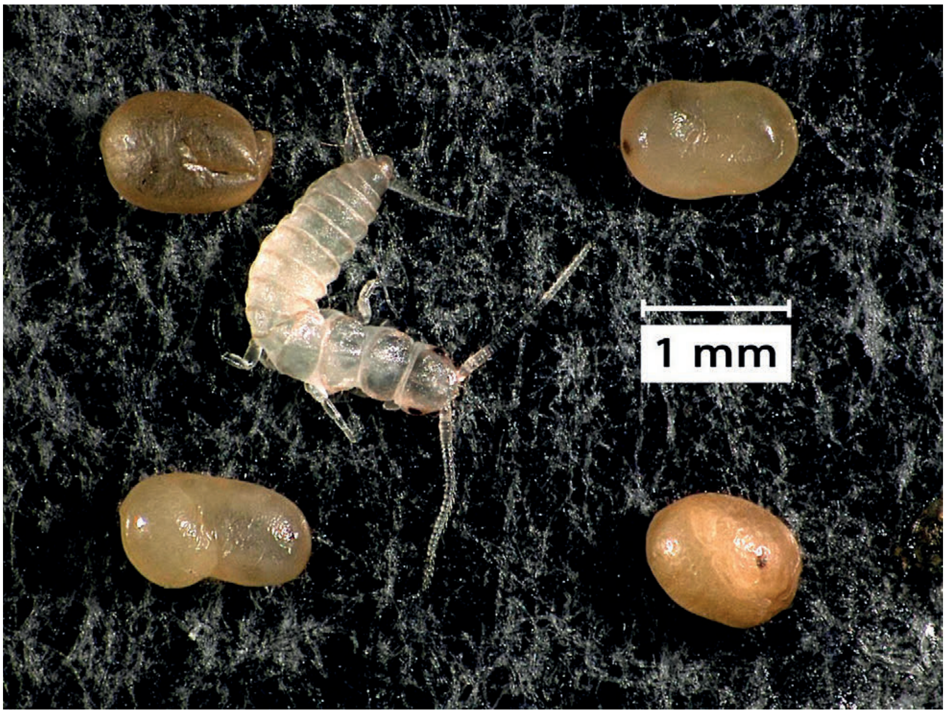


**Figure 4** The hatching of a nymph after a treatment demonstrates this as unsuccessful (original magnification ×50) (© Judith Wagner).

**Table 2** Summary of results for freezing: an overview of tested parameters and stages of grey silverfish.

| | | |
|---|---|---|
| **Temperature** | **In freezer:** | **– 20** °C |
| | In archival box: | below 0 °C after ~3 hours |

| **Treatment time [hours]** | ***C. longicaudatum* specimen** | | | **Survival analysis** | | | **Final results** |
|---|---|---|---|---|---|---|---|
| | stage | quantity | sex | R | R+ | R++ | |
| **4 h** | A | 1 | ♀ | 1 | 1 | 1 | A = 3/3 |
| | | 2 | ♂ | 2 | 2 | 2 | |
| | N | 7 | | 7 | 7 | 7 | N = 7/7 |
| | E | 10 | | | | 10 | E = 10/10 |
| **6 h** | A | 1 | ♀ | X | | | A = 0/3 |
| | | 2 | ♂ | 1 | 1 | X | |
| | N | 7 | | X | | | N = 0/7 |
| | E | 10 | | | | 4 | E = 4/10 |
| **12 h** | A | 1 | ♀ | X | | | **A = 0/3** |
| | | 2 | ♂ | X | | | |
| | N | 7 | | X | | | **N = 0/7** |
| | E | 9 | | | | X | **E = 0/9** |
| **24 h** | A | 1 | ♀ | X | | | **A = 0/3** |
| | | 2 | ♂ | X | | | |
| | N | 7 | | X | | | **N = 0/7** |
| | E | 8 | | | | X | **E = 0/8** |

| | | | | |
|---|---|---|---|---|
| | A | adults | R | recording after treatment |
| | N | nymphs | R+ | recording one day after treatment |
| | E | eggs | | |
| | X | dead | R++ | recording two months after treatment / end of the study |
| Final results: | surviving individuals at the end of the study/number of individuals tested | | | |

**Table 3** Summary of results for heating: an overview of tested parameters and stages of grey silverfish.

| **Treatment time [hours]** | **1 h** | |
|---|---|---|
| | Heating phase: ~1 h | Cooling phase: ~0.75 h |

| **Temperature** | ***C. longicaudatum* specimen** | | | **Survival analysis** | | | **Final results** |
|---|---|---|---|---|---|---|---|
| | stage | quantity | sex | R | R+ | R++ | |
| **40** °C | A | 2 | ♀ | 2 | 2 | 2 | A = 4/4 |
| | | 2 | ♂ | 2 | 2 | 2 | |
| | N | 7 | | 7 | 7 | 5 | N = 5/7 |
| | E | 10 | | | | 9 | E = 9/10 |
| **42.5** °C | A | 2 | ♀ | 2 | 2 | 1 | A = 3/4 |
| | | 2 | ♂ | 2 | 2 | 2 | |
| | N | 7 | | 6 | 6 | 5 | N = 5/7 |
| | E | 10 | | | | 8 | E = 8/10 |
| **45** °C | A | 2 | ♀ | X | | | A = 0/4 |
| | | 2 | ♂ | X | | | |
| | N | 7 | | X | | | N = 0/7 |
| | E | 10 | | | | 5 | E = 5/10 |
| **47.5** °C | E | 10 | | | | X | **E = 0/10** |
| **50** °C | E | 10 | | | | X | **E = 0/10** |

| | | | | |
|---|---|---|---|---|
| | A | adults | R | recording after treatment |
| | N | nymphs | R+ | recording one day after treatment |
| | E | eggs | | |
| | X | dead | R++ | recording two months after treatment / end of the study |
| Final results: | surviving individuals at the end of the study/number of individuals tested | | | |

(Testo 174H) in the test environment. Test runs were evaluated according to the principle 'dead or alive'. The condition of the test insects was checked and recorded by visual inspection and by slight mechanical stimulation using a fine brush, based on the reaction in the form of perceptible movement. Surviving individuals and eggs were checked regularly. Potential hatching of nymphs from the eggs could only be fully evaluated after two months (Fig. 4).

## Results and discussion

### Freezing

During cold treatment over a period of 12 and 24 hours, all stages of *C. longicaudatum* were successfully killed (Table 2). In both cases, the targeted treatment temperature was reached in the core of the test specimen after about 12 hours. This could not be achieved for the treatment times of 4 and 6 hours. A temperature drop below 0 °C could be measured in all archival boxes after three hours. After the treatment time of 6 hours, the death of adults and nymphs was recorded, but hatching occurred after about 30 days in 4 of the 10 eggs tested. The additional time and material required to pack objects can be avoided if equipment with an adaptive freezing treatment is used in which controlled reconditioning of humidity occurs within the rewarming phase, as described by Yoshida (2020).

### Heating

A lethal effect of heat on all stages could be detected at the temperature of 47.5 °C for one hour (Table 3). Although 45 °C was already lethal for adults and nymphs, hatching was still observed. It was striking that at 42.5 °C, a state of shock was initially observed in adults from which they recovered the following day. In the case of the nymphs, moulting was observed after treatment, indicating that no long-term damage was caused by a short-term

**Table 4** Summary of results for anoxic treatment with oxygen scavengers: an overview of tested parameters and stages of grey silverfish.

| | |
|---|---|
| **Temperature** | **22 °C** |
| **Residual oxygen** | **0.1%** |
| | Time interval to reach residual oxygen concentration: ~20 hours |

| **Treatment time [hours]** | ***C. longicaudatum* specimen** | | | **Survival analysis** | | | **Final results** |
|---|---|---|---|---|---|---|---|
| | stage | quantity | sex | R | R+ | R++ | |
| **12 h = 0.5 day** | A | 3 | ♀ | X | | | A = 0/10 |
| | | 3 | ♂ | X | | | |
| | N | 10 | | X | | | N = 0/10 |
| | E | 10 | | | | 8 | E = 8/10 |
| **24 h = 1 day** | A | 3 | ♀ | X | | | A = 0/6 |
| | | 3 | ♂ | X | | | |
| | N | 10 | | X | | | N = 0/10 |
| | E | 10 | | | | 3 | E = 3/10 |
| **48 h = 2 days** | A | 3 | ♀ | X | | | **A = 0/6** |
| | | 3 | ♂ | X | | | |
| | N | 10 | | X | | | **N = 0/10** |
| | E | 10 | | | | X | **E = 0/10** |
| **168 h = 7 days** | A | 3 | ♀ | X | | | **A = 0/6** |
| | | 3 | ♂ | X | | | |
| | N | 10 | | X | | | **N = 0/10** |
| | E | 8 | | | | X | **E = 0/10** |

| | | |
|---|---|---|
| A adults | R | recording after treatment |
| N nymphs | R+ | recording one day after treatment |
| E eggs | | |
| X dead | R++ | recording two months after treatment / end of the study |

Final results: surviving individuals at the end of the study/number of individuals tested

increase in temperature and associated stress. Initial investigations in the test specimens showed that the delaying temperature-buffering effect of paper increases the heating and cooling phases. This also leads to a prolongation of temperature intervals whose values are above the optimum of *C. longicaudatum*. Investigations into whether the lethal effect is related to the temperature level or to a longer time interval above a critical value are still pending.

## Anoxic treatment

A lethal effect on all developmental stages could already be demonstrated for the time interval of 48 hours at a residual oxygen concentration of 0.1% and a treatment temperature of 22 °C. Deaths of adults and nymphs were recorded for each of the treatment intervals examined (Table 4). The increased tolerance of the egg stage is due to a substantially reduced respiratory exchange rate. It can be assumed that a higher survival rate is observed at lower temperatures, whereas increased mortality can be assumed in an even shorter time at higher temperatures because the insects' respiratory rate is increased at a higher temperature, resulting in rapid water loss (Valentin 1990). The addition of more absorber packs can shorten the time it takes to reach a low residual oxygen concentration but this would involve higher costs and material requirements. The results are transferable to the use of nitrogen chambers in which a larger number of objects can be treated.

## Conclusions

The aim of the study was to adapt the treatment parameters for three different treatment methods regularly used in museums to the targeted control of *C. longicaudatum*. The results of the study present the time spans and temperatures needed to kill all developmental stages by freezing, heating and anoxic treatment. The study shows that the egg stage of the grey silverfish is more resistant to treatments than the adults and the nymphs. However, compared to the control of other museum pests such as wood boring beetles or clothes moths, shorter time intervals or temperature changes are required. In the case of freezing at –20 °C, the treatment time can be drastically reduced from 1–2 weeks to 12 hours. The anoxic treatment of objects in bags using oxygen scavengers at 22 °C can also be carried out in the shorter time of only 48 hours compared to previous assumptions of several weeks. When heating, a treatment temperature of only 47.5 °C instead of 55 °C is necessary over the same period of one hour. Thus, physical stress on the objects is reduced and a faster process is generated. All the described treatment methods can be used in a more time-efficient, curative and preventive way when objects and packaging materials are treated if contamination by other pests can be completely excluded in advance.

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## Materials and suppliers

- Archival box, Stülpdeckelbox (Brauweiler) Art.-Nr. 2110016, DIN A4, Folio, Material MW 1.6: KLUG Conservation (www.klug-conservation.de)
- Climate test chamber, Sanyo Gallenkamp ATMOS Chamber MTH-4100
- Data logger, Testo 174H mini data logger: Testo SE & Co. KGaA (www.testo.com)
- Freezer, GGPv 6570 ProfiLine: Liebherr (www.liebherr.com)
- Oxygen absorbers ATCO FTM 1000, schwefelfrei: Long Life for Art (www.llfa.de)
- Oxygen meter, GOX 100: GMH Messtechnik GmbH Greisinger (www.greisinger.de)
- PE film bags Flachbeutel Escal/Alu, 42 × 68 cm: Long Life for Art (www.llfa.de)
- PET test container, 100 ml: ecomserv (www.ecomserv.de)
- PROsorb silica gel, 17 × 14 cm, 150 g, 50% rF: Long Life for Art (www.llfa.de)

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# Pest Partners: increasing engagement with IPM

## Helena Jaeschke

**ABSTRACT** The Pest Partners project was created by South West Museum Development to help museums and cultural heritage collections across southwest England cope with pest outbreaks during the national COVID-19 lockdowns of 2020. The project was designed to support those new to pest management to increase their knowledge and confidence using a variety of resources including a card game, videos and an animation, as well as more conventional guides and a monitoring kit. More than 140 organisations took part and data on over 5,500 pests and indicator species were recorded.

**KEYWORDS** Pest management; museums; heritage; card game; animation; videos; survey; southwest England; COVID-19; museum development

## Introduction

In March 2020, the first COVID-19 lockdown in the UK began, forcing all museums and cultural heritage sites to close. Many staff were placed on furlough or reassigned, and many volunteer-run organisations struggled to establish even minimum staffing for security. At South West Museum Development (SWMD), we had realised that collections would face increased risks when left largely without staff (paid and volunteer), especially as the spring emergence of pests was already starting. Free resources were already provided on our website (Bristol City Council and Arts Council England 2020a) and we had been running a pest feature in our monthly newsletter which was proving very popular. With the increased level of threat, we needed to provide more practical help.

When Historic England announced a COVID-19 Emergency Response Fund (Historic England 2021) we submitted a proposal within the two-week deadline, which included funding and in-kind support from SWMD. We aimed to support organisations which did not monitor for pests or lacked confidence in pest management, and to include any publicly accessible cultural heritage collections in the southwest region, not just museums. The budget and project plan were adjusted with input from Historic England and the project was announced in early July 2020. Several experts with greater knowledge of museum pest management provided thoughtful oversight and advice as we designed the project and created the resources. Their kind contributions are acknowledged at the end of this paper.

## The Pest Partners project

We worked together with Liz Clare of Historic England and Abi Millican of SWMD to generate communications including press releases and social media posts to promote the project. All organisations on our mailing list were notified and emails sent to appropriate cultural heritage organisations to notify their membership. Local radio stations requested interviews and some of the press ran the story.

Any organisation in the southwest of England with a cultural heritage collection which would normally

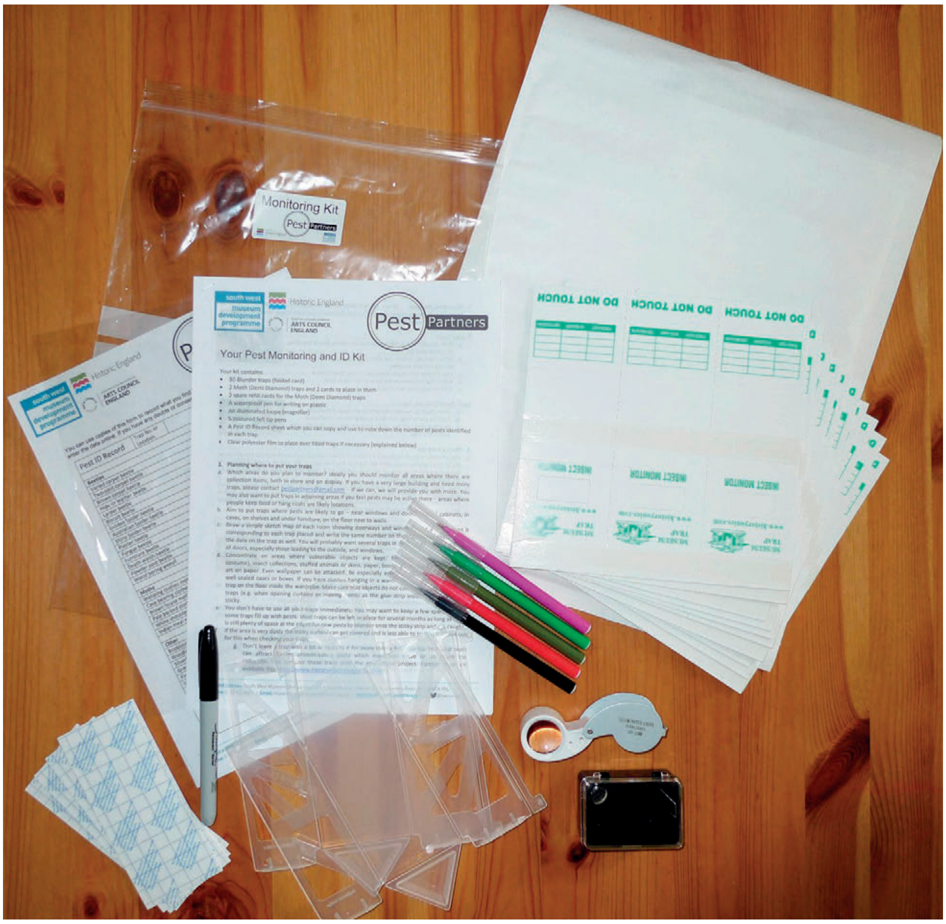


**Figure 1** Contents of the monitoring kit (© SWMD 2021).

be open to the public was eligible to apply, even private historic houses. They were asked to sign a simple charter of commitment and supply two contacts (in case one of them had to isolate). In the first stage of the project, 96 organisations including archives, abbeys, museums and stately homes registered as Pest Partners. They were sent a monitoring and identification kit, which included blunder traps, pens to label the traps and mark pests when counted, and guidance on where and how to place the traps (Fig. 1). We had used the time while waiting for final clearance for the grant to research the best illuminated loupe; this proved an extremely helpful and popular part of the kit and could be used to photograph the pests in detail.

In the brief intervals between lockdowns, five short 'How to' videos were filmed on location by James Stuart of Lightbox Film Co. We are very grateful to the Royal Cornwall Museum, Truro and the South Somerset Heritage Collection, Yeovil for very generously helping us to film on-site. The videos are hosted on the SWMD website (Bristol City Council and Arts Council England 2020a) and show how to set up and place blunder traps, examine objects for pests, and pack boxed and unboxed objects for freezing. Twenty-eight pest and indicator species were chosen for the project, principally those that were most likely to be found in southwest properties and which were more easily recognisable by those new to pest monitoring (Table 1). Partners were encouraged to ask if they needed further information and to send in photos of any species they could not identify. When pest-related problems were found they were provided with further support, including site visits (between lockdowns) as required.

The initial project was set to finish at the end of 2020, but the continuing pandemic and further lockdowns showed that the project would be needed into the spring of 2021. We had originally budgeted for up to 200 Partners, so we had capacity for more. We reopened for applications and registered a further 47 organisations.

**Table 1** Pest and indicator species included in the project (© SWMD 2021).

| **Beetles** | | **Moths** | |
|---|---|---|---|
| Varied carpet beetle | *Anthrenus verbasci* | Webbing clothes moth | *Tineola bisselliella* |
| Two-spot carpet beetle | *Attagenus pellio* | Case bearing clothes moth | *Tinea pellionella* |
| Brown carpet beetle | *Attagenus smirnovi* | Brown house moth | *Hofmannophila pseudospretella* |
| Hide or leather beetle | *Dermestes maculatus* | Pale backed clothes moth | *Monopis crocicapitella* |
| Larder beetle | *Dermestes lardarius* | White shouldered house moth | *Endrosis sarcitrella* |
| Biscuit beetle | *Stegobium paniceum* | Indian meal moth | *Plodia interpunctella* |
| Golden spider beetle | *Niptus hololeucus* | | |
| Australian spider beetle | *Ptinus tectus* | **Other** | |
| Shiny spider beetle | *Gibbium psylloides* | Booklouse | *Liposcelis bostrychophila* |
| Furniture beetle | *Anobium punctatum* | Woodlouse | *Isopoda* spp. |
| Death watch beetle | *Xestobium rufovillosum* | Silverfish | *Lepisma saccharinum* |
| Powder post beetle | *Lyctus brunneus* | Grey silverfish | *Ctenolepisma longicaudatum* |
| Wood boring weevil | *Euophryum confine* | Firebrat | *Thermobia domestica* |
| Plaster beetle | *Adistemia watsoni* | Woodlouse spider | *Dysdera crocata* |
| Fungus beetle | *Corticaria* spp. or *Cryptophagus acutangulus* | Other spiders | Various spp. |

## The survey

An online survey was set up using SmartSurvey which allowed Partners to enter pest data at the end of each month, using dropdown menus to make entry faster and more reliable. Email reminders were sent. Most Partners were able to enter their information but a few used a simple monthly record spreadsheet which was provided. In the eight months from July–Nov 2020 and March–May 2021, data were sent from more than 2,000 traps and locations (e.g. windowsills and floors) with 5,535 pests recorded. The average number of locations per Partner was seven, although some reported pests from as many as 57 locations while others found no pests at all. Survey entries included the numbers of each species found as well as the stage (larval, pupal or adult). The numbers of pests reported in locations varied between 1 and 73: 90% of traps and locations had 1–3 pests, 8% reported 4–10 and only 2% registered 11 or more pests (Table 2).

The sheer number of spiders reported (1,715) swamped the rest of the data, so for pest analysis we removed the category of 'Other spiders' and only included woodlouse spiders because of their specific relationship to a museum pest, woodlice. The results were analysed according to the region of the southwest where they were found and by the month for which they were reported. Full details of the results are available in a report on the SWMD website (Bristol City Council and Arts Council England 2020b) under the title 'Pest Survey'.

There was a high prevalence of species which are known to flourish in damper environments, especially silverfish and firebrats, woodlice, booklice and plaster beetles (Lauder and Pinniger 2006). The 10 Partners which had the highest incidence of moisture-loving species were offered an electronic data logger to monitor the environment and a portable dehumidifier to improve conditions in the area where they considered collections were most at risk. Reports were collated for each of the Partners, appropriate action was suggested to protect the collections and further help offered as required.

## The card game

We were aware that many of the Partners struggled to recruit more staff (even before the pandemic) to help with pest management, so we designed a simple card game which provides a considerable amount of data about each pest on individual cards, including details of simple actions that can be undertaken to protect the collections on a series of Treatment cards (Fig. 2).

**Table 2** The frequency and numbers of pests reported (© SWMD 2021).

| **Species** | | **Frequency** | **No. of individuals found** |
|---|---|---|---|
| Other spiders | Various spp. | 1075 | 1715 |
| Woodlouse | *Isopoda* spp. | 445 | 1330 |
| Silverfish | *Lepisma saccharinum* | 196 | 392 |
| Booklouse | *Liposcelis bostrychophila* | 182 | 610 |
| Varied carpet beetle | *Anthrenus verbasci* | 176 | 422 |
| Webbing clothes moth | *Tineola bisselliella* | 101 | 184 |
| Woodlouse spider | *Dysdera crocata* | 99 | 138 |
| Case bearing clothes moth | *Tinea pellionella* | 49 | 153 |
| Plaster beetle | *Adistemia watsoni* | 41 | 70 |
| Brown carpet beetle | *Attagenus smirnovi* | 39 | 70 |
| Grey silverfish | *Ctenolepisma longicaudatum* | 30 | 43 |
| Firebrat | *Thermobia domestica* | 29 | 32 |
| Brown house moth | *Hofmannophila pseudospretella* | 24 | 32 |
| White shouldered house moth | *Endrosis sarcitrella* | 22 | 27 |
| Furniture beetle | *Anobium punctatum* | 20 | 197 |
| Death watch beetle | *Xestobium rufovillosum* | 16 | 24 |
| Wood boring weevil | *Euophryum confine* | 16 | 18 |
| Australian spider beetle | *Ptinus tectus* | 15 | 23 |
| Shiny spider beetle | *Gibbium psylloides* | 14 | 30 |
| Biscuit beetle | *Stegobium paniceum* | 13 | 13 |
| Hide or leather beetle | *Dermestes maculatus* | 13 | 19 |
| Pale backed clothes moth | *Monopis crocicapitella* | 12 | 19 |
| Fungus beetle | *Corticaria* spp. *or Cryptophagus acutangulus* | 9 | 10 |
| Golden spider beetle | *Niptus hololeucus* | 7 | 11 |
| Two-spot carpet beetle | *Attagenus pellio* | 7 | 8 |
| Powder post beetle | *Lyctus brunneus* | 6 | 12 |
| Larder beetle | *Dermestes lardarius* | 2 | 4 |
| **Total** | | **2658** | **5606** |


**Figure 2** The card game 'Save the Museum!' (© SWMD 2021).

**Figure 3** Dr Data, Inspector Detector and Earl Liminate (© SWMD 2021).

The Pest cards feature pictures of the pest on one side with a life-size silhouette which can be used to help identify pests on traps. The other side gives the common name and scientific name of the pest, with a description of the adult and juvenile form (where appropriate), special information and icons showing the main food source and any environmental preferences. They can be used by staff to increase knowledge and the ability to recognise pests or, with the Treatment cards, as a game for a group to familiarise themselves with the appropriate actions that are required in the event of pest attack. Three pest characters were designed by Danni Gilbert of Sail Creative to be used in the resources and on social media to make the pest species look less daunting. They were named by the Partners as Dr Data, Inspector Detector and Earl Liminate. Danni and her colleague Kat Faid undertook the layout of the cards with all content supplied by SWMD (Fig. 3).

**Figure 4** Still from 'The Museum Life of Pests' (© SWMD 2021).

## The animation

Inspired by the brilliant Collections Rationalisation animation created for SHARE East of England (SHARE 2015) some years ago, we wanted to create a further aid to help cultural heritage organisations recruit more people and encourage a more holistic approach to pest management. Thanks to a grant from the Art Fund's Professional Network Grants programme (Art Fund 2021) we were able to commission Kilogramme Animation Studio to produce an animation lasting just over 5 minutes on integrated pest management called 'The Museum Life of Pests', showing how pests enter and move through a building and how pest management needs to be integrated through all the actions of the organisation to be effective. This can be watched via a Vimeo link on the SWMD website (Bristol City Council and Arts Council England 2020a). Initial results indicate that this may prove as popular as the card game: within six weeks it had been viewed 1,100 times in 51 countries and an audio-described version (to assist the blind or partially sighted) has been viewed 69 times in 14 countries. These statistics were obtained from the websites of SWMD, Museums and Heritage Advisor, the Collections Trust, Icon (the UK Institute for Conservation) and Twitter (Fig. 4).

## Feedback and evaluation

When Partners registered, they were asked key questions about their organisation's experience of pest management as well as their own. This was repeated at the end of the initial Historic England-funded part of the project in December 2020 and the results compared. At the beginning of the project, 70% of

**Table 3** What worked well and suggestions for improvement for the project (© SWMD 2021).

| What worked well | What could be improved |
|---|---|
| **For us** | |
| Clear aims and outcomes | People reading and following instructions |
| Experienced team at SWMD | |
| Flexibility | Finding entomologists and climate change scientists to use the data |
| Good communications, social media | |
| Dedicated email address | Not having a pandemic with multiple lockdowns |
| Supportive pest trap supplier | |
| Online data entry on SmartSurvey | More photos of pest damage |
| **For the Pest Partners** | |
| The Monitoring and ID Kit, especially having free traps | A step-by-step identification guide – e.g. Has it got legs Y/N? |
| The illuminated loupe | A quicker way to enter data on the survey |
| Resources (identification sheets) | Networking with other partners |
| The support, especially reassurance | More people getting involved in our organisation |
| The schedule – having a monthly reminder | Even more resources to share with others e.g. videos |

Partner organisations undertook some kind of monitoring but by the end of December 2020, 96% stated that their organisation would now continue to monitor for pests. The number of respondents who felt confident in their ability to identify pests was 96% compared with only 70% at the start, and 100% felt the project was worthwhile. In addition, we asked for volunteers to undertake a more in-depth interview with a PhD student, Alice Would, placed with the project through the South West and Wales Doctoral Training Partnership. The resulting report on seven interviews provided useful suggestions such as the need for a permanent support network and highlighted that the project had been well received and helpful. In particular, the interviewees found it very useful to be part of a project, that the structure and regular reminders gave them an added impetus to keep monitoring, and that they valued the easy-to-understand guidance, the illuminated loupe and the humour used throughout the project. Their suggestions are included in Table 3.

## The legacy

The project aimed to create free resources to help a larger group of people and organisations engage with pest management. These have been widely promoted through both our channels and those of our partners, and are available on the SWMD website (Bristol City Council and Arts Council England 2020a). It mapped pest incursions across the southwest and gathered a significant body of pest data which we hope will be of use for future cultural heritage and scientific use. We are hoping to engage with a wider pool of entomologists and climate change scientists who might find the data useful and to broker connections with cultural heritage sites and regional groups. Work on finding contacts and fostering a network is continuing.

## Conclusions

This project focused on helping a wider range of cultural heritage organisations get to grips with pest infestations, increase confidence and ability among a wider section of cultural heritage carers, and provide a range of appropriate resources supplementing those already available. The project was received enthusiastically by a broad range of cultural heritage organisations. Three had to drop out of the first phase because of the lack of staff, but almost all continued with the project into 2021. The amount of data produced is considerable and we hope will be of further benefit. The project has brought pest management to the attention of a far greater range of people in varied cultural heritage organisations, and we intend to support their progress in this area as much as possible.

## Acknowledgements

We would like to thank our funders, Historic England, especially Soki Rhee-Duverne and Tim Cromack, and the Art Fund, in particular Emma Coleman and Nancy Saul. We are hugely indebted to David Pinniger, Adrian Doyle, Jane Thomson Webb and Ray Garnett. David continued to provide advice throughout and identified some of the more unusual specimens which were encountered. Although the project's success created a bigger workload than we had envisaged, the flexibility and commitment of the SWMD team made it all feasible and we would like to thank especially Vic Harding, without whose contributions none of this would have been possible, as well as Abigail Millican and Rowan Whitehouse for their enthusiastic and skilful support of the project.

## Materials and suppliers

- Pest traps and products: http://www.historyonics.com/
- Illuminated loupe: https://www.theloupestore.co.uk/Magnifiers-Triplet/Folding-Loupe-with-LED.html
- Printing: https://www.doxdirect.com/
- Ziplock bags: https://www.polybags.co.uk/shop/blue-zip-slider-bag_p943.htm
- Labels: https://www.banana-print.co.uk/stickers-labels/
- Jiffy bags and pens: https://www.whsmith.co.uk/
- 'How to' videos: https://www.lightboxfilm.co.uk/
- Survey: https://www.smartsurvey.co.uk/
- Data loggers: https://www.lascarelectronics.com/easylog-el-usb-2
- Dehumidifiers: https://www.meacodehumidifiers.co.uk/products/meaco-20l-low-energy-platinum-dehumidifier-3-year-warranty-meaco20le

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# Adjusting to fit: shifting an organisation's approach to integrated pest management to better reflect cultural protocols, legal requirements and workplace dynamics

Nyssa Mildwaters and Shannah Rhynard-Geil

**ABSTRACT** Although integrated pest management (IPM) is a central tenet of preventive conservation, it takes considerable effort to embed and maintain in cultural institutions. The Otago Museum in Dunedin, New Zealand, established a formal IPM programme in late 2014 with a newly re-established conservation team, focusing on reducing risk while avoiding disrupting existing internal systems to accommodate staff during a time of considerable change. In 2019, a review of IPM procedures found that the programme remained conservation-centric. IPM was known to be important but was at times seen by staff as a peripheral activity that created unnecessary work and delays. This paper describes how adapting in-house training and communications can tailor IPM to suit specific workplace dynamics. It also explores how conservation staff worked to ensure that IPM complements various legal requirements and obligations such as the Ministry of Primary Industry, the Wildlife Act and the Protected Objects Act. Finally, and perhaps most importantly, the authors discuss how embedding cultural considerations and protocols into the existing IPM programme required a re-evaluation of the approach to certain core activities, leading staff to grapple with uncomfortable questions around balancing cultural requirements with available resources.

**KEYWORDS** Integrated pest management; IPM; adaptation; reflection; cultural considerations

## Introduction

The Otago Museum in Dunedin, New Zealand, is a unique combination of a living tropical environment, traditional museum and active commercial venue, operating within a bicultural context. As such, developing an integrated pest management (IPM) strategy flexible enough to address the complexities of the museum's daily operations, diverse collections, and legal and cultural obligations, is an ever-evolving undertaking. With a change of staff in late 2019 and New Zealand's COVID-19 lockdown in 2020, the team decided to undertake a review of its existing IPM approach established around reducing risk to the collection with limited disruption to internal structures. When reviewing the existing policy, four key areas of focus quickly presented themselves. Firstly, any changes would need to be adapted to the unique workplace dynamics and team interplay that existed within the museum. Secondly, that a more visible alignment to the existing framework of legal requirements and obligations under which each team operated would be essential to avoid staff members experiencing conflict between procedures. Thirdly, following initial discussions with our new Curator Māori, that cultural considerations and protocols would need to be addressed more prominently and proactively than in the past. Finally, the

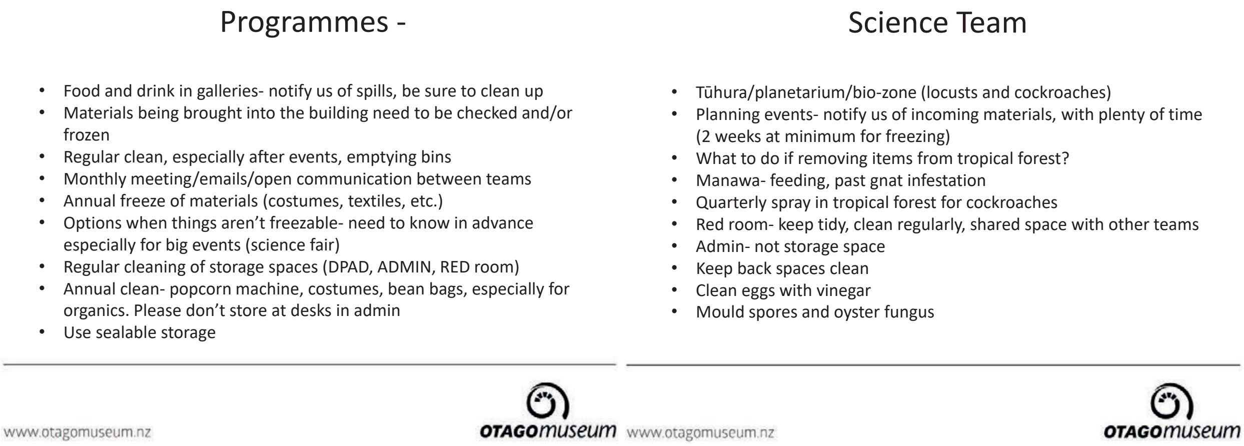


**Figure 1** Examples of two team customised slides from annual IPM training (© Otago Museum Trust Board).

whole programme and approach would need to be practical and pragmatic, balancing cultural and legal requirements with resources such as budget, space and staffing levels.

## Adaptation and workplace dynamics

As a result of the review, it was clear the existing IPM programme required a concerted adjustment to ensure future integration with all museum activities as an aligned programme rather than a parallel set of requirements. The initial aim was to achieve this while keeping the core pillars of IPM relatively unchanged, such as strong quarantine procedures, pre-emptive treatment via freezing, and ongoing pest level monitoring. The overall plan was to consolidate and improve rather than replace.

It was apparent that Otago Museum staff required a better understanding of conservation operations and activities. Individuals also needed to feel a greater connection to IPM 'regulations' if they were to take ownership of integrating IPM into their daily workflows. All museum staff from the director to the external cleaners needed to fully apprehend the consequences of an infestation, including how and why it would impact all staff activities. To facilitate this connection, conservation staff revised how IPM information was communicated. Annual IPM training was altered to establish a team-focused programme, highlighting general IPM tenets familiar to the vast majority of museums and pinpointing how IPM could be integrated into museum roles using applicable examples and team-specific scenarios (Fig. 1). Counterintuitively, keeping team training siloed improved information uptake and engagement. Each of the 14 group sessions provided staff with an opportunity to openly discuss roles, how perceived disturbances caused by IPM procedures could be minimised, and to raise concerns and questions with conservation staff.

These discussions strengthened relationships between the teams and conservation staff, leading to other changes being implemented, such as conservation staff attending quarterly front of house and science engagement team meetings. This allowed regular reporting and feedback as part of general operations. The new training structure also deepened the understanding of group dynamics and interplay, and identified those teams needing additional support to incorporate IPM into daily roles. It distinguished areas that required further improvements and illuminated existing inter-team issues that were potentially derailing IPM activities. The training provided an opportunity for conservation staff to highlight areas where teams, such as venues and programmes, could collaborate with conservation staff regarding difficult conversations with clients or external parties around IPM procedures. The emphasis during and after training was that staff are supported by conservation, not hindered or judged.

By changing the approach to training, the conservation team's understanding of varying roles across the museum also shifted and evolved, clarifying motivations and mindsets of key colleagues within each team, and permitting the development of more effective IPM strategies and tailored communication

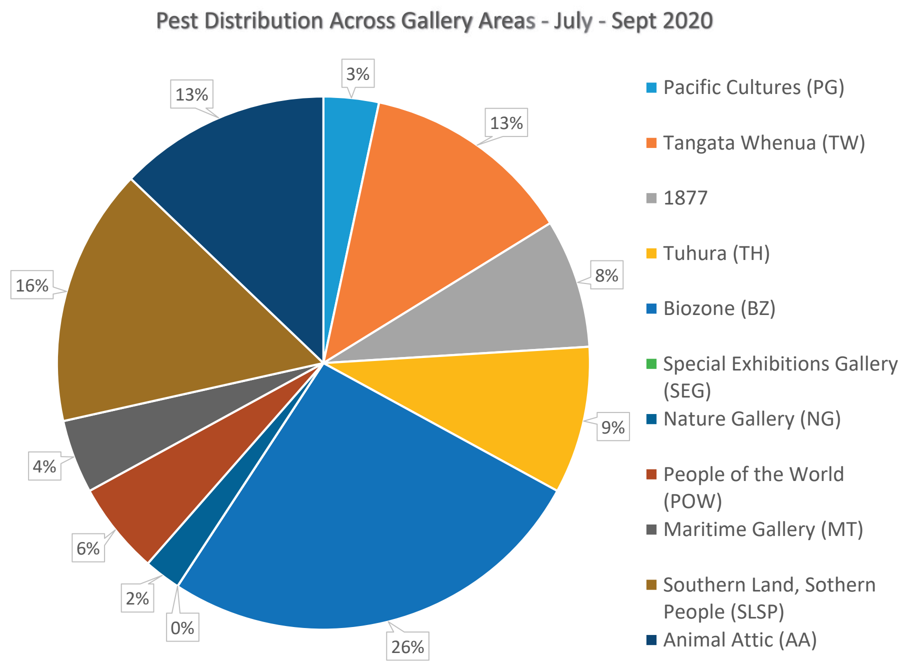


**Figure 2** Chart showing the distribution of pests across the museum's galleries which has led front of house staff to request further pest identification training (© Otago Museum Trust Board).

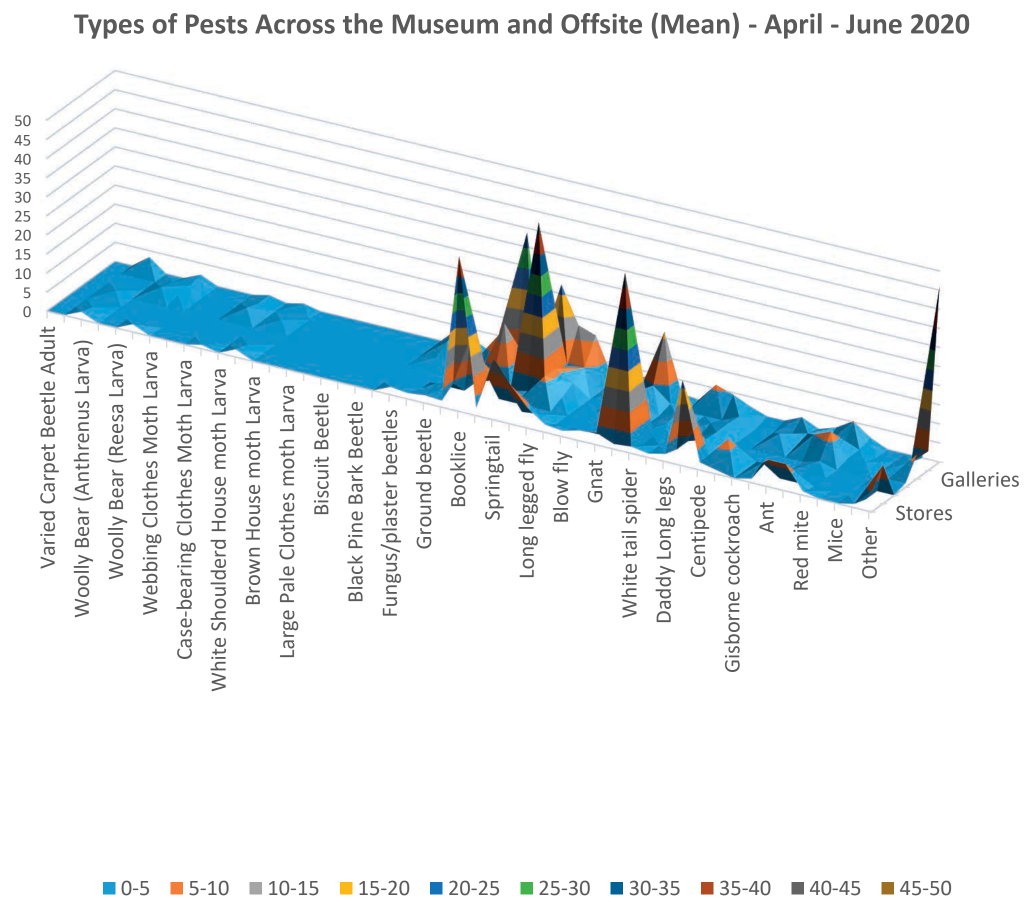


**Figure 3** Diagram showing mean pest numbers by species across designated zones in the museum, resulting in front of house staff adjusting their approach to gallery checks (© Otago Museum Trust Board).

plans. For example, after training, certain key team members were approached to arrange regular informal catch-ups. By gaining buy-in from these key individuals, we also gained independent advocates, promoting IPM in daily team activities. This approach led to unexpected outcomes, such as several operational managers suggesting that conservation considerations should be integrated into Otago Museum's new venues and events booking system, Priava.

In addition to the new training, the conservation team now shares IPM-related information at staff briefings, museum leadership, operational manager and individual team meetings to improve communication. Where in the past the focus was on reminding people to report issues and follow procedures, staff now report on outcomes and management of particular IPM issues. Efforts are also made to thank particularly progressive teams. Changes to data interpretation are not complete however: following the work of Henderson *et al*. (2017) the conservation team is improving pest data analysis in Excel to produce meaningful graphics. Sample graphics recently shown to front of house staff have demonstrated how visuals can spark further interest and understanding of the direct impact staff actions have on pest management, especially within staff spaces (Figs 2 and 3).

The end result of the new training programme's first round and change in communication style has been a significant increase in staff members actively monitoring for pests in the gallery spaces, incorporating freezing schedules into their events, and proactively making choices that reduce pest risks within their workflows. Additionally, staff increasingly communicate a desire to help with annual housekeeping activities, openly address other conservation-related requirements earlier in the event or project preparation, and regard conservation as solution-oriented and flexible.

## Legal requirements and obligations

Prior to re-evaluation, there was no reference in the training materials or documents regarding dependent legal requirements and obligations of Otago Museum staff. No consideration was given to the following issues:

- The museum's role as a repository for Māori cultural material under the Protected Objects Act 1975.
- The presence of wāhi tapu storerooms at OM for holding kōiwi tangata in line with the Ngāi Tahu Kōiwi Tangata Policy.[1]
- The need for a containment facility in accordance with Environmental Protection Authority (EPA) and Ministry for Primary Industries (MPI) standards as part of operating the museum's Tropical Forest.

IPM was isolated as a museum collection-focused activity, independent of wider issues.

It was noted that non-collection teams, such as the cafe or Tropical Forest, would regularly inquire if certain IPM information was available to demonstrate that the museum was meeting particular legal, licencing or accreditation standards. Given that these teams were working in high-risk pest areas of particular interest to conservation staff, a concerted effort was made to adapt IPM to complement existing obligations. For the first time, conservation formally liaised with team managers on how IPM could assist them, rather than forcing their work programmes to fit IPM. Some established activities were found to be working. For example, the Living Environments manager uses IPM activities, such as quarterly spraying of the Tropical Forest plant room to remove Gisborne cockroaches, which demonstrates the museum's ability to manage pests in line with Zoo Aquarium Association Australasia and MPI standards. These conversations also revealed that frequently moved or destroyed traps, which subsequently changed monthly pest data, were the result of a cafe cleaning routine required by Dunedin City Council to maintain food certification.

The result of these discussions was a number of small but significant changes to the IPM programme, such as automatically forwarding relevant records of treatments and inspections to associated team managers, meeting their legal requirements. Conversely, conservation staff's annual quarantine and containment facility training with the Living Environment manager became integrated with IPM. Equipment or material leaving the Tropical Forest is now treated using a quarantine freezer, removing the need to use a costly external contractor. Adjusting the focus to using IPM to benefit these teams and support them


**Figure 4** Otago Museum Values Statement (© Otago Museum Trust Board).

in their work has had significant benefits. Teams are more willing to make adjustments to their practice, such as changing how higher risk materials are stored within the building and agreeing to assist with IPM-related housekeeping activities.

The success of this approach with non-collection teams led conservation staff to repeat the process with collections-specific legislation and obligations to better understand the legal requirements and how they affect colleagues. As one of the four authorised museums under section 16 of the Protected Objects Act 1975, the museum is obligated to hold any qualifying cultural material brought to it until ownership is determined by the Māori Land Court. In accordance, the Act's related material is now treated in the same manner as loaned items with the Ministry of Culture and Heritage acting as owner.

A less clear-cut area is the regular deposition of dead birds recognised as taoka species under the Wildlife Act 1953. As an organisation with a permit to hold such material from the Department of Conservation, Otago Museum accepts and stores these animals for the Department and the Komiti Taoka Tuku Iho (KTTI) who decide the allocation and use of these taoka species. The museum is not required to hold this material under its permit but has a long-established community obligation. With this material, the IPM priority is to make the transition between deposition and freezing smooth and fast. Rather than depositing material into isolation, the decomposing birds are immediately double bagged and placed in a quarantine freezer before being transferred to long-term storage. Understanding the KTTI process allows conservation staff to more effectively communicate why the IPM procedures for Wildlife Act specimens differ from other materials brought into the museum. Although the resulting changes from aligning IPM with legal obligations may appear small, these actions add a greater degree of legitimacy to the programme.

## Embedding cultural considerations and protocols

The values set out in Otago Museum's most recent annual plan[2] act as a foundation for all operations (Fig. 4). These ideals clearly acknowledge that the museum and staff have a responsibility for the tangible and intangible in its collection. Although the museum has significant processes in place around exhibition, lending and accessioning of cultural material – including the museum's Māori Advisory Committee, Curator Māori and Pouhere Kaupapa Māori positions – cultural elements within the IPM strategy have only recently been formally established with the appointment of Dr Gerard O'Regan to the Curator Māori and Pouhere Kaupapa Māori roles in 2020.

Initial discussions focused on the wāhi tapu storerooms which hold kōiwi tangata from Ngāi Tahu tribal lands. Housed in the museum, the wāhi tapu rooms are managed by Ngāi Tahu in line with the Ngāi Tahu Kōiwi Tangata Policy. Any programmes or activities undertaken in these spaces by conservation staff are discussed with the Curator Māori and if necessary, the Māori Advisory Committee. In accordance with pre-existing cultural protocols, IPM tools such as brushes, microfibre cloths and a ladder had previously been purchased for sole use and storage in these rooms and not removed. However, as part of IPM's re-evaluation, the need for conservation staff to vacuum the wāhi tapu rooms was identified. By discussing cleaning routines with the curator, conservation staff were better able to understand the mindset behind existing protocols. After consensus was reached, the team was able to vacuum the space using a conservation vacuum that had never previously been used to clean objects or deal with food. As the vacuum would not come into direct contact with kōiwi tangata, it could be removed from the space following specific protocols.

Utilising a fresh perspective, the team discussed wider IPM policy and further cultural considerations, including freezing procedures. Prior to the review, natural science specimens, humanities items and Wildlife Act birds were wrapped separately but frozen together. Conversations regarding options included clarifying the necessity of physical cleaning and blessings between runs, the practicality of wiping the freezer between loads, and demonstrating object preparation to the curator. Following these initial discussions, several weeks elapsed before Curator Māori became available: this time was used by conservation staff to work through various practical options. Due to limited space and the number of freezers available, a compromise was reached: items are now wrapped individually and processed in separate freezer runs to avoid contact. Object orientation awareness during freezing is now added to IPM procedures. Finally, it was formally agreed it was culturally essential kōiwi tangata continue to be directly transported to the wāhi tapu stores without quarantine and an additional wāhi tapu freezer should be sought.

## Balancing cultural requirements with available resources

One of the most challenging aspects of revaluating the IPM programme was feedback around cultural considerations and requirements. This was not due to opposition but to a concern as to the resources necessary to enact best practice not being available. It took considerable time to acquire our existing walk-in quarantine freezer and the prospect of finding funds and earthquake-appropriate space for two further freezers was daunting.

Balancing cultural requirements with more mundane considerations such as budget was uncomfortable. As conservators, we always wish to respect cultural protocols; however, some changes are not currently possible. Open and honest conversations are crucial to build relationships and cannot be avoided, no matter how difficult. We can only improve through continued examination and consensus.

Time between discussions around appropriate cultural protocol is integral to compromise. We had to look honestly at what was possible given a small, two-person conservation team, prioritising management of expectations. We needed written procedures to align with reality, while acting with integrity. Ensuring our non-Māori team understood the thinking and mindset behind suggested improvements was essential – indeed, Dr O'Regan emphasised that this was more important than acting immediately.

Perhaps the most useful outcome was beginning in earnest an ongoing dialogue around integrating IPM and cultural requirements at the Otago Museum. Both sides acknowledged that a realistic compromise was presently the only option and a good beginning. The conservation team would work towards the ideal over time and discussions around cultural requirements would be a living, breathing process. From a conservation management perspective, these discussions have highlighted the need to review wider cultural protocols and expectations in relation to IPM.

## Conclusions

Despite the limited resources, the conservation team created a bespoke programme carefully balancing the museum's assets with achieved benefits. The team also began ensuring that the daily cultural considerations and protocols observed in other aspects of their practice are reflected in the IPM programme. There is, of course, more work to do, particularly around the museum's significant Pacific collections, but initial steps have been taken and the team is comfortable with the conversations that are likely to arise.

The conservation team's review of Otago Museum's IPM programme has demonstrated the importance of treating IPM procedures as live documents demanding continual reassessment. A blend of fresh eyes and institutional knowledge helped the team make numerous small, but essential, improvements to the existing programme. Although the intended outcomes of the museum's overall IPM strategy have not changed, these carefully targeted adjustments have transformed how IPM is viewed at the museum.

## Notes

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# Pestily ever after: 20 years of IPM at National Museums Scotland

Catherine Haworth

**ABSTRACT** The collection at National Museums Scotland (NMS) covers a range of materials across five curatorial departments: Natural Sciences, World Cultures, Science and Technology, Scottish History and Archaeology, and Art and Design. Across these departments we hold a collection of over 12.4 million objects and specimens including taxidermy, entomology, textiles, transport, furniture and many other items susceptible to pest attack. The collections are spread across five sites with buildings varying in age and complexity. The integrated pest management (IPM) programme at NMS has evolved over the past 20 years. It has developed as our understanding of the way pests interact with our buildings and collections has grown, and as we have worked on major redevelopment projects designed to increase access and care of the collections. Reflecting on the developments and changes over this period, communication stands out as a key factor in improved IPM processes. This paper discusses the impact of major redevelopment projects, organisational staff structures as well as other opportunities to improve IPM at NMS.

**KEYWORDS** Communication; relationships; training; data

## Introduction

National Museums Scotland (NMS) introduced its first integrated pest management (IPM) policy in 2000 at the same time as appointing its first preventive conservator. Prior to this, pest-related work had been carried out by the Conservation department and curators in the Natural Sciences department. This included some pest trapping and the running of a methyl bromide chamber. The newly appointed preventive conservator sat within the science team in the Conservation and Analytical Research department. At this time, the collections were spread over many sites including commercial storage locations.

In 2005, structural reorganisation moved the preventive function from the conservation team to a newly formed collections care section within the Collections Management department. Moving away from the interventive conservation team could have severed important links. However, relationships had already been established and communications were maintained. In 2012, the Collections Services department was formed from the merger of the Collections Management and Conservation and Analytical Research departments with the intention of creating a framework for a more unified provision of collections management, care and conservation. Following this, further changes increased preventive resources with the collections care team growing to consist of the preventive conservator, assistant preventive conservator, and two collections care technicians – all working under a dedicated collections care manager. This team currently shares an office and laboratories with the analytical science team at the National Museums Collection Centre where the interventive conservation teams are also based.

## New opportunities due to organisational changes

Over the past 20 years, NMS has been delivering a masterplan focused on developing new gallery spaces at each of its display sites and collocating stored collections to the National Museums Collection Centre. NMS now has four dedicated display sites and the National Museums Collection Centre, which holds research collections and objects not on display as well as providing facilities for research, conservation, digitisation and collections care. The collections care team has played a key role in the delivery of this masterplan, with specific responsibility for collection storage planning and object moves. This has had a significant impact on the IPM programme at NMS, with outcomes that might not have been possible had preventive conservation not been part of a team with the technicians.

The direct involvement of the technicians in re-storage projects – including collections of costume, taxidermy and furniture – enabled us to embed pest awareness and quarantine programmes into each project. NMS was able to eliminate existing webbing clothes moth (*Tineola bisselliella* (Hummel, 1823)) problems by the freezing of collections (in freezer containers at –18 °C for two weeks). Once treated, objects moved into new or refurbished stores, allowing us to designate many buildings as 'clean'.

The major redevelopment of the Royal Museum building had to mitigate against a webbing clothes moth infestation during installation. Redisplay included vulnerable items from the Natural Sciences and World Cultures collections. Technicians were able to control the distribution of objects to minimise exposure to moths. Alongside this, preventive conservation staff provided pest awareness training for installation teams and installed transfluthrin emitters in cases to manage the risk.

Outside of major projects, teaming preventive conservators with collections care technicians has been invaluable. The technicians coordinate the day-to-day movement of objects around and between sites. As part of the same team as the preventive conservators, the technicians are up to date with 'clean' and 'dirty' areas and move objects via quarantine when required. Although the team has no formal risk maps drawn up (Doyle *et al*. 2007) this concept is used to help designate spaces.

Twenty years ago the quarantine facilities at NMS were limited to two chest freezers in the corner of a storage room and only high-risk objects were treated. A number of pest infestations and large acquisitions led to the purchase in 2005 of a walk-in freezer. It was installed in a dedicated room at the National Museums Collection Centre, with enough space for storage, preparation and treatment of incoming objects. The new quarantine facility meant that the capacity to treat objects increased significantly but was still reliant on curators entering new acquisitions into the quarantine process.

Reorganisation of the registrar team has centralised paperwork and transportation of new acquisitions. Improvements to the collections database (Axiell) allows information to be gathered electronically in the pre-acquisition module and made available to all those who need to access it. The registrars, as part of the same department as collections care, feed all the required information to the preventive conservation team. Most of this information is disseminated via the museum's electronic workflow system, Top Desk, which has a quarantine form. The registrars enter details including expected arrival date, a brief description and the materials of which the item is composed. The preventive conservators can access this system from any computer, allowing more effective work programming. This system has replaced a paper log, which had to be filled in when the curators physically brought objects to the quarantine room. In some cases, there was no advance warning of items entering quarantine and no information such as from where they had come, causing delays in the process. Registrars are also responsible for managing loans. The developments to the collections database and electronic workflow system have also improved the quarantining of returning loans.

Pre-COVID-19, the difficulty was that not all objects arrived onto the NMS estate via the quarantine room. However, as the collections care team was one of the few teams with regular duties allowed on-site during the lockdowns caused by the pandemic, the quarantine facility has now become the destination for object delivery. This change has enabled a smooth and effective incoming object process with new acquisitions and returning loans entering via quarantine, moving on to conservation for condition reporting, photography for imaging and then to store or display. Clear communication channels with registrars acting as a link between curatorial teams and collections services has simplified the process.

## Knowledge exchange

Training is a large part of our IPM programme, which until recently had remained relatively unchanged since its introduction nearly 20 years ago. The core sessions were either internal (with two main strands for front of house staff or collections-based staff) or for external museums and galleries across Scotland through our National Partnerships Knowledge exchange scheme.

Over the years, adaptations have been made to the front of house sessions for specific groups, for example, library, education, building maintenance and project staff. Our main aim with these training events is to focus on a key message and keep the content light-hearted. The most important takeaway is to associate the preventive conservators with any pest activity and ensure when any staff member sees anything pest related at an NMS site, their first response is to contact the preventive conservation team. During the training sessions when insect samples are passed around, someone is always surprised at how small the insects are, even though size is mentioned repeatedly in the presentation. Our mascot, a dead squirrel (Fig. 1), also makes an appearance and is a reminder of the damage that undisturbed webbing clothes moths can inflict.

The biggest improvement to the training has been the introduction of a single point of contact for anyone wishing to report pest activity. Previously we asked people to contact us in our offices or through our personal emails. Since launching our 'pest desk' email we have had more incidences reported to us, undoubtedly saving some objects from webbing clothes moth damage. Some information is also provided through our incident reporting system, again a generic email to 'collections care'. This simple change has made it much easier for staff to reach us.

Our second strand of in-house training is aimed at staff in the collections directorate; curators, conservators and any staff, volunteers, or students that come into regular contact with the collections. This session includes pest identification and quarantine procedures. Work to improve communication has come in the form of simplifying guidance and procedures with straightforward flowcharts of the quarantine workflow process (Fig. 2). The changing responsibility of the registrars, as described above, has also streamlined procedures.

**Figure 1** The IPM training mascot (© Amy Fokinther, National Museums Scotland).

The external training we provide to colleagues across Scotland is a dual exchange of information. The sessions involve insect identification and discussion around the key elements of an IPM policy. Case studies of previous infestations at NMS provide a good talking point and the most successful sessions are those in which people bring their own pest problems to the table for group discussion, allowing everyone to learn. During COVID-19 restrictions, all in-person training sessions were paused. To respond to this challenge, the collections care team worked with the national partnerships and the digital media team to implement a suite of collections care training webpages converting IPM, object handling and object labelling training from PowerPoint presentations and hands-on activities into webpages with videos. It was a challenging process to move from practical sessions to communicating them through the written word with some short videos. Insect identification is best achieved with physical specimens, but we were fortunate to be able to provide

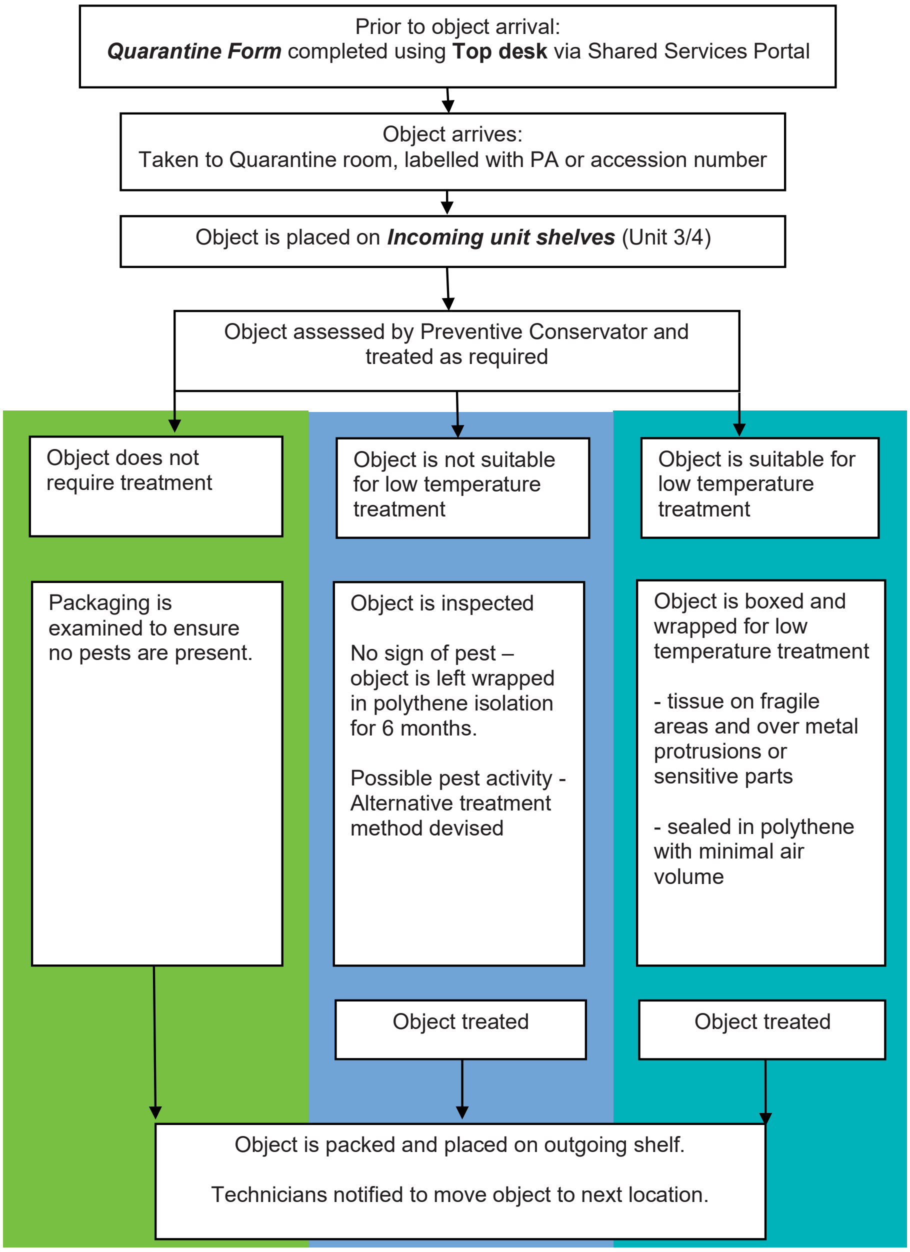


**Figure 2** Quarantine workflow diagram.


**Figure 3** Images of *Anobium punctatum* De Geer, 1774, for training (© Ashleigh Whiffin National Museums Scotland).

some detailed photographs taken by one of our entomology curators (Fig. 3).

The webpages (Fig. 4) are supported by online sessions with the opportunity for attendees to ask questions, but the setting is more stilted than the training room and there is more work to be done to create a relaxed learning environment in this format. The online training has benefits as it enables us to reach colleagues who may not have funding to travel, a problem for many smaller museums across Scotland in recent years. Previously we have taken the training to various locations around Scotland in order to reach a more geographically diverse

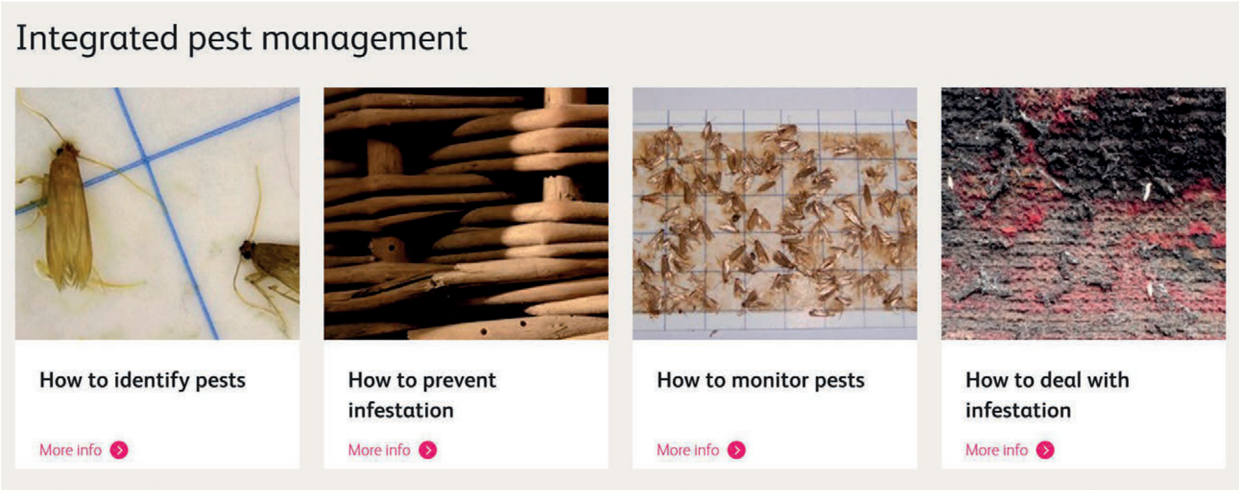


**Figure 4** Sections of the National Museums Scotland IPM training webpages.

audience. This can now be achieved with only an internet connection.

Knowledge exchange is not just something that we offer – communication within the IPM community has a significant impact on the way we have dealt with some of the pest problems that we have experienced. The Pest Odyssey framework has been an invaluable learning experience, and formal events and informal chats have contributed to the success of IPM at NMS. Small nuggets of information from a colleague at another institution can unlock the key to successfully tackling a tricky infestation. The openness of IPM practitioners to others is invaluable, however, pest issues seem to be discussed less frequently in relation to loans. Open discussions on pest problems with regard to loans would further aid the efficiency of our quarantine programme and effective pest management sector-wide.

## Data

Pest trap data were previously collected on paper sheets and entered in Excel. However, because the terminology used was not standardised and the format of the tables was ineffective, it was not possible to analyse the data. Improvements have been made to the Excel formatting and the way data are collected and recorded, enabling quick analysis of the facts and figures presented on pest populations to help identify problem areas. Our understanding of the way in which pests interact with our buildings and collections has greatly improved, allowing us to pinpoint problems, prioritise resources and improve the efficiency of treatments. These figures are also a useful communication tool with senior management teams. As ever, these techniques are constantly evolving as we look for ways to make our communications as relatable as possible to our budget holders (Baars and Henderson 2020).

## Conclusions

Reflections on the last 20 years reveal just how many improvements have been made by moving from conservation to collections management teams, with preventive conservation now sitting alongside both teams. The strong links and improved communication with conservators, curators and registrars, as well as data management and workflow systems, have made our IPM processes possible on a significant scale and enabled us to make the most of limited resources by being more efficient. COVID-19 provided opportunities and challenges, but we have emerged in a stronger position with more streamlined quarantine procedures and a superb training resource in our IPM webpages.

We now have stores that are designated 'clean' and have remained so over a number of years, even though we still have an endemic webbing clothes moth problem in some of our display sites. Our main problem area, the Museum of Scotland, is due for development in the next 10 years, and ideas are being sought on improvements to make the building less of a pest risk both before and after development. Learning from the successes of the masterplan delivered to date, applying what has worked and revising what has not, will help to inform this development and have a substantial impact on insect pest populations.

In just 20 years, NMS has gone from occasional pest treatments with two chest freezers to a centralised quarantine facility managing the majority of objects moving and enabling treatment of any items displaying signs of pest. Work is under way to further develop the quarantine facility at the National Museums Collection Centre, relocating it from its current position inside a collection storage building to a purpose-built set of rooms in a dedicated logistics building with adjacencies to loading bays. We look forward to sharing the next 20 years with our IPM colleagues across the country.

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# Eltham Palace: 900 years of history, 20 years of IPM in practice

Dee Lauder and David Pinniger

**ABSTRACT** This paper defines the evolution of pests and integrated pest management (IPM) procedures at Eltham Palace in London, a large historic house with many environments and challenges. Pest trapping was established in 2001 and the house has been monitored since. Initially, the main pests were *Anthrenus verbasci* (Linnaeus, 1767) in the house and *Lepisma* Linnaeus, 1758 in the Great Hall. Discovery of silverfish on traps in the art deco rooms caused concern and water ingress was rectified by building work. *Tineola bisselliella* (Hummel, 1823) was detected in 2008, and in 2016 there was a rapid expansion in numbers. Our objective has been to identify the source of the moths and prevent damage to vulnerable historic textile collections. *Tineola* pheromone traps have shown that the population is breeding in debris in inaccessible voids. In 2018, *Attagenus smirnovi* Zhantiev, 1973 was confirmed, giving the first record of this species from a historic house in London. The key challenge is the difficulty of housekeeping in a historic structure with inaccessible areas which cannot be accessed for deep cleaning. The priority of the IPM programme is to identify pest sources and risks and take action to ensure that the collections are not damaged. The IPM programme at Eltham can serve as a model for other historic properties.

**KEYWORDS** Historic house; insect pests; IPM; *Tineola*; *Anthrenus*; *Attagenus*

## Introduction: a history of Eltham Palace

Eltham Palace in London has a long history. First recorded in the Domesday Book, the estate was presented to Edward II in 1305. It was developed as a luxurious royal retreat and nursery, and by the mid-1400s had become one of the largest and most frequented royal residences in the country. Henry VIII grew up at the palace with his brothers and sisters, and it was often used for Christmas court celebrations accommodating around 800 people. However, due to the extensive rebuilding of nearby Greenwich Palace, giving easier access for the court by river, Eltham Palace gradually became less frequented until it was used mainly for hunting purposes. By 1660 the palace and chapel were practically in ruins, largely due to the impact of the English Civil War: all that remained were Edward IV's Great Hall, with its adjacent Court House or 'Buttery', some fragments of other buildings and the 15th-century bridge crossing the moat.

The current house, built in the 1930s on the site of the original palace, incorporates the Great Hall, which boasts the third-largest hammer-beam roof in England (Fig. 1). It is an iconic 20th-century art deco residence renovated by Stephen and Virginia Courtauld. English Heritage took the property into its care in the 1990s and insect pest trapping, as part of an IPM programme, was introduced in 2000, since when the property has been continuously monitored by its trained staff.

**Figure 1** Aerial view of Eltham Palace today (photo 24457_015 © Historic England Archive).

## History of insect pests

When trapping started at Eltham in 2001, the first insect pests found on traps were varied carpet beetle adults and larvae (*Anthrenus verbasci* (Linnaeus, 1767)), two-spot carpet beetles and larvae (*Attagenus pellio* (Linnaeus, 1758)), booklice (*Liposcelis* (Motschulsky, 1852)) and silverfish (*Lepisma*). In the last 20 years, a wide range of pests has been found, mostly in low numbers (Table 1) including all the species on the English Heritage monitoring spreadsheet (Lauder 2009; Lauder and Xavier-Rowe 2011) with the exception of golden spider beetle (*Niptus hololeucus* (Faldermann, 1836)).

## Changes in pest population

Since 2001, a number of new species have appeared at Eltham Palace (Table 2). Adult clothes moths (*Tineola bisselliella* (Hummel, 1823) and *Tinea pellionella* Linnaeus, 1758) were not trapped until 2008, and then only in low numbers (see later). Guernsey carpet beetles (*Anthrenus sarnicus* Mroczkowski, 1963) were first found in 2012 but have not increased in numbers since then. Pale-backed clothes moth (*Monopis crocicapitella* (Clemens, 1859)) was initially found on the *Tineola* pheromone traps in 2015. This species is identified from bird nests but is regularly attracted to *Tineola* lures in houses (Pinniger 2011). It is not yet clear if it can attack dry woollen textiles and numbers remain low at Eltham.

The most interesting transition involves *Attagenus*. From 2001, all the adults and larvae of this genus at Eltham were *A. pellio,* but in 2017 we noticed that some of the larvae appeared to be a lighter brown in colour than the normal *A. pellio*. Aware of the recent spread of brown or vodka beetle in London (Pinniger 2015), our suspicions were that these larvae might be *Attagenus smirnovi* Zhantiev, 1973. As the larvae of the two species are extremely difficult to distinguish, staff at Eltham were alerted to look for adult beetles and in 2018 the presence of *A. smirnovi* was confirmed with the discovery of a few beetles on traps. It now seems that at Eltham, *A. smirnovi* has replaced *A. pellio*: is this an indicator of climate change (Stengard Hanssen *et al*. 2011)?

## Case studies of key insect pests

### Carpet beetles *(Anthrenus verbasci* and *Attagenus pellio)*

Initially the main insect pest species caught on traps were adults and larvae of varied carpet beetles

**Table 1** Species of insect pests found on traps since 2001.

| | |
|---|---|
| **Moths** | |
| Brown house moth | *Hofmannophila pseudospretella* |
| Case-bearing clothes moth | *Tinea pellionella* |
| Webbing clothes moth | *Tineola bisselliella* |
| Pale-backed clothes moth | *Monopis crocicapitella* |
| White-shouldered house moth | *Endrosis sarcitrella* |
| **Beetles** | |
| Varied carpet larvae | *Anthrenus verbasci* |
| Guernsey carpet beetle | *Anthrenus sarnicus* |
| Dark carpet beetle | *Anthrenus fuscus* |
| Two-spot carpet beetle | *Attagenus pellio* |
| Larder beetle | *Dermestes lardarius* |
| Vodka or Brown carpet beetle | *Attagenus smirnovi* |
| Biscuit beetle | *Stegobium paniceum* |
| Furniture beetle | *Anobium punctatum* |
| Death watch beetle | *Xestobium rufovillosum* |
| Wood weevil | *Euophryum confine* |
| Australian spider beetle | *Ptinus tectus* |
| White marked spider beetle | *Ptinus fur* |
| Six-spot spider beetle | *Ptinus sexpunctatus* |
| Plaster beetle | *Adistemia watsoni* |
| Mealworm | *Tenebrio molitor* |
| **Other insects** | |
| Common booklouse | *Liposcelis bostrychophila* |
| Silverfish | *Lepisma saccharinum* |

**Table 2** Key insect pest species and date when first found.

| Date | Species | |
|---|---|---|
| 2001 | Varied carpet beetle | *Anthrenus verbasci* |
| | Two-spot carpet beetle | *Attagenus pellio* |
| | Silverfish | *Lepisma saccharinum* |
| | Common booklouse | *Liposcelis bostrychophila* |
| 2008 | Webbing clothes moth | *Tineola bisselliella* |
| | Case-bearing clothes moth | *Tinea pellionella* |
| 2012 | Guernsey carpet beetle | *Anthrenus sarnicus* |
| 2015 | Pale-backed clothes moth | *Monopis crocicapitella* |
| 2018 | Vodka or Brown carpet beetle | *Attagenus smirnovi* |

(*A. verbasci*) (Fig. 2). This species has continued to be found on traps, but in lower numbers since 2011 due to regular deep cleaning of vulnerable textiles and targeted housekeeping measures being deployed. With the help of the property-based staff, this regime has prevented damage to collections. However, in the last two years, staffing issues and the COVID-19 pandemic have made it difficult to maintain these measures, and the number of insects trapped has started to rise again. The results from traps in 2021 will indicate whether the population has remained high requiring remedial action. Early trapping records also list adults and larvae of two-spot carpet beetle (*A. pellio*). The numbers found on traps have declined gradually since then, probably due to the cleaning of fireplace flues which could be accessed.

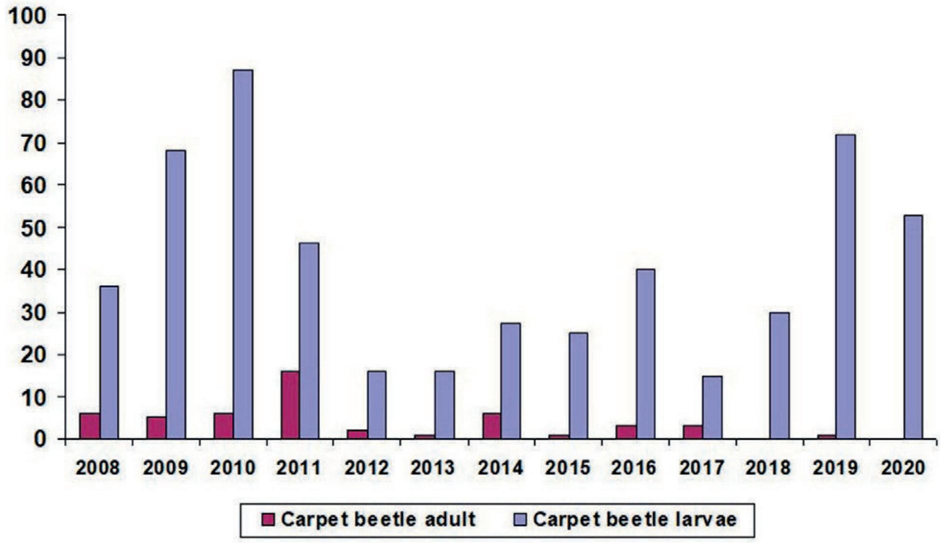


**Figure 2** Numbers of varied carpet beetle (*Athrenus verbasci*) adults and larvae trapped 2008–2020.

## Silverfish (*Lepisma saccharinum*, Linnaeus 1758)

Since trapping started in 2001, large numbers of silverfish (*L. saccharinum*) had been found on traps in the Great Hall. This has a stone floor with many damp microenvironments, but with very few vulnerable objects in this area, it was considered that the silverfish did not present a serious risk. However, in 2011, numbers recorded were extremely high, with 1,290 being found on traps both in the Great Hall and in other locations in the house. This problem now needed to be thoroughly investigated and remedial action taken. The main concern was the increased numbers of silverfish caught on traps on the ground floor of the house, particularly in the Billiard Room, the Flower Room, the Dining Room and the Italian Drawing Room. This increase indicated a continuing problem with damp ingress: the deployment of additional sticky blunder traps showed that most of the silverfish were caught on traps placed near to the windows and outside walls, with some also being found in fireplaces.

The site technical manager was informed and asked to investigate the damp ingress problem. Pointing works around the window areas on the south side were carried out in 2012 to resolve the problem following his investigation. During our site visit, it was discovered that the bottom sections of the lead downpipes in this area had been stolen. These were temporarily replaced and new lead pipes installed in 2012. Blocked drains were also found and subsequently cleared of all debris. The water ingress was the cause of the high humidity microenvironments and because our site visits and the IPM trapping programme gave clear early warning of the problems, this was rectified by the building work and maintenance, thereby avoiding any further damage.

## Webbing clothes moth (*Tineola bisselliella*)

Webbing clothes moths (*T. bisselliella*) were not detected in the property until 2008. In 2009, Killgerm AF pheromone lure board traps were deployed to monitor this new threat to the collections (Fig. 3). The number of moths on traps gradually increased until 2016, when there was a rapid expansion of the population. A key objective since then has been to identify the source of the moths and prevent damage to vulnerable and historic textile collections. The initial focal point was in the Boudoir and the adjacent Library Room, and a number of objects were treated using Constrain pyrethroid microemulsion spray or in an Integrated Contaminated Management controlled humidity high-temperature treatment chamber.[1] Other measures undertaken included the cleaning of open fireplaces and treating accessible

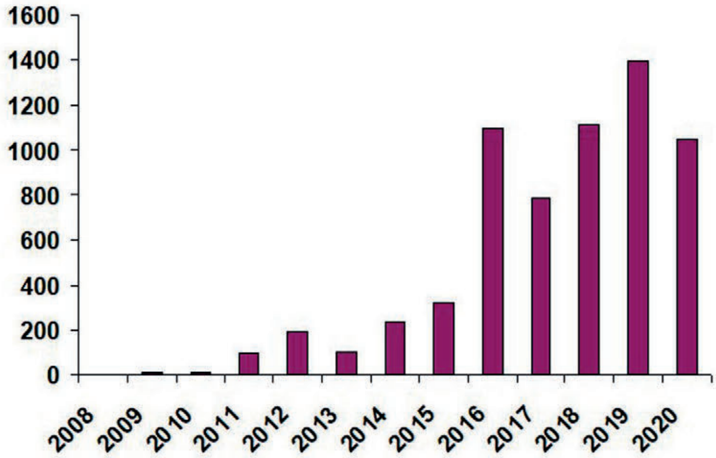


**Figure 3** Numbers of webbing clothes moth (*Tineola bisselliella*) trapped 2008–2020.

**Figure 4** The Great Hall corridor (© English Heritage).

wall voids behind the false wall panels in the Library with a desiccant dust.

Deployment of the *Tineola* pheromone traps in a targeted grid has enabled more detailed mapping of the moths. Recent evidence indicates that the population is breeding in debris in inaccessible voids under the floorboards in the Great Hall corridor outside the Boudoir and Library Room, and probably in the adjacent wall voids which connect throughout the property (Fig. 4). Underfloor heating is fitted directly below these floorboards and covered in insulation. The pipes are also very close to the underside of the floorboards and lead up into wall voids. This means that all of the voids found here, where we know the moths are thriving, cannot be accessed or treated without the removal of the heating pipe works.

The moths have now spread around the house, probably as a result of the interconnecting voids, and are now well established. The key challenge faced within a protected historic building such as Eltham Palace is the difficulty of carrying out effective deep cleaning and housekeeping schedules in a historic structure with many inaccessible areas that cannot be opened up for cleaning and treatment. Unfortunately, most of these areas are also untreatable with any insecticide which is registered for use. However, it is possible that some other voids can be treated with a desiccant dust, although this has proved difficult to carry out.

### Other pest issues

Pigeons and other birds were nesting on parts of the building in large numbers and a regular cleaning programme targeting removal of the bird guano and debris was undertaken in 2011. A trial of the 'Bird Free' deterrent was also carried out by an outside contractor but the English Heritage building maintenance team found that although this was initially successful on the south elevation, where the largest numbers were evident, the birds simply relocated to other areas. The deployment of a handler with a Harris hawk in 2014 has proved more successful at keeping the roosting bird numbers down (Pinniger and Lauder 2018) and this has been retained.

## Conclusions

Due to the early warning of pests established through the trapping programme, the vigilance of the staff and the high standards of housekeeping in the visitor areas, any damage to collections by moths and other insects has been minimal. It will require continuing high levels of housekeeping to prevent damage in the future and to maintain this standard, extra resources to be made available when required have been prioritised. The additional benefit of having trained staff able to carry out localised treatments also contributes to keeping these costs low. Additional difficulties have been caused in 2020 and 2021 by the restrictions in staff access and movement during the COVID-19 pandemic. The long-term effects of this on pests may become apparent in the future at Eltham Palace and other properties.

The priority of the IPM programme has been to identify insect pest sources, assess their risks and take early action to ensure that the historic contents are not damaged. This has proved successful at Eltham Palace and the IPM programme serves as a model for other historic properties. However, it must be recognised that it is a continuing process which requires resources including regular input from trained staff. The general lesson learned from this case study is that we have had to learn to live with these insect pests, but with our highly developed training skills and vigilance, we can restrict and manage the risks posed by them to our vulnerable collections.

## Acknowledgements

We are indebted to the site staff at English Heritage who have helped with the IPM trapping programme by providing accurate and much needed data since 2001.

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# IPM at Kyushu National Museum: developing strategies and cooperation

Rika Kigawa, Hiroki Watanabe, Ayako Izumita, Shiho Tomimatsu and Mika Matsuo

**ABSTRACT** The Kyushu National Museum in Dazaifu, Japan opened in 2005 and an integrated pest management (IPM) policy was adopted at the start of the construction process. Basic strategies of sanitation, deep cleaning and careful observation of pest signs were fundamental policies that needed to be instigated. Staff understanding of the IPM policies was extremely important and systems of cooperation with external contractors and volunteers have been built up over a period of 10 years. The IPM training and awareness courses for different groups – curators, external museum staff, volunteers and contractors such as cleaning staff – were tailored to help them understand the necessity of IPM in a museum. In the meantime, effective control methods to cope with the occasional invasion of insect pests via incoming objects and surges of trapped insects in certain areas have been of great importance. We have tested and learned effective strategies to counter and deal with common museum pest insects such as silverfish. This paper describes the communications and technical aspects of our thorough efforts to retain a desirable museum environment.

**KEYWORDS** Integrated pest management; IPM; museum

## Introduction: early stage of constructing IPM policies

The opening of the museum in 2005 coincided with the phasing out of the commonly used fumigant methyl bromide in Japan (UNEP 1999). A thorough cleaning regime in storage areas and related spaces was implemented (Honda 2019). Volunteers participated in the integrated pest management (IPM) activity such as preparing and regular setting of insect traps and a company whose staff had curatorial experience helped with monitoring and cleaning in storage. A non-profit organisation (NPO), which was born from the volunteer group's activity, has carried out inspection and identification of captured insects on approximately 400 traps twice a month (Honda 2019). In 2020, as a result of the COVID-19 pandemic, this time interval was reduced to once a month. Since the building has a large seismic isolation system which supports all the galleries and storage areas, the structure is flexible, meaning that it is not very easy to separate areas, therefore it is crucial to control pest insects within the entire building.

## Preventive measures

Staff of the environmental management section within the Museum Science division are responsible for IPM activities. Treatment options for incoming objects include oxygen scavengers, a nitrogen


**Figure 1** (a) Nitrogen treatment chamber; (b) $CO_2$ bubble; (c) walk-in freezer (–30 °C); (d) inside of walk-in freezer; (e) humidified warm air heat treatment (60 °C); (f) heat treatment (60 °C).

treatment chamber (Fig. 1a), $CO_2$ bubbles (Fig. 1b) and the use of freezers at –30 °C (a small one indoors and a large outside freezer room) (Fig. 1c,d). On one occasion, a moisture-controlled heating strategy (Fujii *et al.* 2020) was adopted to treat wooden base parts of a festival float that was exhibited in the entrance area (Fig. 1e). A heating chamber adjusted to 60 °C is used for regular treatment of the cushions employed to protect objects during transportation (Fig. 1f).

**Figure 2** (a) Improving the seals of food waste bins; (b) removing corrugated paper protective sheets and adoption of insect-resistant sheets.

## Coping with problems caused by silverfish

In 2015, the results of our trap monitoring indicated an escalation in the numbers of silverfish captured. The silverfish had a white colour and differed morphologically from common species such as *Ctenolepisma villosum* (Fabricius, 1775), *Ctenolepisma longicaudatum* Escherich, 1905 and *Lepisma saccharinum* Linneaus, 1758 (Thomsen *et al*. 2019). The species of this silverfish has not yet been identified and investigations are currently ongoing. Unlike the general description of the characteristics of common silverfish, this species tolerated moderate humidity around 50–60% RH. A few captured insects observed in a glass jar supplied with a sheet of corrugated paper multiplied very quickly in the moderate humidity.

When we investigated the circumstances in the building, it was discovered that a typhoon had caused a water leakage on the first floor during the year, and several other areas required attention. In order to manage the situation, the following measures were undertaken. Food waste bins were replaced by metal ones with tight-fitting lids (Fig. 2a) and corrugated paper protective sheets in storage spaces were exchanged with insect-resistant materials (Fig. 2b). Floor tiles were removed for deep cleaning (Fig. 3a) and regular deep cleaning of spaces under shelves in stockrooms (Fig. 3b), under and inside the exhibition cases (Fig. 3c,d) was implemented. Pyrethroid emulsion was injected (Fig. 3e) or applied with brushes alongside floor–wall boundaries (Fig. 3f). By removing the insects' food sources, the numbers on traps decreased significantly year by year and are now almost back to the initial level.

## IPM courses, talks and regular 'Environment working group' meetings

Initially, courses were only held for volunteers and the NPO staff but were then made available to staff

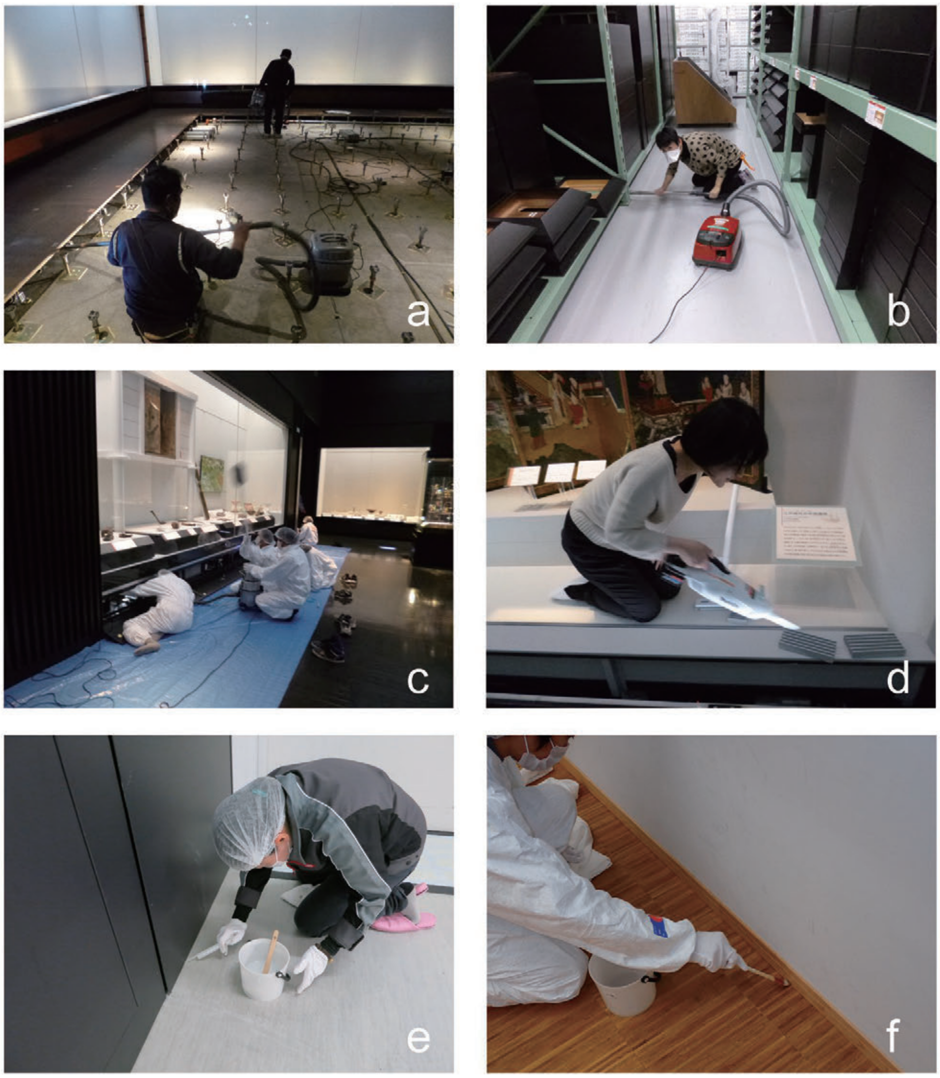


**Figure 3** (a) Deep cleaning beneath the floor; (b) under stock room shelves; (c) under exhibition cases; (d) and inside a case. (e) Application of pyrethroid emulsion by injection and (f) with a brush to the wall/ floor border.

from other museums (Honda 2019). In 2016, the courses were modified to include a public IPM seminar involving a large audience (Fig. 4a) followed by a two-day IPM course for about 30 participants with exercises and discussions. The rise in silverfish numbers was the catalyst that spurred us on to create opportunities for sharing awareness with internal members such as curatorial staff and management. IPM courses for internal staff (Fig. 4b) have been held annually since 2016 and talks for volunteer and cleaning staff, as well as to groups such as 'girls' archaeology' (Fig. 4c), are held in a fun-like atmosphere. Events to understand insects such as 'making specimen trial' have been held for volunteer group members who help with IPM activities (Fig. 4d).

Once a month, inter-divisional 'Environment working group' meetings are held with about 20 staff from curatorial, facility management and general management during which IPM matters are regularly reported and policies involving environmental control of galleries and storage are discussed (Fig. 4e). A synopsis of the agenda is reported in curatorial and management meetings in order to share the findings.

From 2020, due to the COVID-19 situation, holding the usual seminars and courses for outside institutions became difficult so we initiated individual one-hour online discussions with staff from approximately 10 institutions in order to share knowledge on IPM (Fig. 4f). One helpful aspect of private online meetings is that several members of staff from each museum can join in the discussion


**Figure 4** (a) IPM seminar; (b) internal IPM course; (c) a talk to a girls' archaeology group; (d) 'making a specimen trial' with a volunteer group; (e) 'Environment working group' meeting; (f) online IPM discussion event.


**Figure 5** Fun IPM materials such as file folders, sticky notes and notepads provide an introduction to major museum pest insects.

and ask frank questions regarding problems specific to their work environment, thereby facilitating understanding of the necessity of IPM.

## Attitudes to IPM

It is very important to talk about IPM using humour. Original IPM materials to help people feel 'familiar' with major museum insects were produced (Fig. 5) thanks to a kind donation from the Kyushu National Museum Supporting Membership. The drawings of insects and the overall design of the materials were made by the staff in our division and distributed to other museum staff, course participants, children joining in museum activities and students attending lectures at the museum.

Having experienced working in the division responsible for implementing IPM, we understand that very clear explanations of why IPM is important are necessary. Well-illustrated scientific presentations of the data with a simple explanation will result in effective communication. The basic attitude of 'openly sharing situations' is indispensable for a prompt response. Then 'do it ourselves first' is an important principle as simply asking other people to do something never works. In the first case, it is crucial that our division makes every effort to implement effective IPM measures. Honesty and openly sharing a situation and asking for urgent help is also very important, and it is crucial that cooperation from others is acknowledged. We believe that these attitudes are the essence of IPM in a museum.

## Acknowledgements

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# Instruction versus practice: where can we improve upon IPM?

Alex Rowe, Simoní Da Ros and Katherine Curran

**ABSTRACT** Mismanagement of pests in museums, collections and archives represents one of the most important threats for the conservation of cultural heritage. Despite the introduction and widespread uptake of integrated pest management (IPM) in the past two decades, IPM instruction seems to stay the same. We query whether there are common issues that could be addressed within general guidance to further assist individuals running IPM schemes. Therefore, this paper seeks to highlight common challenges faced by those practising IPM in the hope of inspiring further improvements in IPM instruction. To gain some insight, we conducted interviews with 10 IPM professionals from a variety of cultural heritage roles, backgrounds and organisations. Once interviewed, we analysed the responses, coded those deemed 'negative perceptions' and explored these for common themes and issues. Four areas of concern were identified: impressions of IPM; limited resources; human error; data collection, analysis and communication. This paper highlights where there might be a disconnection between standard IPM instruction and actual practice by comparing these comments to British Standards Institution instructions. We concluded that participants struggle the most with limited resources and human error, suggesting that these areas could benefit from improved instructions.

**KEYWORDS** IPM instruction; British Standards Institution; human error; limited resources; staff engagement

## Introduction

Classified as an agent of deterioration by the Canadian Conservation Institute, pests are one of the primary threats to cultural heritage (Michalski 1990). As such, over the last 20 years, integrated pest management (IPM) has become a staple in preventive conservation practice in cultural heritage establishments (Staniforth 2013). However, alongside all innovations and discussions surrounding the topic, IPM instructions do not seem to reflect the evolution seen elsewhere. As exemplified in Table 1, there is a very clear similarity between IPM described in Pinniger and Winsor's popular 1998 publication and the British Standards Institution instructions issued in 2016: BS EN 16790.

Generally, the method seeks to avoid, block, detect, respond and recover, which encourages cultural heritage institutions to adapt the scheme to fit their own individual contexts (Strang and Kigawa 2009). This allows for flexibility and avoids a prescriptive approach although, as with any collective human endeavour, it is still subject to some issues. We query whether these can be negated somewhat through adaptations to instructions therefore this paper seeks to identify common issues experienced by those leading IPM programmes. Through interviews with 10 cultural heritage professionals, we have identified four areas of concern:

- Impressions of IPM.
- Limited resources.

**Table 1** The six general steps in integrated pest management.

| Pinniger and Winsor 1998 | BS EN 16790, 2016 |
|---|---|
| 1. Avoiding pests | 1. Understanding material vulnerability |
| 2. Keeping pests out | 2. Recognising pests (the main species and the damage they cause) |
| 3. Identifying pests and pest activity | 3. Assessing the situation, inspection and monitoring |
| 4. Assessing the problems | 4. Reducing risks |
| 5. Solving pest problems | 5. Solving pest problems |
| 6. Reviewing IPM procedures | 6. Post-treatment monitoring |

**Table 2** Part 1 of the interview comprised general and open questions discussing IPM.

| | Part 1 General questions |
|---|---|
| 1 | Where in your role have you come into contact with IPM? |
| 2 | In your understanding, what is the intended outcome/ aim/ focus of IPM? |
| 3 | Why do you think heritage institutions use IPM as opposed to other pest control regimes? |
| 4 | How were you introduced to IPM and what was your initial impression of it? |
| 5 | Have you noted any benefits from the scheme? |
| 6 | Have you noted any drawbacks from the scheme? |
| 7 | Who else is involved in IPM in your establishment? |
| 8 | Is there a good system of communication in place between everyone? |
| 9 | How much time do you invest in IPM? |
| 10 | In comparison to other preventive conservation concerns, light, temperature, dust, RH, do you invest more or less time? |
| 11 | In your opinion, is this time investment well spent/ adequate (delete one)? |

- Human error.
- Data collection, analysis and communication.

Explored in depth, we highlight where instruction and practice clash to inspire further research into improving IPM guidance.

## Methodology

Interviews were conducted during summer 2019 via face-to-face meetings or by phone. Participants were selected through snowball sampling (Noy 2008). Semi-structured interviews allowed interviewees to speak freely on guided topics, where both closed- and open-ended questions were used to generate qualitative and quantitative data while providing an environment in which ‘digression can be very productive’ (DiCicco-Bloom and Crabtree 2006: 315) (Tables 2 and 3). Interviews averaged 30–45 minutes each, producing in-depth answers. For the sample size, our initial goal was to interview 20–30 participants based on Baker and Edward’s (2012) ‘medium-sized’ group, however we noted that 10 participants were enough to ‘penetrate beyond a very small number of people without imposing the hardship of endless data gathering’ (Adler and Adler, cited in Baker and Edward 2012: 9). Finally, we used the British Standards Institution’s instructions (BS EN 16790) as a comparison. To maintain confidentiality, participants were grouped into job categories and referred to as ‘intern’, ‘IPM lead’ or ‘IPM consultant’. The results have been separated into four areas of concern with the addition of subcategories to display common themes where needed.

## Impressions of IPM

At the core of IPM instruction is the desire to minimise intervention by accepting and monitoring low pest levels (BS EN 16790: 5). Unfortunately, with the past popularity of quick, chemical solutions, IPM can be perceived as being too gentle in its approach.

**Table 3** Part 2 of the interview comprised questions focusing specifically on IPM instruction.

| | **Part 2 IPM instruction questions** |
|---|---|
| 12 | a. Have you seen the steps written out like this before, or presented with a diagram etc.? Or IPM leads/ consultants<br>b. Do you inform staff of the steps involved in IPM (as seen)? |
| 13 | Can you see evidence of these steps in the daily running of IPM? |
| 14 | On paper these are supposed to be equally as useful – would you say this rings true in application? |
| 15 | If you had to choose, which of the stages would you say is the most useful? Why? |
| 16 | Which would be the least? Why? |
| 17 | Which of the stages would you say is the most difficult to carry out? Why? |
| 18 | Which would be the easiest? Why? |
| 19 | Does your institution use chemical treatments during any of these steps? |
| 20 | After reading these, is there anything instructional you might add to these guidelines? |

As one participant explained, 'pests are seen as a dirty thing, and so chemicals are a quicker way to kill them'. Consultants who commented suggested two reasons for this misconception: pest presence represents either a personal failure or a failure of IPM. On the side of personal failure, one consultant talked about times they have had to joke 'I hope you're not losing sleep over this' or convince staff 'to learn to live with it – it's just the way it is'. Despite being well trained, accurate trackers, the participant found that staff still needed such reminders. Conversely, another consultant found that IPM's policy of minimal intervention can be misinterpreted as ineffective because of its failure to remove all pests. In an anecdote, they noted the reluctance of overseas clients to conform to European Standard IPM policy: 'for them that was so hard; they wanted a standard that said "we don't want any [pests]", 0%', explaining that cultural perceptions of pest control can be a major obstacle to IPM. The main takeaway for this participant was that with 'IPM is not just the image … it's better for you … it's cleaner and non-toxic, but it's also a paradigm shift.'

## Limited resources

### Initial investment

IPM 'should also be achievable in terms of human, financial, and logistic resources' (BS EN 16790: 8). However, participants suggested that it can be hard to convince people of the initial investment required. As one participant explained, 'it takes several years of data before you start to get a real picture'. Another concluded that 'people don't want to put money into preventive conservation and in the end, it becomes much more expensive'. Therefore, it seems that the first hurdle to IPM involves convincing stakeholders to commit to the investment.

### Staff

Another scarce resource cited was staff time and training, as a well-integrated scheme requiring staff participation and inclusion. Starting with training, instructions suggest that it can be delivered in many ways: 'oral presentations and/or hand-outs, for example explanatory posters with pest images. Follow-up training shall be carried out at regular intervals' (BS EN 16790: 10). These seem reasonably achievable, however, several participants suggested that refresher training can end up being resource-intensive. One participant reported that 'it [training] is continual', rather than at regular intervals as suggested, due to 'high turnover' in the cultural heritage sector: 'People come and go, new staff come in, you've got to train them … and just when you think "right, I've finished, I can go off and help that" – no, they leave.' Being an in-house consultant, they reflected that training was not particularly costly for their establishment, but that the lack of it could result in much higher costs to maintain a good level of IPM understanding among staff: '[without training] you're going to rely upon external courses and consultants'. These comments could be indicative of poor management on the part of establishments but was mentioned sufficiently often to perhaps warrant further instruction on the topic in general IPM guidelines.

Offering another perspective, an IPM lead stressed that 'it's very resource-intensive in terms of the collection care assistant's time'. Looking again at the relevant British Standard, it seems very straightforward to instruct that 'The IPM policy is [should be] built on a framework, which defines all roles and responsibilities' (BS EN 16790: 11). While this is manageable when adequate staff numbers are available, they noted that 'It's a major drawback when we don't have collections assistants in post; we recently recruited someone, but the post has been vacant during this process.' Therefore, with staff an unpredictable factor, IPM becomes increasingly difficult.

## Human error

As a natural follow-up to staffing problems, the 'human error' category includes issues of misunderstandings, poor identification and a lack of engagement. These errors lead to the real or perceived inflation of pest count data through either negligence or poor reporting.

### Misunderstandings

Within the 'misunderstandings' category, participants spoke of well-meaning staff who were misguided in their IPM efforts. For example, one IPM lead noted that after working to 'boost the profile of IPM', staff members were then 'putting down too many traps and failing to understand that if you put down more traps you will catch more pests, but it doesn't necessarily mean that you've got a bigger problem'. Another IPM lead recounted a similar tale of misguided enthusiasm where due to health concerns volunteers could not follow trap protocol: 'the only place they [volunteers] could distribute traps was in the middle of the floor'. This participant surmised: 'people want to do it, they want to buy traps. How well they do it? Well, I think there's a bit of a gap.'

### Poor identification

Identification of pest and non-pest insects was also noted as an issue. Participants suggested that 'people are less good at identifying pests than they think they are'. This was interesting as 'identification' was voted the easiest step in IPM instructions when participants were asked to rank the six steps (Table 1) (Pinniger and Winsor 1998) in order of difficulty (Table 3: 18). However, several participants gave examples of how challenging correct identification and damage tracking can be. An IPM lead reported receiving regular queries about non-pest insects: 'I've got people emailing me often with insects that are not pests … So, like ladybirds, or flies, they're not deemed pests because they don't pose an actual risk or threat.'

Outside of the time required to respond, these queries are mostly harmless and even show a level of IPM engagement. However, poor identification becomes an issue when it starts to affect monitoring data. On reviewing pest data with staff, one IPM lead noted that 'people say "ooh, we've got quite a lot of silverfish", [and] I nearly always go back to "have you noticed any damage?" And they say "no"'. Similarly, a consultant found that even well-trained staff can struggle with identifying new species: 'I [explained] the difference between a booklouse and a winged booklouse, because winged booklice aren't actually a pest … and the difference the year after, when you compare the booklice caught … the numbers just drop.' Without these interventions, the incorrect data could have led to an erroneous allocation of resources to solve non-existent problems.

### Lack of staff engagement

Finally, as a scheme that requires integration, lack of staff engagement can be problematic. One IPM lead remembered the pushback they had faced when implementing risk zones. According to the guidance, 'eating and drinking shall be forbidden in storage areas and, if possible, limited in other areas housing cultural heritage' (BS EN 16790: 12). However, this participant noted: 'people are resistant to change, so if you try to change their little break-out space (their eating space), they get really precious and … tend to lash out'. While the IPM lead put time into fun engagement activities, they found that with some changes '[staff] can be resentful'. This is not to say that this is the fault of the IPM instructions, but it is an issue that cropped up regularly when participants talked about integrating staff into the scheme. This could suggest that cultural heritage professionals dealing with IPM are looking for more suggestions as to how to engage general staff in something they may consider has little to do with them.

One consultant found that sometimes the biggest barrier to engaging staff in IPM is the management itself: 'When we want to gather all of the staff … I get emails saying "oh we're busy", "does everybody need to come", "could just the people involved come?"' Although a recurrent issue, in an effort to tackle this, the participant noted that 'I always start with management and talk about money … and that makes it much easier.'

## Data collection, analysis and communication

Issues concerning large volumes of data collected were also raised by IPM leads. One noted how time-intensive data analysis can be, expressing their desire to automate the activity: 'There's no way to automate it either … It's not like environmental monitoring where you can set something up to automatically do your reports … it does take that human element to carry out the activities.' Another described the process of collating the data sent to them as extremely time consuming because 'it's literally me with a spreadsheet of email addresses'. They explained, 'Although I've been doing this for several years now, there are still people that don't email me the returns.' Like the IPM lead mentioned above, they saw the solution in the automation of tasks: 'If we had more money this would be easily resolved with a simple database, [where people] would upload their figures.' Differing from the earlier idea, the barrier to automation here is resources. Nevertheless, there is a shared desire to automate tasks to improve the efficiency of analysing IPM data.

Finally, a consultant spoke of the need to do more with collected data than just solving infestation problems. The British Standard shares this view, suggesting that 'analysis, assessments and results concerning IPM, shall be an integral part of the organisation's documentation system, for reference and in order to continuously revise and improve IPM' (BS EN 16790: 14). Unfortunately, in practice, the participant reported that 'people did monitoring but they didn't always act on their monitoring data'. As such, although the pests were dealt with, the full potential of the data was not reached. Instead, they proposed that data should be used to educate staff, otherwise 'while [institutions] may be able to improve a particular environment to keep pests at bay, the lack of shared data means that there is no change in terms of people's practice and habit'.

## Conclusions

Interviews with cultural heritage professionals highlighted four areas of concern, classified here as 'Impressions of IPM', 'Limited resources', 'Human error' and 'Data collection, analysis and communication'. The largest and most discussed sections involved limited resources and human error, suggesting that these IPM-related areas can be challenging.

Additionally, it is important to mention the constant discourse on general staff and their involvement in IPM. As an integrated scheme, IPM stresses the importance of staff involvement and awareness, however, their lack of understanding or half-hearted commitment is mentioned in every area of concern. In 'Impressions of IPM', the lack of understanding among those both new to IPM as well as those with experience affected their interpretation of the scheme. 'Limited resources' acknowledged the need for constant training and its stress on limited resources. 'Human error' gave the strongest case for improving areas of staff involvement, providing examples of misunderstandings, poor identification and a lack of engagement. Finally, 'Data collection, analysis and communication' appears as an area that could be further explored to increase staff awareness on wider data applications. From this, the main concern is the need for additional instruction when it comes to managing those interacting with IPM schemes.

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# Integrated pest management: from monitoring to control

Christian Baars and Jane Henderson

**ABSTRACT** The purposes of pest monitoring are (1) quality control of a pest management programme and (2) communication of pest occurrence information to different user groups. Good pest monitoring practice requires unbiased data analysis and interpretation which, in turn, relies on data being collected in a consistent manner. The Pest Occurrence Index (POI) was developed to open up a discussion on the managerial, psychological, analytical and communication practices that are in danger of being overlooked when the focus of pest management is the counting of insects. This paper offers an overview of the development of the POI in integrated pest management (IPM) in the cultural heritage sector, considers progress to date and examines two major updates: that pest monitoring data are sensitive to the frequency of monitor inspection; and how to integrate into systematic pest monitoring any incidental encounters of pests not collected on monitors but found randomly. Clear parallels between pest monitoring in cultural heritage properties and population studies in ecology demonstrate that effective and unbiased analysis of results requires standardised monitoring approaches and data collection.

**KEYWORDS** IPM; museum; pest monitoring; data analysis; pest occurrence index; communication

## Introduction

Integrated pest management (IPM) is an umbrella term for a wide range of activities to protect museum or cultural heritage collections against pest infestation. Despite the clarity with which IPM is described, we have experienced some practitioners conflating monitoring with management. Within preventive conservation, it is not unusual for data collection to become the end point of environmental management practice (Henderson 2018). In IPM practice and literature there appears to be a focus on pest identification and counting (Henderson *et al.* 2017). Unfortunately, the familiarity of data collection can mask a lack of efficacy in pest management because monitoring alone will neither manage a population of insect pests to safe levels nor necessarily lead to any changes in practice.

Data collection without analysis, interpretation and presentation omits the critical stages necessary for reflective scrutiny of the success of pest management. Conservators seeking support for pest management from managers and colleagues should attend to the creation of appropriate messages for distinct audiences. Effective messages are better characterised by their ability to satisfy the needs and interests of their audience than to represent the expertise of those offering the message (Henderson *et al.* 2017). Many IPM questions identify dynamic challenges, such as the spread of an established pest within a collection over time or climate change-induced distribution patterns, but data are not always comparable across rooms, collections or buildings, leading to problems with data management and interpretation.

## Principles of population monitoring

Monitoring pest populations over time yields important information for decision-making with regard to protective measures which may be costly and inconvenient, hence the quality of the information on the population density is of primary importance (Petrovskii *et al*. 2011). Most insect monitoring methods are subject to biases impacted by a variety of factors (see McCravy 2018). In our experience, there is some evidence that blunder monitors tend to over-represent large-bodied species; for example, psocids are frequently too small to climb onto the card. We can learn much about population monitoring from ecology, where the fraction of sampling units in a landscape in which a target species is present is an extensively used concept. Detection probabilities are affected by the size of the sample area (Anderson and Marcus 1993), the number of monitor days (i.e. the number of monitors multiplied by the number of days sampled) (see McComb *et al*. 2010), potential food sources and habitat. Capture probabilities must be considered to allow an unbiased estimate of relative abundance (Menkens and Anderson 1988). This is particularly important when assessing trends over time during circumstances when conditions affecting detection probability vary from year to year.

## Influence and communication

A review of IPM practice at National Museum Cardiff concluded that work was needed to present data in a way which considered the needs of the audience receiving the information. Henderson *et al*. (2017) suggested the use of novel dynamic, visually attractive and meaningful graphical data representations to achieve improvements in communication. Additional work described the process undertaken to categorise and support a range of receiver needs and abilities prior to communicating a pest monitoring message (Henderson *et al*. 2020). In striving to organise and represent data which changed the mode of communication, the authors identified much of current data quality and data analysis were not fit for purpose. One flaw undermining our data representation was the impact of the changing density of pest monitors on the number of insects identified. Fluctuations in the number of pest monitors are common to many IPM programmes, highlighting a need for a consistent approach to analysing pest monitoring data which would remove variability.

## The introduction of the Pest Occurrence Index

A novel approach to analysing pest monitoring data by way of calculating an index was developed and tested successfully at National Museum Cardiff. The Pest Occurrence Index (POI) is a measure of pest activity which integrates the number of individual pest counts with the number of monitors deployed and the area of each room monitored, decreasing unintentional bias introduced by previously used analytical techniques (Baars and Henderson 2020). This abundance index provides data that can be used to compare populations in different places or times.

Calculation of the POI requires that contextual information – such as type of collection affected, room size and number of pest monitors deployed – must be reported to enable meaningful data interpretation (the development of the POI is described more fully in Baars and Henderson 2020). Application of the POI results in data interpretation which more closely reflects actual trends in pest populations, rather than artefacts of monitoring methodology. The result of the POI calculation is a rational number expressed as a decimal. Due to the widely prevalent natural number bias (Lortie-Forgues *et al*. 2015), Baars and Henderson (2020) suggested including a factor to create a natural number POI ($POI_n$) with the intention of aiding communication.

The POI represents a paradigm shift in the reporting of pest management and has been adopted by the start-up environmental monitoring and management company Conserv as the basis for analysing pest occurrences. As part of Conserv's free integrated pest management software, Conserv Cloud, the POI has reached hundreds of collections care professionals since its launch in April 2021.[1]

## Calculating the Pest Occurrence Index (POI)

The POI is calculated by initially computing the sum of the numbers of occurrences for all pest species observed on pest monitors:

Equation 1: $\text{pests}_{\text{sum}} = \sum_{i=1}^{n} F_i$

F = number of occurrences recorded for each pest species,
i = index of summation,
n = the upper bound of summation (read as 'sum of $F_i$, from i = 1 to n', meaning: add up the number of all recorded occurrences from the first to the $n^{th}$).

The sum '$\text{pests}_{\text{sum}}$' is then divided by the number of monitors per room, the size of the room, and the length of time the monitors were exposed between pest checks:

Equation 2: $\text{POI} = \dfrac{\text{pests}_{\text{sum}}}{D \times E \times t}$

D = number of monitors in this room,
E = the room size in $m^2$,
t = the length of time (in days) of exposure of the monitors in this room between pest checks.

The resultant POI is a rational number expressed as a decimal. It is widely known that many people have considerable difficulties with numbers expressed as decimals (Hiebert and Wearne 1986, Putt 1995, Lortie-Forgues et al. 2015). Because our emphasis is on communication in an easily understandable format to broad types of audiences who do not necessarily have specific mathematical expertise, the result of equation 2 is multiplied by a factor of, for example, 1000 to create a natural number for POI ($\text{POI}_n$).

Equation 3: $\text{POI}_n = \text{POI} \times 1000$

The decision to introduce a factor is therefore communication-led with the intention of decreasing natural number bias.

## POI 2.0: making time a factor

Detection probabilities are affected by the number of monitor days (i.e. the number of monitors × the number of days sampled) (McComb *et al.* 2010), so the time elapsed between successive observations should remain constant (Engeman 2005). In cultural heritage institutions this is difficult to achieve as the interval between monitor checks is rarely exactly the same number of days. Different institutions inspect their monitors on different time scales, hence data between collections, buildings and institutions are not necessarily comparable. This lack of standardisation presents a challenge for the assessment of regional or national trends which require the aggregation of data from different institutions.

A pragmatic solution to avoid detection probabilities being affected by the number of monitor days is to integrate time as a factor into the POI calculation. This can be achieved by the inclusion of time (in days) in the POI formula and has the effect of standardising detection time in addition to the already existing spatial factors.

## Incidental encounter data

Once the application of the POI was scaled up, questions about its use began to arise. 'One thing we heard repeatedly from potential users was that they also wanted to be able to record pest sightings and counts directly in spaces. Say, for example, a windowsill, or other place in a space where pests are seen that are not places where monitors have been put down. How would you include pest counts taken in a space, but not in a monitor, in the POI calculation?'[2]

While the identification and retrieval of any insect pest in a cultural heritage collection setting provides reliable evidence of presence, randomly encountered insect finds are very difficult to integrate into any systematic pest analysis and provide little value for trend analysis. If a volunteer reported finding three larval casings near a window in the store one week but it was unknown whether they were there the previous week, we could not use this information to determine population trends. There are three possible responses to these data.

## 1. Ignore any data not originating from pest monitors

Data from incidental observations constitute a sampling methodology that differs from that of the use of blunder monitors: the former is a type of active visual survey, the latter is passive sampling. In any systematic monitoring programme, monitoring methods should not be mixed. Montgomery *et al*. (2021) provided simple guidelines for maximising return on insect benchmarking data with a recommendation that the locations of visual surveys remain fixed to enable surveys to be compared from year to year, but in most museum environments incidental observations remain one-off observations. This means that the same location is very unlikely to be surveyed repeatedly, thereby introducing variation and inconsistencies into the monitoring programme that may result in data becoming skewed, leading to either under- or overestimation of the level of pest activity.

We acknowledge that it is psychologically counterproductive to treat incidental encounters as irrelevant because IPM managers have worked hard to encourage colleagues to engage with pest management and inform them of any insect finds, not least through the ubiquitous and popular English Heritage pest posters (English Heritage 2021). But for the purposes of data analysis, incidental finds should be omitted from datasets.

## 2. Treat incidental observation as a separate report

By creating a separate entry on the monitoring spreadsheet for random finds it would be easy to integrate these data into the calculation of the POI. In this scenario, all finds would be accounted for and reported. This is likely to be a psychologically satisfactory method as it appears to respect diligence and completeness for those reporting the data, ensuring that everyone who has participated in reporting feels validated. In mathematical terms however, these data remain questionable because just as the number of pests found in a space sometimes correlate to the number of pest monitors (Baars and Henderson 2020), the number of random finds may correspond with certain factors, such as the presence of engaged and observant staff. Such a measure may be a better indicator of the impact of IPM training rather than the threat from insect pests to the collection. If pest monitoring aims to monitor trends, the approach of integrating random finds into the POI calculation would undermine the quality of the results.

## 3. Use incidental observations as a gateway for additional IPM decision-making

The two approaches above indicate the joint criteria of the need for consistent data collection and the necessity to maintain the enthusiasm of stakeholders in the monitoring process. The third solution offered here aims to satisfy both needs by identifying a series of decisions triggered by random reports but not including the finds in the POI. This may be developed into a flowchart based on the location, scale and identity of pests found, but requires testing in practice. For now, it is sufficient to identify a series of questions to be addressed if random finds have been entered into a database. The trigger questions may include the following:

- Does this find represent a threat to your collection?
- Is there anyone who should be notified (for example, the owners of loan objects)?
- Is there an immediate quarantine or housekeeping need?
- Is a pattern emerging for the species, location or season – or can the data be used to establish a pattern?
- Are you monitoring in the right number of places within that space?
- Should the location of the find become a permanent monitoring point?

- Is it likely that this problem has gone undetected for some time and if so, is there a need for a strategic response such as training or a review of staff responsibilities?

## Summary and outlook

The purposes of pest monitoring are quality control of a pest management programme and communication of pest occurrence information to different user groups. This requires unbiased data analysis and interpretation which, in turn, relies on data being collected in a consistent manner. There is currently still a bottleneck for insect monitoring in getting from the insects on the monitor to accessible data. We need to build tools for the efficient capture of all data and metadata associated with observations (Montgomery *et al*. 2021). The POI was proposed as a tool to achieve this. Our focus has been on standardised data collection and effective communication. This latest work considers that the length of time between pest checks, in addition to the density of pest monitors, affects the conclusions drawn from monitoring data. We also addressed the issue of incidental pest encounters, and how to integrate them usefully into a systematic pest monitoring programme. The POI is now a valuable tool for intra- and inter-institutional comparisons based on robust and consistent data such as, for example, for the assessment of emerging threats in the context of climate change-induced distribution patterns. If adopted widely, the cultural heritage sector will create greater opportunities to collaborate, communicate and act upon their hard-won pest data.

## Notes

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# An international IPM survey of resources and activities conducted by the MuseumPests Working Group

Lisa Goldberg, Eric Breitung, Zoë Hughes, Suzanne Ryder, Julie Unruh and Joel Voron

**ABSTRACT** The MuseumPests Working Group conducted a survey in 2019 to gather information on current trends in resource allocation and operational practices in institutions aiming to monitor and manage pest activity. The survey investigated collections' pest control methods, budgets, personnel parameters, pest populations and use (or lack thereof) of institutional policies. The survey was posted to several different listservs resulting in 377 respondents primarily from the USA and Europe but also reaching five continents. The survey data were evaluated using Survey Monkey's innate analytics and Tableau, an open access data visualisation programme. The use of Tableau allowed us to expose relationships between the datasets. Using the survey data and other integrated pest management (IPM) resources, the team reports on the topics of inquiry as well as notable relationships. Although some of our data were flawed by the constraints of the survey construction, we were able to extract a range of interesting conclusions based on budget and institutional size, treatment preferences based on geography and job responsibilities, and potential areas for future work by those involved in IPM.

**KEYWORDS** IPM; survey; resources; MuseumPests.net

## Introduction

The MuseumPests Working Group is an unaffiliated group of museum and collections care professionals who collaborate remotely and convene once a year to further projects and update information on their website. The site includes free and accessible key information on prevention, monitoring, identification, solutions and resources about museum pests. The site also hosts a listserv facilitating crowd-sourced discussion on pest identification and treatments.[1]

This worldwide survey was created by five MuseumPests Working Group members with different backgrounds in cultural heritage institutions. Recognising that huge progress has been made in the field of IPM within the cultural heritage sector over the past few years, the survey was built on the premise that IPM now has an established role in managing pest risks to collections. There is increased awareness, training widely available, along with different options for treatment and monitoring, as well as good examples of policies and best practice. Conducting a worldwide survey on pest remediation in cultural heritage institutions was one way to establish the validity of this notion. The research questions that formed the foundation for the survey included:

- Who is carrying out IPM? Can we see trends in the types of institutions?
- What resources have been allocated to IPM and have they changed over time?

***Table 6. Sources of Damage or Loss among Institutions that Reported Damage or Loss in the Past Two Years by Institution Type***

| | CAUSE | ALL INST. | ARCHIVE | HISTORICAL SOCIETY | MUSEUM | SCIENTIFIC COLLECTION | LIBRARY |
|---|---|---|---|---|---|---|---|
| | Percentage of institutions that reported damage/loss within the past 2 years | 32% | 25%* | 32% | 36%* | 32% | 26%* |
| Environmental | Water or moisture | 56% | 74%* | 56% | 57% | 41%* | 55% |
| | Improper storage or enclosure | 45% | 50%* | 29%* | 46% | 44% | 50%* |
| | Physical/chemical deterioration | 41% | 34%* | 36%* | 40% | 43% | 45% |
| | Light | 35% | 32%* | 44%* | 36% | 10%* | 33% |
| | Pests | 27% | 4%* | 23%* | 35%* | 54%* | 12%* |
| | Airborne particulates or pollutants | 15% | 9%* | 12% | 17% | 4%* | 16% |
| Human | Handling | 44% | 50%* | 28%* | 42% | 44% | 54%* |
| | Equipment obsolescence | 24% | 64%* | 26% | 18%* | 3%* | 32%* |
| | Prior conservation treatment/restoration | 7% | 27%* | 2%* | 7% | 3%* | 6% |
| Random | Vandalism | 20% | 6%* | 20% | 21% | 1%* | 22% |
| | Natural disaster | 10% | 6%* | 2%* | 12% | 6%* | 10% |
| | Fire | 2% | 3% | 0.2%* | 3% | 0%* | 0.2%* |

* Indicates that the percentage reported for the institutional type is outside a 95% confidence interval on the percentage for all institutions (All Inst.) reported in the first column in red. Italicized text indicates findings based on a contingency item (i.e., the top row highlighted in green is the screening item), including only those institutions that indicated they had experienced damage/loss with the past two years.

**Figure 1** Institute of Museum and Library Services report 2019 (p. 19).

- Our group believes that there are increased resources for and awareness of IPM, but have these had an impact?
- Can we see trends as to how institutions are responding to the introduction of pest management programmes?
- Is MuseumPests.net meeting the needs of our community?

Although responses were received from institutions worldwide, some of the data were difficult to interpret due to inconsistencies in the results, the specificity of the questions, and the number of open answer questions. In addition, the small number of respondents for some categories or answers resulted in datasets that were too small to allow meaningful interpretation.

The group also interrogated other sources of IPM information to answer the research questions. In 2002, Suzanne Ryder, Thomas Strang and Robert Waller conducted a pest management survey asking similar questions to those posed in this survey.[2] Notably they received only 19 responses: when compared with the 377 responses received for our survey, this serves as a gauge to measure growing awareness and concern regarding pest issues. Unfortunately, we were unable to evaluate the results for the survey by Ryder *et al*. because the dataset was very limited, and the recording and presentation of data at that time did not follow any standard, making useful comparisons impossible.

Similarly, the US Heritage Health Index (HHI) surveys from 2004 and 2014 also showed an increased awareness and concern about pest problems. When comparing the 2004 data to the 2014 data, pest damage rises from 2% to 27% (Fig. 1). While we cannot speculate about a rise in pest populations, we can potentially attribute this to increased awareness and vigilance in monitoring and maintaining pest-free environments (HHI 2005).

As the first comprehensive survey of condition and preservation needs, the HHI 2004 survey encompassed 30,827 institutions in the United States and highlighted pressing institutional needs such as storage space, emergency or disaster planning, lack of staffing, and insecure funding streams. While the data on pest activity and control were minimal, the full report indicates that pest damage was ranked similarly to damage as the result of handling, prior treatments, airborne particulates and pollutants. The conclusion was that the need for 'integrated pest control is among the lowest ranking urgent need'. The summary report indicates that the most urgent preservation need presented by the survey results is for environmental control, defined inclusively to encompass high humidity, light, temperature, pollutants, dust and *pests* (IMLS 2019).

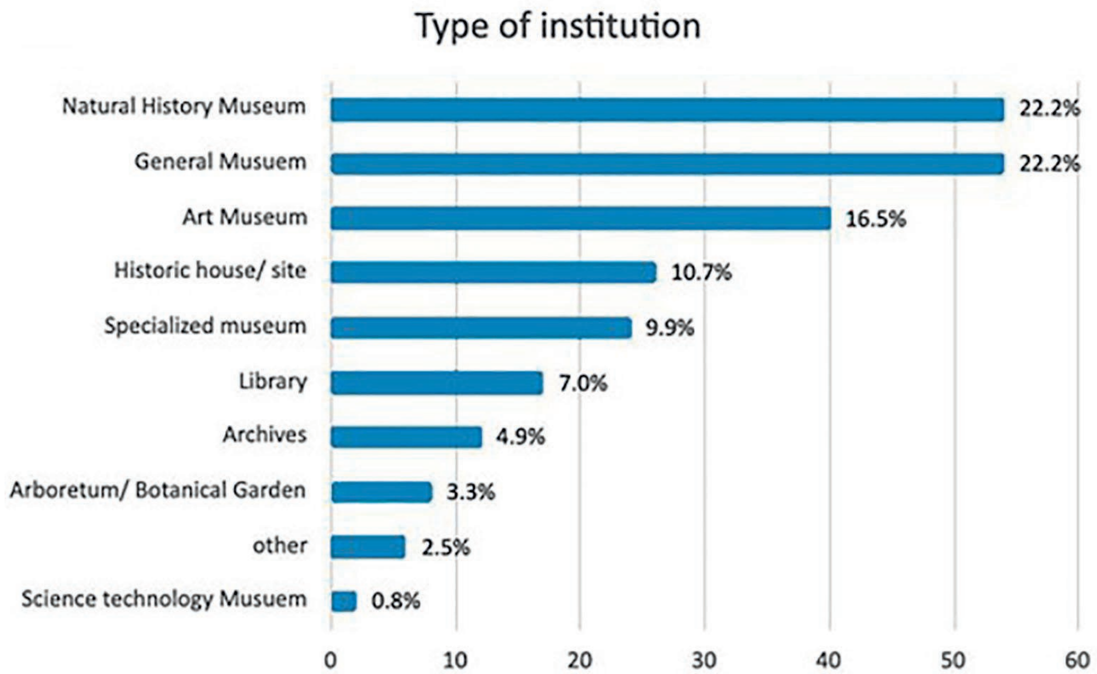


**Figure 2** Chart showing the types of institutions taking part in the survey.

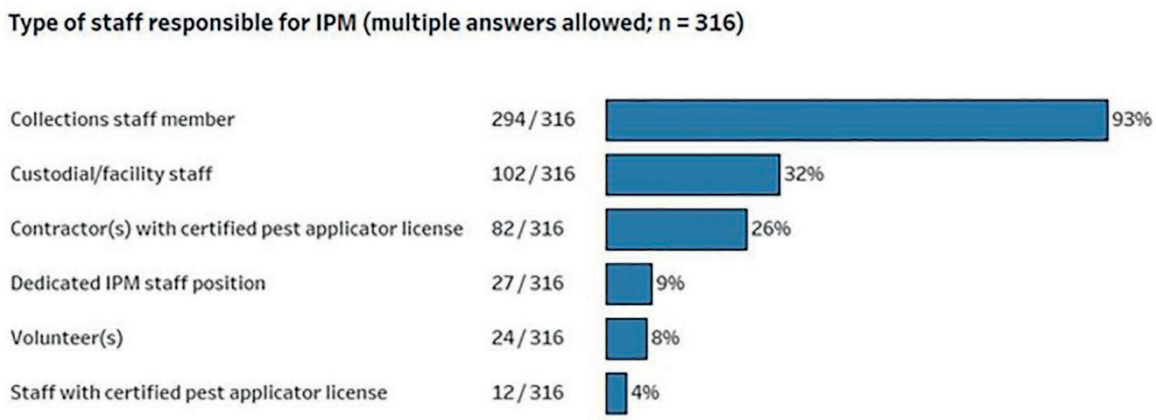


**Figure 3** The staff responsible for IPM within these institutions.

## Results

We were able to determine from the survey data that IPM has been adopted by the majority of respondents' institutions: 65% have established policies and many have adopted policies and procedures that are differentiated by space use, with 90% of institutions following procedures or guidelines related to food consumption. In addition, approximately 95% of institutions indicated that they monitor or trap to determine the presence of pests, suggesting that IPM at its most basic level has become a standard part of collections care.

Our survey was in English so the geographical distribution is not surprising. The majority of the responses came from North America and Europe – there were no respondents from Africa or Asia – and most were received from natural history and general museums with a few from science and technology (Fig. 2). Most revealing, however, is that science and technology museums, libraries, botanical gardens and archives represent the lowest number of respondents, indicating that more work is needed to bring IPM training and awareness to these audiences.

| | Insufficient data | 0-1 year | 1-2 years | 2-3 years | 5 years or more | Total respondents |
|---|---|---|---|---|---|---|
| Damaging moths | 66.01% | 11.76% | 7.84% | 6.54% | 7.84% | |
| | 101 | 18 | 12 | 10 | 12 | 153 |
| Damaging beetles | 56.41% | 17.95% | 10.26% | 8.97% | 6.41% | |
| | 88 | 28 | 20 | 14 | 8 | 156 |
| Silverfish and booklice | 54.84% | 18.06% | 12.90% | 9.03% | 5.16% | |
| | 85 | 28 | 20 | 14 | 8 | 155 |
| Nuisance pests (eg. Cockroaches, other beetles, spiders, flies) | 56.08% | 24.32% | 10.14% | 4.05% | 5.41% | |
| | 83 | 36 | 15 | 6 | 8 | 148 |
| Termites | 88.52% | 6.56% | 0.00% | 2.46% | 2.46% | |
| | 108 | 8 | 0 | 3 | 3 | 122 |
| Rodents | 69.50% | 15.60% | 5.67% | 7.09% | 2.13% | |
| | 98 | 22 | 8 | 10 | 3 | 141 |

**Figure 4** Chart showing the number of responses which recorded an increase in pest numbers over a designated period of time.

We gathered staffing information by asking a series of questions to determine the person(s) responsible for IPM within the institution. Resolving variables such as departmental responses, the number of buildings on-site and location – both when constructing the questions and while analysing the results – proved somewhat difficult. When using the results to look more specifically at who is performing IPM at these institutions, it was noted that 93% of IPM responsibility for day-to-day activities are undertaken by collections staff. This group encompasses all those who work with collections (Fig. 3).

Multiple answers were allowed to include staff with diverse responsibilities across their institutions. These data demonstrate that, unsurprisingly, the majority of IPM responsibility is carried out by conservation and collections management staff with little involvement by staff from other departments. It is interesting to note the very small percentages of people, in roles other than collections, who play a part in IPM.

Our attempts to evaluate budgetary constraints and allocation of resources were investigated through a number of questions that focused on overall institutional budget and funds allocated for IPM work using a series of number ranges. We then attempted to correlate these data with specific questions about job responsibilities to understand where and how institutional allocations affect IPM activities. We also wanted to find out if there was a correlation between the type of institution, general annual budgets, and percentage of funding expended on pest management. However, the results were difficult to interpret because most respondents could not or did not report their institutional or departmental budgets. When we used these data to illustrate other trends by combining data from several questions, our ability to make definitive conclusions was hampered by the small numbers or responses in some datasets. Where budget information is available, funding for pest management activities appears to be low. Less well-funded institutions, even those with established IPM policies, have the lowest funding resources for IPM. From the data we can also see that for institutions with higher budgets for IPM, the percentage of those with IPM policies is correspondingly high at 90%.

Correlating budget with IPM responsibility revealed that institutions with the highest budgets are the most likely to have a dedicated IPM staff position, use certified pest contractors and have the highest percentages of staff with pest applicator licences. While institutions with a dedicated IPM position are rare, they seem to be concentrated among large institutions with generous IPM budgets. When these data are compared to institutional type, the graphs are remarkably similar, suggesting a gap in IPM awareness, budgetary allocations and pest control for specific types of institutions, such as libraries, archives and institutions with smaller collections (e.g. historic houses).

Another area explored in this survey was whether there were noticeable trends in pest populations. For simplicity, we categorised pests into six large groups:

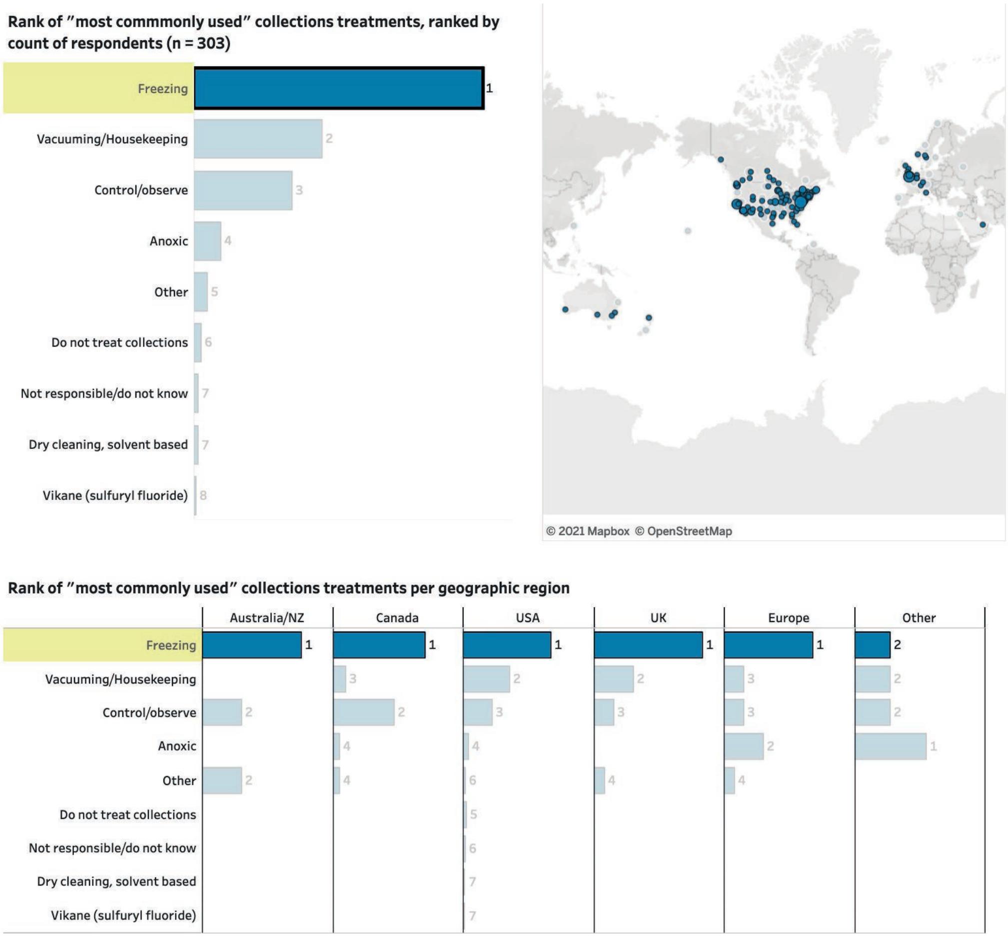


**Figure 5** Most used treatment method by count and geographic distribution.

moths, damaging beetles, silverfish and booklice, nuisance insects, termites and rodents. Analysing the results was complicated and compromised by how questions were phrased: the ranges we chose for pest responses had the potential for very different numerical results depending on which part of the range was actually used to represent the final numerical value. This created very large 'error bars' in the charted comparisons, making them difficult to interpret. When we requested observational data about our six groups over a staggered time frame, the most common response was that there were insufficient data, perhaps because we asked for observation and remembrance rather than use of actual data (Fig. 4). Increases in the 0–1 year category were the largest for each of the six groups. While slight, there does seem to be an increase in pest captures for each pest category, with perhaps a larger increase for nuisance pests. Whether this is an artefact of increased vigilance or better memory for most recent pest evidence cannot be ascertained.

We also collected data on treatments used on collections, within buildings and exterior spaces. These questions were phrased in a way that permitted respondents to choose multiple answers, allowing for different kinds of responses. Several interesting trends resulted. For all institutions, low temperature (or freezing) was reported as the most commonly used treatment, both by count and geographic distribution (Fig. 5). In contrast, the response for anoxia was very low with significant differences between geographical regions. Geographic distribution is perhaps skewed by governmental regulations. It is notable that there were no reports of the use of anoxic gases in Australia or the UK; the highest percentages were recorded from Canada and the US. When we related treatment choices to budgetary frameworks, the situation became somewhat more complex. Data correlating treatments used with budget (for IPM and institutional) revealed that institutions with higher budgetary frameworks are more inclined to

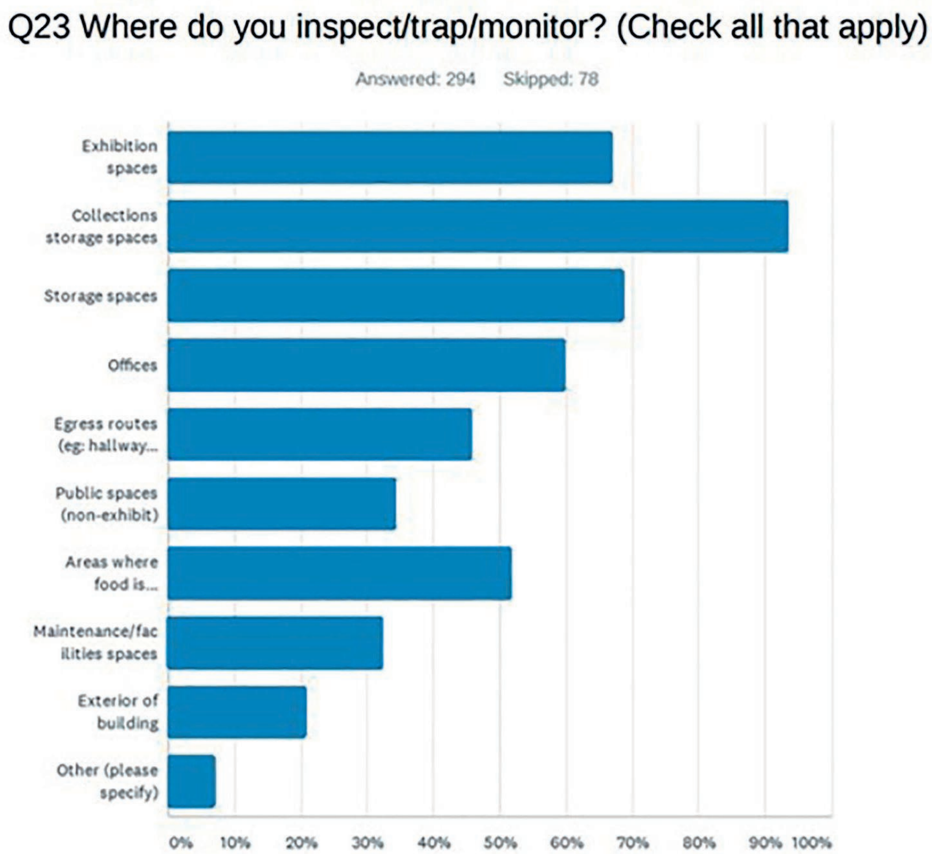


**Figure 6** Chart showing the locations of the insects being monitored.

use anoxia, suggesting that there is a financial barrier to performing these treatments.

For indoor spaces, trapping, use of chemical dusts, desiccants and chemical baits were most common, with lethal traps leading at approximately 82%. Again, when the type of treatment was correlated with budget, the trends indicated that lower funded institutions did not report the use of chemical baits and desiccants as frequently as those with higher funds. Institutions with funding in the middle ranges (25K to 100K for institutional and 25K to 50K for IPM funding) reported the use of chemical products, suggesting the employment of contracted pest management services to treat these areas. These results were especially significant for smaller institutions: those who reported that they had no knowledge about the treatment of indoor spaces were approximately equivalent to institutions whose IPM funding ranged from less than 10K to 25K. Conversely, almost 50% of respondents indicated either that their institution never treats external areas or that they were not responsible for this activity, suggesting that the importance of exclusion strategies needs to be emphasised in awareness training. This view is supported by survey results indicating the locations where inspection/monitoring takes place (Fig. 6). Areas with the lowest responses include egress routes, public spaces, maintenance/facilities spaces and building exteriors.

When asked how respondents received training, the most common answers were online resources and relevant literature, followed by in-house training and IPM conferences/workshops/seminars. The number of respondents indicating higher education/certification in IPM totalled approximately 12%. When we correlated the use of the MuseumPests.net site with institutional budget, a clear relationship could be seen between budget size and awareness, indicating that we need to make more effort to reach smaller, lower funded institutions. These data reinforced our assumptions that institutions with lower budgets are less likely to use MuseumPests.net. It is unclear if this is due to lack of resources or a lack of awareness of this tool. When combined with the low number of respondents from some types of institutions, this represents an opportunity for investment in outreach and the development of resources to target smaller or more sparsely staffed institutions.

## Conclusions

Using the data gathered from this survey, we can conclude that IPM is being used widely as the means of controlling pest populations. Many institutions have invested time and effort in creating policies, procedures and guidelines to limit pest activity; 65% have established policies and approximately 95% of institutions indicated that they monitor or trap pests. These figures suggest that the fundamental principles of IPM have become an accepted standard in collections care. In addition, it was also found that:

- Less well-funded institutions seem to spend the least on IPM.
- Although educational opportunities for information on IPM in the cultural heritage sector have increased with the growth of online resources, there are few museum professionals who are educated in pest management at an academic or licenced level.
- Low temperature is the predominant treatment choice for pest control of collections. Use of anoxia seems to have geographical and fiscal limitations.
- Funding for IPM activities still appears to be low. Institutions with dedicated IPM positions are rare and are concentrated in institutions with large budgets for IPM.
- IPM activities are performed mainly by collections staff. However, some data show that institutions with mid-sized budgets may be contracting out their IPM needs, especially for the treatment of indoor non-collection and outdoor perimeter areas.
- A large percentage of staff do not seem to be aware of IPM activities, indicating a knowledge gap that may be related to either sharing of administrative knowledge about institution-wide activities and/or a general lack of knowledge concerning the importance of exclusion in IPM.
- From the data we were unable to draw any irrefutable conclusions about increases or decreases in pest activity or whether IPM is having a positive impact in controlling pest populations in cultural heritage collections.

## Acknowledgements

We would like to thank all those that took part in the survey.

## Notes

1. See https://museumpests.net/.
2. This work has not been published.

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# Warrang/Sydney IPM Group: a regional-specific digital collaborative forum

Jessica Gray and Rehan Scharenguivel

**ABSTRACT** The varied ecologies and climates across Australia have led Australian integrated pest management (IPM) practitioners to adapt research developed in the northern hemisphere to fit regional-specific challenges. The Warrang/Sydney IPM group is a regional-specific digital collaborative forum developed to address these local challenges. Understanding Sydney's subtropical climate and ecological variance is crucial for the city's IPM practitioners. Developing a collaborative approach between institutions increases the sustainability of our IPM programmes. We have created a digital platform that acts as a central repository for sharing practices and information on IPM. The use of digital collaboration tools is found across all fields of academia, including cultural heritage institutions: our approach was informed by research into the methodologies of their use and trialling a variety of tools. Online regional-specific collaborative groups are by nature dynamic and foster long-term knowledge building. The collation of data across institutions is a sustainable approach for sharing individual knowledge and supporting best practice IPM across a specific region.

**KEYWORDS** IPM; museum; communication; networks; digital; collaboration; regional

## Introduction

The Warrang/Sydney integrated pest management (IPM) group, affectionately known as 'Pest Buds', provides an online collaborative forum for IPM coordinators in Sydney, Australia. The need for a specific geography-based group is driven by the regional challenges of the area and the difficulties of bridging the distance between Australia and northern hemisphere-based suppliers. These challenges led us to create an online platform designed to tackle IPM issues on a local level. A variety of platforms was investigated and compared to find the most suitable for the group. Overall, the Warrang/Sydney IPM group has provided local cultural heritage practitioners with a tool they can use to foster discussion of local issues and connect with their colleagues, creating a hive mind approach to the unique challenges Australia faces.

## Specific challenges

### Distance

Australia is geographically isolated from the academic and professional circles of Europe and North America. This creates difficulties with communication and differences in professional challenges and conservation methodologies. The challenges faced in an Australian regional context are not always represented in the body of literature and research in the worldwide conservation community. This isolation was exemplified by the production and shipping difficulties during the COVID-19 outbreak, when many suppliers reduced or stopped shipping to Australia altogether due to the unpredictable logistics experienced during the pandemic (Gibson *et al.* 2020: 199). This resulted in local cultural heritage practitioners being unable to use certain treatment methodologies that are part of low-chemical IPM practices, such as long-term anoxic bag treatments using Escal and RP-System.

### Sydney climate

Australia has wide climatic variance across the continent ranging from temperate, subtropical, tropical and hot arid (Heritage Collections Council 2002: 48). Sydney sits within a subtropical and temperate climate range, meaning that it faces a unique set of challenges when compared to other areas (De Dear *et al*. 2018: 1297). Some aspects of Sydney's climate that impact IPM practices include:

- Relatively even rainfall throughout the year and a coastal environment which creates a higher average humidity thereby providing a favourable environment for insects (Child 2007: 59).
- Moderate temperatures throughout the year with hot summers and mild winters which affect insect growth, behaviour and breeding cycles (Brimblecombe and Lankester 2013: 19–20).

### Climate change

On a global scale, climate change is affecting all museums and galleries across the world, however, regional challenges must also be considered. The ways in which these changes are tackled require regional-international collaboration. Climate change has already been attributed to an increase in extreme weather events in Australia, which has caused major bushfires and flooding (CSIRO 2020). During these disaster situations it is important to take a localised approach to support and find local mitigation strategies. In future years, climate change is likely to result in increasing climatic variances that will lead to changes in insect patterns, as shown overseas, with similar changes also likely to occur in Sydney (Brimblecombe and Lankester 2013: 20).

### Biodiversity

Sydney's climate directly affects the biodiversity of the region, impacting pest species and life-cycle patterns. In the Sydney region, some insects do not enter diapause during the winter period as temperatures remain mild and do not drop significantly (Child 2007: 58). This impacts pest management practices as pest activity requires attentive monitoring and control throughout the year. Australia has a unique biodiversity that affects the pest species found in a cultural heritage context. Many native species that affect Australian collections have not been sufficiently studied or researched. This can lead to difficulties in identifying Australian species found in collection spaces and in determining their risk to collections. Regional networks assist in contextualising pest species that may not be known to cultural heritage environments elsewhere.

### Biosecurity

Cultural heritage institutions in Australia face unique challenges due to the strict biosecurity legislation on imports and exports. The Australian government's Australian Quarantine and Inspection Service (AQIS) oversees biosecurity and dictates quarantine and pest eradication methods for import and export. AQIS allow four prescribed biosecurity treatment options:

- Heat treatment
- Methyl bromide fumigation
- Sulfuryl fluoride fumigation
- Insecticide (Department of Agriculture, Water and the Environment 2021)

This legal framework for biosecurity presents a novel challenge for Australian cultural heritage institutions when acquiring objects or receiving loans from international sources, as these materials are subject to import regulation and the prescribed methods can be destructive for collection material (Borig 2011: 105).

## Group development

Predominantly a natural history and cultural museum, the Australian Museum has many cultural and historic materials that are vulnerable to pests, necessitating a

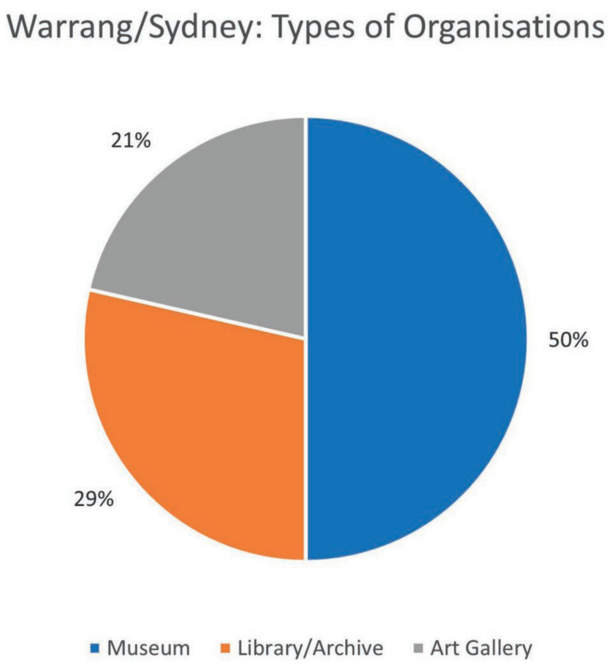


**Figure 1** Chart showing the different types of organisation by group based on percentage.

long-standing and active IPM programme. Continuing development of the programme requires collaboration and knowledge sharing between the different cultural heritage institutions of Sydney and has facilitated collaboration through methodologies, source materials and a shared-knowledge base. We determined that creating an ongoing platform accessible to a network of Sydney IPM practitioners would encourage this form of collaboration across institutions. Prior to the creation of this platform, we researched effective collaboration methodologies, which became increasingly important throughout the COVID-19 lockdowns, as well as platforms that would enable archival storage of discussions, promote collaboration and facilitate ease of use.

## Digital collaboration

Collaboration between institutions is not new and benefits can be seen in many individual programmes throughout cultural heritage management (Bakhri 2021; Tanackovic and Badurina 2009). On an international scale, sharing resources on pest management has proved to be highly useful to resolving complex problems and finding solutions within this niche field (Arenstein *et al*. 2008). These ideas can be implemented at a local scale to deal with ongoing and specific local issues. This problem-solving method has also been shown to be advantageous within other research fields, such as universities that collaborate to share analytics and research knowledge on a local level in order to resolve wider scale issues (Van Noorden 2014: 126). The hive mind approach builds on individual experiences and research to solve problems that may exist within individual organisations as well as those shared across a region.

During the COVID-19 pandemic, in-person networking opportunities declined and IPM-specific online events were difficult to coordinate with a smaller number of cultural heritage professionals compared to the northern hemisphere. This was due to the lack of pest management-specific knowledge-sharing groups within the Oceanic region.

## Platforms

We investigated several different options to evaluate an appropriate platform for engagement. A short summary of these investigations is given below.

### In-person

Face-to-face meetings are important in developing close ties in working together and fostering friendships (Dalkir 2018: 119). This option provides opportunities to openly discuss ideas and solve problems together. However, organising times and locations that suit in-person meetings can create logistical challenges and hurdles. Face-to-face meetings require someone to record and document the discussions. Additionally, these types of meeting could not safely take place during the COVID-19 pandemic. These meetings can provide a supplement to online discussion as they foster a sense of community. However, keeping primary contact within the virtual sphere alleviated the outlined issues.

### Email

Email is a standard day-to-day communication platform for most work-related discussions. This format

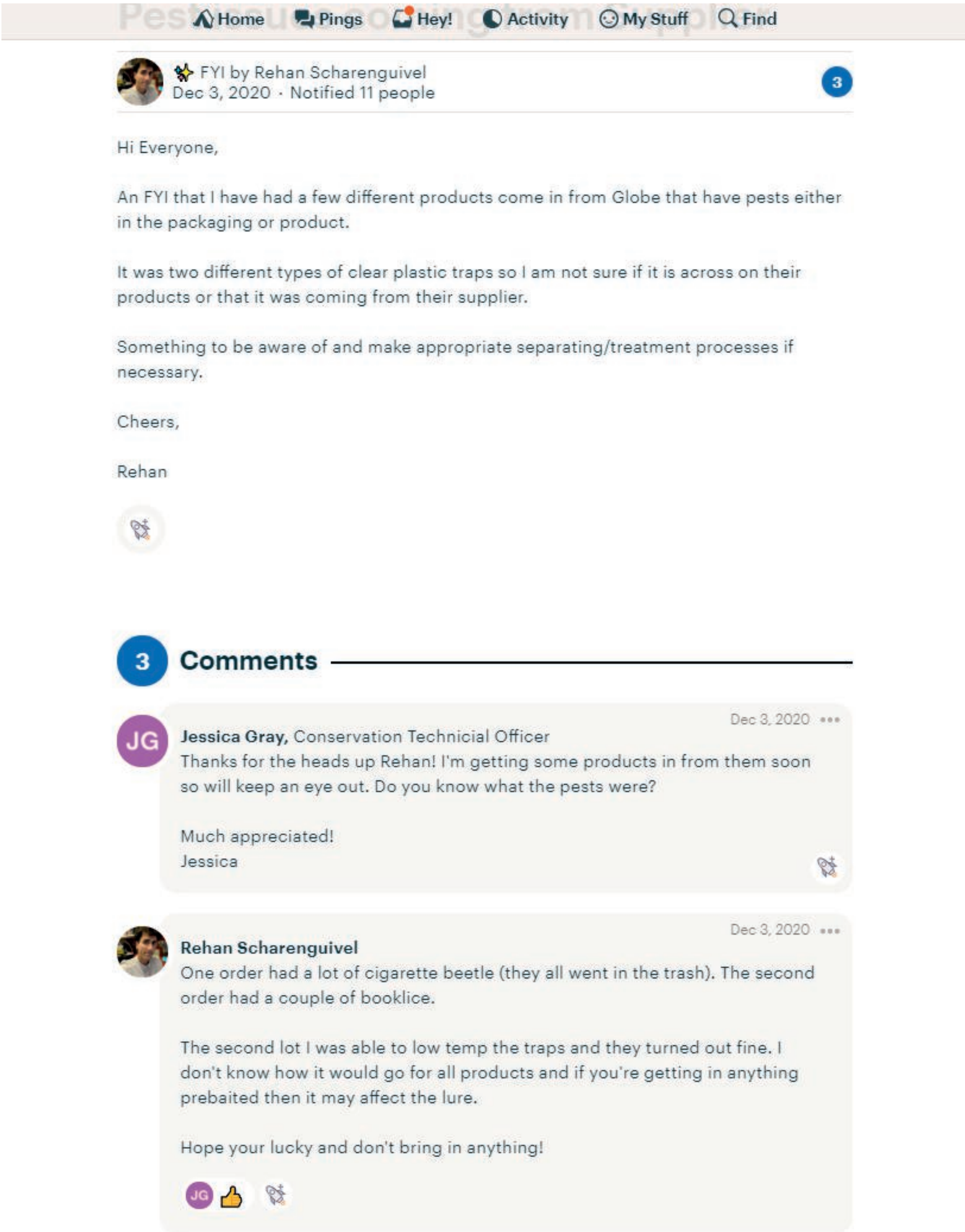


**Figure 2** Screenshot of Basecamp showing the discussion of supplier issues.

is used successfully for a variety of museum-based discussion groups and provides collaboration on an international scale (Christodulaki and Sloggett 2017: 358). On a regional scale, the drawbacks include inherently limiting communication to the correspondents involved and difficulties in fostering a sense of community; communication through email presents a sensation of reduced social culpability (Sklaveniti 2018: 7). While contact details for local cultural heritage practitioners are crucial in creating personal connections, other platforms offer greater well-rounded formats for deeper discussions.

## Microsoft Teams

Microsoft Teams is a popular platform for internal organisational communications and meetings. During the pandemic, digital platforms became commonplace in fostering a workplace environment during isolation. The Teams platform is in use across several

Sydney cultural heritage institutions, however, logistically Teams requires one organisation to act as host, introducing difficulties for guest users to successfully interact. Guest accounts have limited functionality such as being unable to upload files and create meetings, which then results in an undue hierarchy in an informal group.

### Basecamp

Basecamp is a project management web application with the primary purpose of sharing ideas and collaborative working. It has been widely used by conservators in Australia to communicate across institutions for its easy-to-use format, data storage and search capabilities. The platform allows for open-thread discussions and sharing of files, as well as individual direct messages. Users can also have notifications sent directly to their email accounts and reply through email if that is their preference. The free version of Basecamp does have limitations on the number of users, which may impact its suitability for large regions and informal groups.

After this preliminary research into the benefits and limitations of these platforms, it was decided that Basecamp would be the most suitable for a Sydney-based group of IPM practitioners. It was chosen because it provides archival storage of discussions, promotes collaboration and facilitates ease of use. The system, created between the Australian Museum and the Museum of Applied Arts and Sciences, includes all the government-funded cultural heritage institutions of Sydney (Fig. 1).

## Basecamp functionality

The two main components of Basecamp that have been utilised by the Warrang/Sydney IPM group are the message board and the documents and files folder. The message board is the primary communications function – anyone in the group can post a message and other users are able to comment, creating discussion threads attached to the post (Fig. 2). The documents and files folder is a separate page that allows users to upload files and share resources. It provides quick access to these resources without having to scroll through posts on the message board in order to locate them.

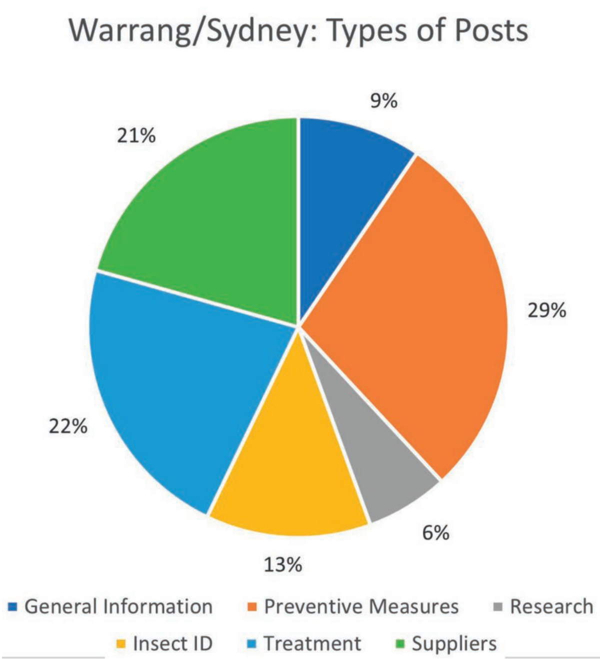


**Figure 3** Chart showing the different types of posts as of August 2021.

## Basecamp in practice

The group formed in the middle of 2020 and although still in its infancy, has become a virtual space for IPM practitioners in Sydney to share insights and ask questions on a variety of topics (Fig. 3). Some of the tangible benefits arising from the group include:

- Sharing resources and methodologies for a damp-heat pest eradication method using a humidity-controlled heat chamber.
- Providing information on suppliers of anoxic treatment materials, including high gas barrier film and different options for oxygen scavengers.
- Policy sharing with the benefit of the material being archived in the system for ongoing access.
- Sharing information on the presence and number of high-risk pests to confirm if they are localised, alert others to the problem, and build knowledge on pest activity in the region.

Expanding on this, with a specific example relating to supply issues within the Sydney context, the lack of suppliers for cultural heritage-specific materials and pest management products has been a commonplace discussion thread, particularly when a supplier has an issue that might affect a museum. This occurred recently when one pest supplier accidentally sent out material infested with storage pests due to an unknown infestation at its warehouse. This information was shared on the Basecamp platform alerting other practitioners, and led to discussions about alternative suppliers until the issue could be resolved.

## Conclusions

The Warrang/Sydney IPM group provides a much-needed online collaboration network for local cultural heritage practitioners to problem solve as a group and to share solutions. Cultural heritage institutions in Sydney face many unique challenges but collaborating on a local level builds region-specific knowledge on local IPM solutions and ensures that we are providing the best IPM practice for the collections for which we care.

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# From pamphlets to websites: the evolution of IPM resource material

David Pinniger, Amy Crossman and Jane Thompson Webb

**ABSTRACT** The first reference to what became known as integrated pest management (IPM) in museums was *Getting the Bugs Out* by Phillip Ward in 1976. Although of limited availability, it was a template for later and more comprehensive publications. Museum IPM papers started to appear in conferences of the International Institute of Conservation (IIC), International Council of Museums (ICOM) and Institute of Conservation (Icon), and the first international museum IPM conference was held in Sweden in 1998 followed by the first Pest Odyssey conference in London 2001. The proceedings of this and subsequent conferences in London, Vienna and Stockholm provide an incomparable resource covering all aspects of IPM. Other sources of pest information include posters and identification cards. The value of the poster *A Helpful Guide to Insect Pests Found in Historic Houses and Museums* produced by English Heritage in 1998 and completely revised in 2021 is shown by 25,000 copies distributed to more than 20 countries. The rapid development of computer-based resources has transformed our information base. 'What's Eating Your Collection.com', revised in 2020, is a comprehensive web-based IPM resource and there are now web-based museum IPM resources in other countries. This volume presents the proceedings of the first online heritage IPM conference, and perhaps this will be the way forward in the future for creating resources and sharing information.

**KEYWORDS** IPM; integrated pest management; heritage pests; museums

## Introduction: historical sources

Some of the first publications on pests were essentially to provide advice on preserving objects when they were collected. The great collectors of the 18th and early 19th century faced very long sea journeys and wished to bring their specimens home intact. John Coakley Lettsom's *The Naturalist's and Traveller's Companion*, first published in 1772, gives instructions on the preservation of taxidermy and what we now call ethnographic material. Charles Darwin was probably one of the most famous of these collectors to follow his advice and, thanks to mercury and arsenic, most of his collections are still available for study today.

A book by Montague Browne called *Practical Taxidermy* was published in 1884 and became the standard taxidermy manual for many years until well into the 20th century. Among many recipes recommended for preventing insect attack are 'Browne's arsenical soap' and 'Waterlow's corrosive sublimate' which, he warns, is dangerous as it is based on mercuric chloride. Other 'anti-insect nostrums' include tobacco and sulphur but he adds a telling comment relating to attack by *Anthrenus* sp.: 'Do not rely on them (chemicals), trust only to light and constant supervision' (Fig. 1).

Tobacco powder was also used in the 19th century to protect Egyptian mummies (Buckland and Panagiotakopulu 2001) and later the toxic ingredient, nicotine, was widely used as an insecticide. Other published anti-pest advice was included in manuals on managing a household. Mrs Isabella Beeton's *Book*


**Figure 1** Victorian case of beetles damaged by *Anthrenus verbasci* (© 2021 DBP Entomology).

*of Household Management*, first published in 1861, with many later editions, contains recipes and remedies to control clothes moths including camphor, cedarwood, tobacco and bog myrtle. Prevention of moths in wardrobes and drawers was achieved by soaking linen in turpentine, the smell of which was probably guaranteed to repel moths and anything else – including people.

## Specific publications on household and stored food pests

Before the specialist publications on museum pests, sources of accurate information on the pests could only be found in other areas such as household and stored food products. Two early publications which concentrate on specific pests were published by the British Museum (Natural History) in the 1930s: *Clothes Moths and House Moths* (Austin and McKenny Hughes 1932) (Fig. 2) and *Furniture Beetles* (Gahan 1932). These are the first publications we have found which contain good illustrations of the insects and the damage they cause with accurate and detailed information on the insect pest, its biology, ecology and control. Interestingly, the clothes moth booklet recommends heat as a method of control. It also advocates fumigation with hydrogen cyanide or carbon disulphide, which were in regular use 100 years ago but would not be acceptable today.

A key publication was Busvine's *Insects and Hygiene* first published in 1951 and with many later editions (Busvine 1986). This book, which remains a useful source of information, covers a wide range of pests including a chapter on wood-boring insects and one on clothes moths and carpet beetles. Like many books on pests written in the 1950s and 60s, it starts with control measures before dealing with the pests and their identification. Together with Busvine, the principal guide to insect identification was *Common Insect Pests of Stored Food Products* first published by Hinton and Corbet in 1943, with the last revised edition by Mound in 1989. This book has never been replaced and should be part of every urban entomologist's library. *Collins Guide to Wildlife in the House and Home* (Mourier and Winding 1973) was one of the first books to contain accurate illustrations of household pests in colour and is still a useful source of information on a wide range of cultural heritage pests (Fig. 3).

*Recognising Wood Rot and Insect Damage in Buildings*, originally published in 1987 by Bravery *et al.* from the Building Research Establishment was, and still is, one of the best guides to wood-boring insect pests and damage in the UK. It was completely revised in 2003 (same authors) and although now out of print, is available as a download.

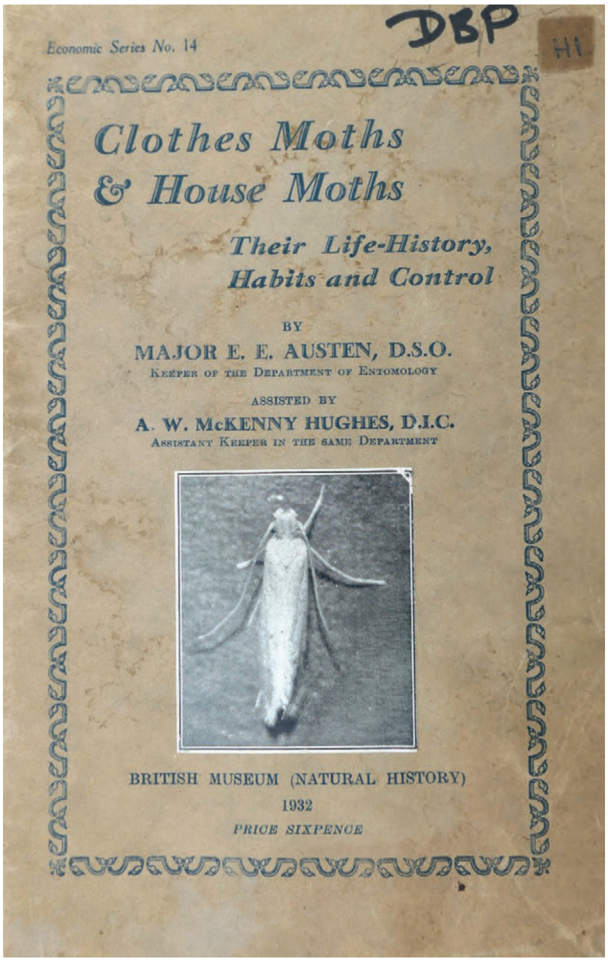


**Figure 2** *Clothes Moths and House Moths* BM (NH) 1932 booklet cover (© 2021 DBP Entomology).

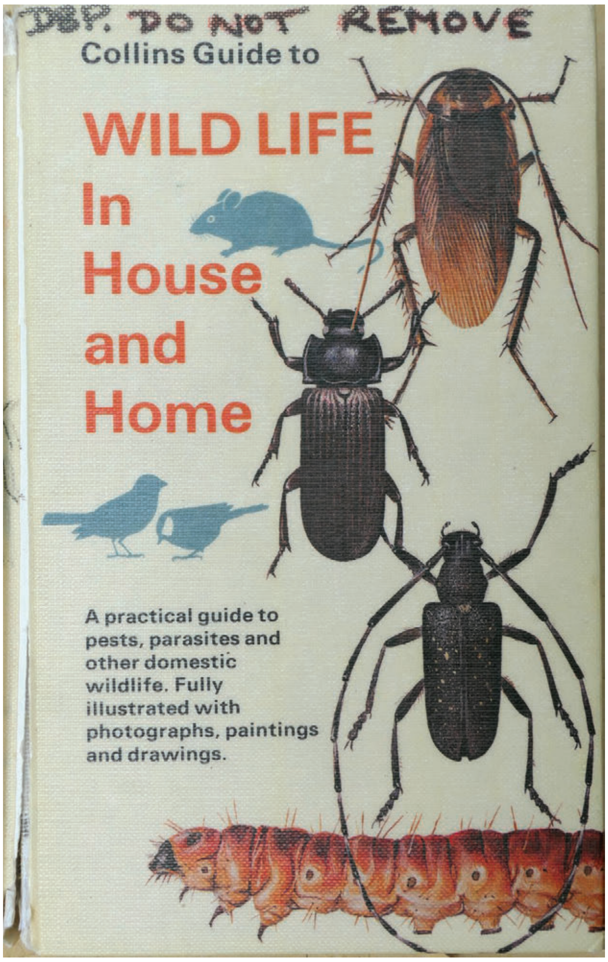


**Figure 3** *Collins Guide to Wildlife in House and Home* book cover (© 2021 DBP Entomology).

## Museum pest books

One of the first references to what became known as IPM in museums was *Getting the Bugs Out* by Phillip Ward, published by the British Columbia Provincial Museum in 1976. Although of limited availability, it was a template for later and more comprehensive publications such as: *A Guide to Museum Pest Control* (Zycherman and Schrock 1988); *Insect Pests in Museums* (Pinniger 1989); *Heritage Eaters* (Florian 1997); *Irish Indoor Insects* (O'Connor and Ashe 2000); *Pest Management in Museums, Archives and Historic Houses* (Pinniger 2001); *Pest Management: A Practical Guide* (Pinniger 2008); *Integrated Pest Management in Cultural Heritage* (Pinniger 2015); *Buggy Biz and Fluffy Stuff* (Brokerhof 2003); *Combatting Pests in Cultural Property* (Strang and Kigawa 2009); and *Pests in Houses Great and Small* (Pinniger and Lauder 2018). Pest books and booklets have also been published in many other languages, including Swedish (Akerlund 1991), Japanese (Yasutomi and Umeya 1995), French (Flieder and Capderou 1999) and German (Noldt and Michels 2007; Pinniger *et al*. 2016).

## Publications in journals and conference proceedings

Papers on museum pests first appeared in a range of non-museum scientific journals such as the *Journal of Stored Products Research* (Armes 1988) before being included in conservation journals such as *The Conservator* (Daniels 1997) and museum-related journals such as the *International Journal of Museum Management and Curatorship* (Rossol and Jessup 1996). There was a similar picture with papers presented at international conferences, with some key papers in the *Proceedings of the International*


**Figure 4** (a) Japanese insect cards and (b) 'Save the Museum' cards (© 2021 DBP Entomology).

*Conference on Insect Pests in the Urban Environment* (Cox *et al.* 1996) and the *International Conference on Biodeterioration of Cultural Property* (Strang 1995).

Museum IPM papers then started to appear in cultural heritage-related conferences of the International Institute for Conservation (Child and Pinniger 1994), International Council of Museums, Committee for Conservation (Brokerhof 1999) and the Institute of Conservation (Gilberg 1990). The first international conference dedicated to museum IPM was held in Sweden in 1998 and was followed by the first Pest Odyssey conference in London in 2001 (Kingsley *et al.* 2001). The published proceedings of this and subsequent conferences in London (Winsor *et al.* 2011), Vienna (Querner *et al.* 2013) and Stockholm (Nilsen and Rossipal 2019) provide an incomparable resource covering all aspects of IPM from initial research to practical case studies.

## Posters, leaflets and cards

More accessible information on pests has been provided by posters, leaflets and identification cards. All the earlier sources which included museum pests were produced for use in food storage such as *Insects in Food Stores* (MAFF 1993) or urban pest control such as *An A–Z of Pests in Your Home* (BPCA 2006). Many pest-related leaflets and information sheets have been produced over the years but most tend to be ephemeral and difficult to find. A series of leaflets produced by the British Library Preservation Advisory Centre included *Pests in Paper-based Collections* (Pinniger 2012). This has since been revised (2021) and is available online, but not as a printed version.

The value of the poster, *A Helpful Guide to Insect Pests Found in Historic Houses and Museums*, first produced by English Heritage in 1998, and completely revised in 2008, is shown by the print run of over 25,000 copies distributed to more than 20 countries worldwide over a 10-year period. A completely new version of this poster, *Insect Pests in Historic Houses and Museums*, was produced in 2021 and is available in print form or online (English Heritage 2021). Card games are a great idea to make learning about pests more entertaining. As far as we know, the first set was produced by Kigawa and Strang in 2001 for use in IPM training in Japan (Fig. 4a). In 2021, a set of useful and informative cards called 'Save the Museum', which feature all the key insects, was produced by South West Museum Development, funded by Historic England (Fig. 4b).

## Online resources

Although guides on paper have a valued and continued place, it is the rapid development of computer-based resources which have recently transformed our information base. 'What's Eating Your Collection?' (Fig. 5) was originally produced as a CD to provide a follow-up resource to IPM training. As with all CD-based data, it was inflexible and time-consuming to update and so was revised in 2009 to create a web-based resource with a guide to pest identification and IPM practice. Many new

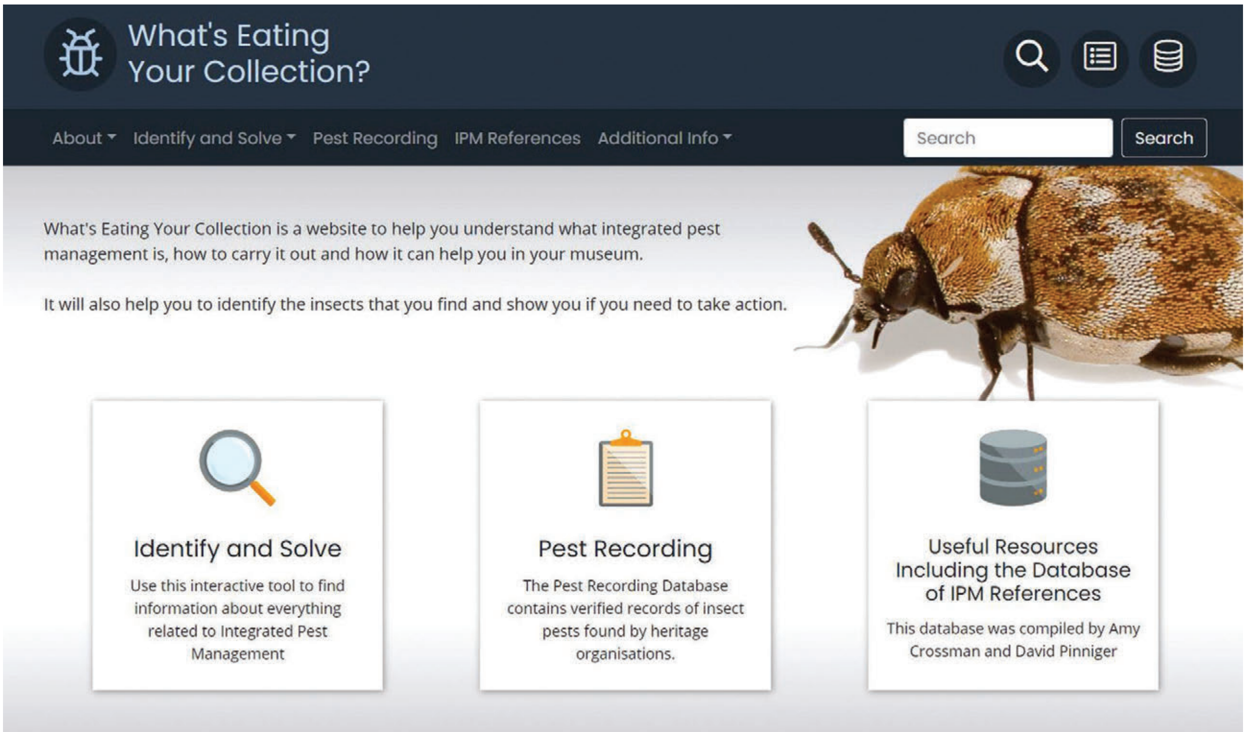


**Figure 5** Screenshot: What's Eating Your Collection?

images of pests and damage have been added since then as well as new features including an IPM reference database (Thompson Webb 2020).

There is still some work to do, including expanding the functionality of the mapping of pests which would allow international recorders to add information. Sources of funding are very important in order to create and then maintain a website: the new version of 'What's Eating Your Collection?' could not have proceeded without the financial support of cultural heritage organisations in the UK. There are now web-based museum IPM resources in the USA, Germany, France and Japan, a selection of which are listed at the end of this paper.

## The future

The year 2021 heralded the first online cultural heritage IPM conference *A Pest Odyssey – The Next Generation* that allowed far more people to participate. Although this decision was made due to the global COVID-19 pandemic, perhaps this is indeed the way forward in the future for creating more accessible resources and sharing information. However, this brief review should serve to emphasise that there is still great value in the printed word contained in past publications, which are now being made more accessible by these online resources.

## Disclaimer

This paper is a very personal view of the subject and reflects the key sources which have helped the authors in many ways. Many other important sources have been omitted due to space limitations.

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# Debugging instructions for easy empowering of IPM

Christa Deacy-Quinn

**ABSTRACT** This paper describes the methodologies and strategies that I have found most useful in developing a successful integrated pest management (IPM) program for a small museum or historic building. Recruiting museum colleagues to participate and training student employees in IPM involves setting and celebrating small and actionable goals. Utilizing knowledge and experience that does not involve pests eases the inexperienced towards a successful IPM practice. Providing concrete examples, person-to-person mentoring, and easy to read training materials encourages and empowers individuals to lead IPM efforts.

**KEYWORDS** Training; accessible; manual

## 'I have no idea what I am doing! How do I teach anyone else?'

My first professional experience with pests was almost 30 years ago when I was employed at the University of Illinois in Urbana-Champaign in the World Heritage Museum, the predecessor institution to the Spurlock Museum of World Cultures where I now work. The original museum was located in a historic multi-use building on the campus. As Collections Manager, my responsibility was the preservation and care of the artifact collection. My museum studies training and professional experience was object oriented and did not pay much attention to the management of the creatures that might damage them. The building itself, including the museum, was heavily infested with a wide variety of pests, including mice, pigeons, German cockroaches (*Blattella germanica* Linnaeus, 1767), silverfish (*Lepisma saccharinum* Linnaeus, 1758) and varied carpet beetles (*Anthrenus verbasci* (Linnaeus, 1767)). Pest control, cleaning and repair of the building were performed by multiple different units on campus that did not communicate well either with each other or the museum. At that time, the only means used for pest control were pesticides – not just in and around the building, but on and near the artifacts themselves.

When I was first given this assignment, I was completely unaware of how to deal with insects, and I had no idea where to start. I did not have control over the pest management for any of the museum's spaces, but the director allowed me to limit access to the artifact storage spaces in order to end the use of pesticides there. As an introduction to the basics of integrated pest management (IPM), I found two books very helpful: *Insect Pests in Museums* (Pinniger 1989) and *A Guide to Museum Pest Control* (Zycherman and Schrock 1988).

As I became more familiar with aspects of IPM, it became clear that I needed to engage all staff members, as well as our 15–20 part-time undergraduate student workers, in learning how to deal with pests. My challenge was: how do I make training on this subject something that is interesting, simple and actionable? I could not ask them to read an entire book, so I decided to get them thinking about a number of basic activities that they could regularly perform: keeping an eye out for pests anywhere in the museum, watching for loose materials dropping off from any artifacts in the exhibit spaces and storage areas, and understanding which artifacts were susceptible to attack from pests (organic) and those which were not (inorganic).

In 2000, as we prepared to move into a new facility, the Spurlock Museum building, we faced an additional challenge – how to avoid the possibility of transferring any pests from our old to the new location. Artifacts were inspected for signs of pests before being packed. If there was a pest concern, students would bag the objects, and then freeze them for several weeks. Once removed from the freezer, the artifacts were vacuumed and packed ready for the move. The packed boxes were marked with a sticker if they contained objects composed of organic materials and an additional sticker if they had previously been infested. Thanks to the students' attention to detail, we did not translocate any pests to the new building.


**Figure 1** IPM kit (© The Spurlock Museum, University of Illinois at Urbana-Champaign 2021).

## New building, fresh plan

After moving to our new museum building, I was able to implement a much more robust IPM program, with policies and procedures that emphasized teamwork among the now-increased number of staff within the museum, teamwork that started with each employee signing a statement of commitment to museum IPM as part of on-boarding. In the statement, staff members agreed, among other things, to eat only in designated areas, use covered waste bins, report any pest sightings anywhere within or around the building, and if they were able, to catch and bag any observed pests (Fig. 1). The statement also emphasized the fact that if we all worked together, we could significantly reduce the number of pests in the museum, the danger to the collection and the need for pesticides.

Working with the museum's Information Technology specialist, I developed two FileMaker Pro databases to track both the types of pest issues occurring in the museum and their specific locations. Our new building provided us with an excellent opportunity to track and monitor pests as they first appeared on the scene. This monitoring became the key to detecting any potential pest-conducive conditions in the building. We set up approximately 75 traps around the three floors of the museum, and undergraduate students were trained to harvest the traps, identify the insects caught and input the data into the newly created databases.

During the early years of the Spurlock, I continued my studies on IPM through correspondence courses, my own observations and experimentation within the museum, and earned my Pest Management License for Structural Pest Control in 2005 and Mold Remediation Certification in 2013. As I learned more, I started to create a student training manual, which quickly became too long to be of much use to the students. It was clear that training all students to do different aspects of the IPM work was inefficient so we decided to create a dedicated position for a single student worker interested in specializing in IPM and willing to commit to 8–10 hours of work per week. Much of the student's time was spent harvesting and setting the traps, identifying pests, and inspecting incoming and existing artifact collections for pests. Regular inspections of the exhibits and the building as a whole for pests, dead insects and spiders' webs were also part of the job.

**Figure 2** Christa Deacy-Quinn (bottom right) teaching with specimens in 2010 (© The Spurlock Museum, University of Illinois at Urbana-Champaign 2021).

Training for the position initially included personal supervision and study of the museum's IPM manual, beginning with intensive one-on-one work identifying pests and inspection procedures. After about a month, the student was given more independence. It took about four months before the student was able to work fully independently and proficiently. However, this intensive training model proved to be unsustainable: I could not maintain this level of time investment as my other responsibilities grew. As a result, I added more information into the training manual as a backup when I was unavailable. It soon became apparent that the text-heavy manual was difficult for people to absorb, even when punctuated with graphics. I tasked the IPM students to investigate resources (webpages, books and articles) that they found helpful, and saved these for reference and future training. However, in general, real-life examples proved to be the best teacher. Thus, one of the first activities I set each new IPM student was to perform an inspection of the museum's mechanical room. This task was an excellent way to introduce students to the importance of paying close attention to detail, to help them learn how to scan a space comprehensively from side-to-side and top-to-bottom, and how to use a flashlight to control the direction of lighting to better seek out tiny signs of pest activity.

As many of our IPM students became very proficient during their years working with us, they took on the responsibility for the primary training of their successors during their final months at work (Fig. 2). I also created a collection of common invertebrate specimens that could be compared to those found in traps (Fig. 3), a group of pest-damaged objects to help students and staff recognize signs of pest infestation, as well as examples of identified frass and droppings.

## Evaluating the Spurlock program

As the Spurlock's IPM program continued to develop, I began to receive requests to teach workshops at the regional, state, national and international levels, and

**Figure 3** Insect specimen, frass and dropping collections (© The Spurlock Museum, University of Illinois at Urbana-Champaign 2021).

have done so now for over 375 preservation specialists. I also received invitations to consult on IPM issues with other museums, historic houses and similar institutions. As a consequence, it seemed appropriate to try to get a professional, outside evaluation of the program before disseminating my ideas extensively to others. Consequently, the museum invited the independent, non-profit group, Green Shield Certified, operated by the IPM Institute of North America to undertake their certification process in 2012. Following their extensive inspection of our practices, we became the first museum in the United States to be awarded the Green Shield Certification. With that stamp of approval, I felt confident about teaching our program to others. Locally, we were able to present the museum as a model for IPM to the rest of the university, and eventually the institution as a whole dramatically reduced its use of pesticide applications, and instead switched to the more progressive IPM procedures.

I have been able to become a significant influence within the University of Illinois for system-wide changes in its pest management programs. I serve on the university's Integrated Pest Management Working Group, in which we work on a wide range of issues, and I also provide lectures, demonstrations and workshops for departments, alumni events and other committees. I teach graduate level courses in artifact preservation in the university's School of Information Sciences. I also add my voice on campus and in local print and broadcast media to emphasize instances of our work on artifact preservation to the general public.

## Now to empower others

Over the years of teaching at workshops and conferences on the topics of collections management and

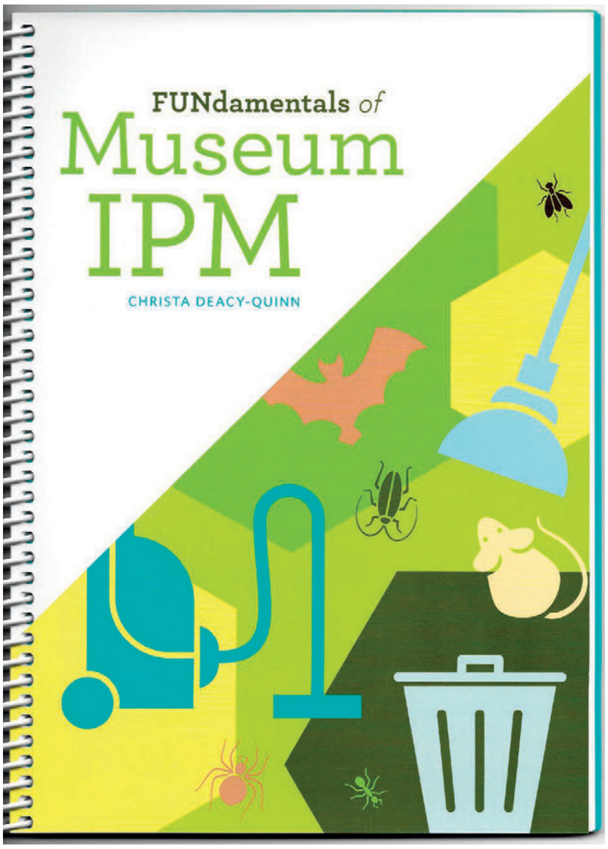


**Figure 4** *FUNdamentals of Museum IPM* cover (© Christa Deacy-Quinn 2021).

preservation, I have continually pondered on how best to introduce IPM to peers and aspiring museum professionals. Most museums do not have large IPM budgets or dedicated positions for IPM specialists. Administrators of most museums need information which is accessible to non-specialists and that will guide them toward effective, but inexpensive and simple ways to minimize the damaging effects of pests on their collections. Many of the wonderful resources that are available now have been geared towards those who are already familiar with basic IPM methodologies. It had been my goal in teaching and workshops to focus on the types of practices that would be most beneficial to small museums and historical buildings. In 2019, this goal led to the publication of *FUNdamentals of Museum IPM* (Fig. 4) a manual specifically intended for museums without professional IPM staff members (Deacy-Quinn 2019).

Thanks to a generous grant from the North Central IPM Center, the book is available free of charge to those requesting it. Since it became available in December 2019, over 325 hard copies have been ordered. The free online PDF version is also

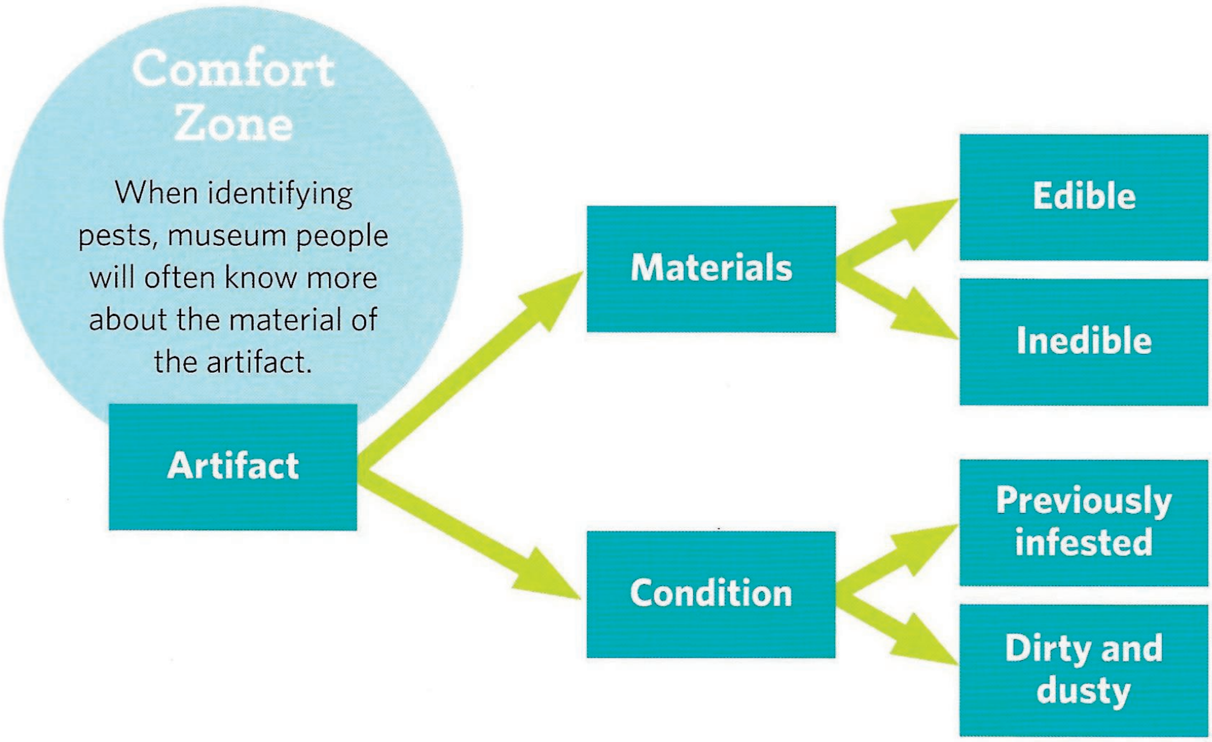


**Figure 5** Infographic page 19 from *FUNdamentals of Museum IPM* (© Christa Deacy-Quinn 2021).

available: as of May 2021 has been downloaded over 880 times by cultural heritage-collecting institutions from all 50 states in the United States as well as 55 other countries. The basic thrust of the book is simple: the foundation of IPM is good housekeeping to reduce the potential risk of infestation. A surprising amount of problems can be eliminated by simply making sure the building is clean, sealed and clutter-free. For example, when we deep cleaned our museum, we reduced the occurrence of dermestid pests by 80%. I enable readers to trust and use the knowledge they have about their own collections to assess pest risk; for example, the recognition that organic objects are at a higher probability for pest attack than inorganic objects. A number of infographics and decision flow charts are provided in the book (Fig. 5) a method that I, as a person with a learning disability, have found very helpful.

I have also encouraged enthusiasm towards the concept of IPM, and the importance of celebrating the small wins, since IPM is a cumulative battle. I also emphasize the significance of keeping calm: no building will ever be pest-free, and the discovery of one pest is not necessarily indicative of a major infestation: even if many pests are found there will still be time to react.

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# A collaborative approach to developing an IPM programme in Myanmar

Amy Crossman

**ABSTRACT** The development of integrated pest management (IPM) within the Myanmar cultural heritage sector is in its early stages. This paper outlines the origins of IPM in Myanmar, examining the role of training provision for capacity building, considering both the taught aspect and its practical application. The journey towards achieving an integrated approach to IPM in museums across Myanmar's vast geographic expanse and varied climatic conditions is detailed. Two general training sessions initiated by the British Council in preventive conservation identified the threat of pest attack as a priority area for further training, paving the way for the final dedicated IPM training workshop. Pilot monitoring and trapping programmes have been instigated in three of Myanmar's museums, yielding some interesting results. It is clear that the occurrence of less familiar insect pests – such as *Gastrallus indicus* Reitter, 1913, the Indian bookworm beetle – means that the need for specialist entomological support is essential. As IPM pervades so many collection care activities, it was found to be an effective method to reinforce wider concepts of preventive conservation within the training. A collaborative approach to IPM training was successful in gaining the interest and attention of all staff and engaging them with wider preventive conservation issues.

**KEYWORDS** Soft diplomacy; integrated pest management; IPM; identification; new species; *Gastrallus*; Indian bookworm beetle; Myanmar; preventive conservation; training

## The British Council's International Museum Academy Myanmar Programme

The British Council worked with the Myanmar museum sector to commission conservation training for Myanmar museum staff, in support of a wider capacity-building programme through the International Museum Academy (IMA) Myanmar. The programme was instigated as a response to the identified critical need for skills development in the wider museum sector, and the significant skills gap in conservation (British Council 2021a,b). The preventive conservation strand of the IMA programme was initiated in 2018. Further to the first two rounds of training in preventive conservation, integrated pest management (IPM) was identified and highlighted as a priority area for further training, complemented by collections management.

A skills assessment of the state of the conservation profession within Myanmar museums, training conservation needs for the country and recommendations for future training in conservation requirements were incorporated into the first two preventive conservation training sessions. Further to this, in collaboration with Myanmar authorities and to coincide with the International Council of Museums International Museum's Day 2019, 'Museums as Cultural Hubs: The Future of Tradition', the British Council convened a museums seminar day in May

2019 which was used as a platform to showcase IPM to staff at all levels in Myanmar museums. This was found to be a highly effective method of advocating and promoting the IPM message across the country, gaining significant buy-in from senior management. It was this that served as a mechanism to initiate the final specialist IPM training programme.

The programme, managed by the British Council, has been successful in achieving its goals. The impact of the training has been felt countrywide, with over 60 key museum professionals employed in conservation works from over 20 of Myanmar's museums having taken part in the training, enabling dissemination of knowledge to a greater number of people in their host institutions in the form of cascade training (British Council 2021a,b). A further seven delegates attended the in-depth, specialist IPM training workshop.

## Myanmar museums and pest risk

There is little known entomological data available on economic, domestic, agricultural, and urban insect pests, let alone the more niche insect pest threat posed to museums and cultural heritage in Myanmar both nationally and regionally. This, in combination with a lack of knowledge of the types and extent of collections held in Myanmar museums, made it difficult to determine pest risk prior to delivering training. It was a certainty that termites are present, however beyond this, little validated data exist: the closest obtainable to a museum context originated from domestic and office settings, but the data are limited and disparate in nature, and require formal verification. A clear opportunity to obtain and develop accurate and verifiable baseline data for museums was seen as key to furthering museum insect pest knowledge countrywide as well as formally identifying and determining pest risk.

## A risk-based approach to an IPM workshop

The specialist in-depth training workshop in IPM came about as a response to the two previous training sessions delivered in Myanmar in preventive conservation. Earlier training rounds focused on the broader topic of preventive conservation were delivered in March 2018 and January 2019. As IPM sits within a wider framework of preventive conservation, it was one component of a wider training programme: other specific areas included ethics and conservation principles, housekeeping, collections care and environmental management. Within this course there was a strong focus on capacity building and a 'train the trainer' element.

The final specialist IPM workshop, 'Integrated Pest Management: A Risk-based Approach to IPM', in October 2019, was devised having been identified by the British Council as a priority area for further training. This was delivered to seven delegates from five of Myanmar's museums at National Museum, Yangon, in October 2019, on the proviso they had attended the two earlier training sessions. The initial two preventive conservation training sessions laid the foundations for the final in-depth session and provided a sound knowledge base from which to work.

The three-day intensive IPM workshop was designed to encourage delegates to think critically about the level of pest risk posed to collections in their home organisations. Due to the dearth of available data on insect pest species, devising an IPM training programme suited to the needs of the country was challenging. The aim was to develop trapping and monitoring practices to generate the necessary datasets to inform targeted future practice, alongside the development and propagation of competency of sustainable IPM practice. Rather than focusing on treatment methodologies, the emphasis of the training was on identifying the issues faced as the first priority as opposed to advocating treatments.

Teaching was delivered via the provision of information, active learning, group discussion, planning and practical skills training. Initial training taught the core concepts, principles and theory of IPM alongside desk-based exercises designed to assist with planning for IPM at participants' home museums (Fig. 1). During the second preventive conservation training session, delegates were encouraged to implement learning within their own museums and asked to consider how they could start to actively implement IPM, taking into account its practical application as well as the development of


**Figure 1** Participants undertaking insect pest identification training (© 2021 Boothee Thaik Htun).


**Figure 2** Extract from the preventive conservation toolkit.

supporting policies and procedures as relevant to their collections and building structures.

In preparation for the specialist IPM workshop, three museums in different regions were selected to participate in pilot monitoring and trapping programmes. Delegates were asked to devise a trapping programme and deploy blunder and pheromone traps accordingly. The many unknowns surrounding pest species, incidence and influencing factors were built into the programme; this proved effective in eliciting discussion from participants on considerations particular to their collections. These exercises served as a useful mechanism in providing an insight into their museums and collections, allowing for adaptation of the training programme to better suit their needs and provoking discussions on unique issues associated with their organisations.

## Outcomes

Some real and tangible outcomes have resulted from the training including increased confidence and awareness in managing pest risk to collections. Museum staff from different museum functions

**Table 1** Insects found in Myanmar museums.

| Known pest | Potential pest (status unknown) | Non-collection pests |
|---|---|---|
| Indian bookworm beetle, *Gastrallus indicus* (larvae and adults) | Clothes moth, *Tineidae* (adult) | Long-necked ground beetle, *Colliurus* sp. (adult) |
| Carpet beetle, *Anthrenus* sp. (larvae) | Shiny spider beetle, *Gibbium* sp. (adult) | Darkling beetles, *Tenebrionidae* (adult) |
| Biscuit beetle, *Stegobium paniceum* (adult) | Household casebearer moth, *Phereoeca uterella* (larvae and adult) | Bean weevil, *Bruchidae* (adult) |
| Subterranean termite, workers (adult) | Booklouse, *Liposcelis* sp. (adult) | |
| Silverfish, *Lepisma* sp. (adult) | | |
| Firebrat, *Thermobia domestica* (adult) | | |

have attended training, resulting in the IPM message spreading far and wide. Staff from all levels of museum practice have actively engaged with IPM practice, from museum directors to security staff. The convening of the museum seminar day was a novel method to showcase the importance of and raising the profile of IPM as a preventive conservation activity, and was a significant step towards engendering interest and commitment from senior management. An IPM Pest Network has been established countrywide, with a designated IPM Champion at each of Myanmar's museums. This network has been instrumental in maintaining impetus during the COVID-19 pandemic.

Creative methods of engaging management have emerged, with delegates proactively suggesting ideas for generating support for IPM within their home institution. Some of these ideas include incorporating IPM into temporary exhibitions and collecting examples of damage for cascade learning sessions. A further outcome is improved professional communications with other countries, potential collaborators in exhibitions, and the production of a preventive conservation toolkit, alongside a series of instructional videos on bite-sized topics (Dawson *et al.* 2019a,b; Crossman 2019a,b). These materials have been translated in Burmese and contain the basis of the training delivery (Fig. 2).

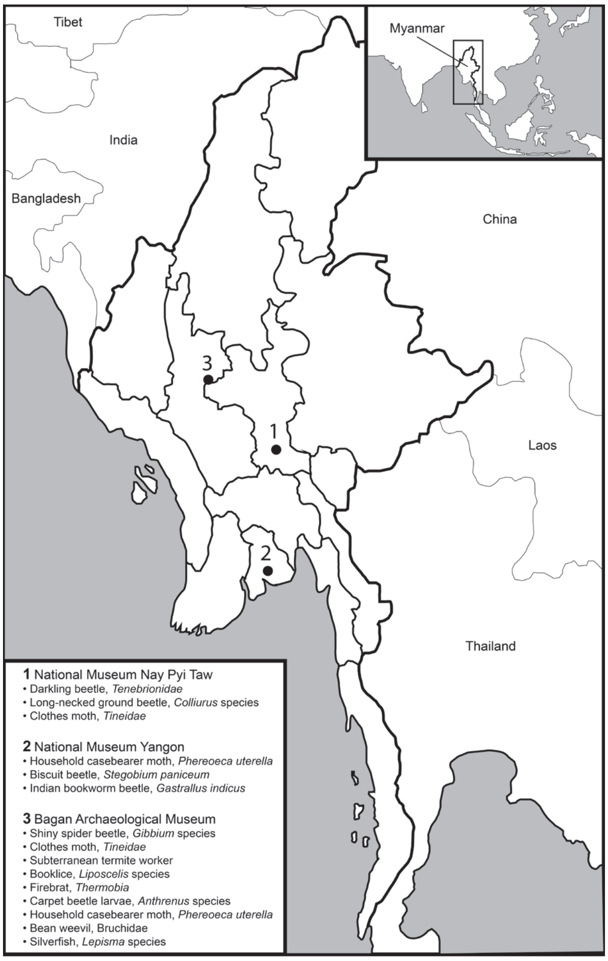


**Figure 3** Map of the distribution of insects found in Myanmar (© 2021 Graeme Carruthers).

## Identification of previously unidentified pest species

One of the most significant outcomes from the training is the generation of pest data from trapping programmes. Pilot trapping programmes were implemented at three selected museums across Myanmar: National Museum, Yangon, Bagan Archaeological Museum and National Museum, Nay Pyi Taw. In collaboration with a consultant entomologist, previously unrecorded insect pest species were identified, providing the first recorded and verified baseline data for museum pests in Myanmar (Table 1). Previously unknown and potential insect pests


**Figure 4** *Gastrallus indicus*, Indian bookworm beetle adult (© 2021 Darren Mann, Oxford University Museum of Natural History OUNHM).

**Figure 5** *Gastrallus indicus*, Indian bookworm beetle damage (© 2021 Amy Crossman, Collections Care Consultancy).

have also been identified (Crossman 2020). Given the large geographic expanse and varied climatic conditions across the country, some variation in insect pest incidence and distribution was expected, and this was borne out in the relatively limited amount of insect pest data obtained (Fig. 3). What is clear is that the occurrence of less familiar insect pests, such as the wood borer *Gastrallus indicus,* the Indian bookworm beetle (Ptinidae) renders the need for specialist entomological support essential (Figs 4–6).

## Lessons learned

Without prior knowledge of collections, materials and pest species present, designing and delivering an IPM workshop was challenging. The lack of insect pest data proved problematic for initial training purposes, where the focus had to be on IPM theory and developing efficient trapping practices, with the long-term goal of providing delegates with the ability to make informed decisions based on the evidence

**Figure 6** Unidentified dotted moth of the *Tineidae* family (© 2021 Amy Crossman, Collections Care Consultancy).

available. In planning the specialist IPM workshop, consideration was given to paring down the course content to be as concise as possible, allowing for more rigorous translation and ensuring sufficient time to overcome comprehension barriers. Delivery of training sessions staggered over a two-year period proved to be effective in allowing delegates time to digest, reflect on and start to embed preventive conservation practice activity as part of their daily work routine. It was clear early in the training that there was some fluidity in programming, and allowance for this shift was built into training delivery. Incorporating actionable tasks and exercises was an effective method of verifying that training had been understood and ensuring the translation of theory into practice.

It is exciting to be able to start identifying insect pest species in Myanmar, both for the development of IPM practitioners in the country and the wider entomological community. Further data on distribution and occurrence are required and is ongoing to determine pest risk more fully. The species of insect pests found indicate a systemic weakness in relation to IPM policies and procedures: this was addressed as part of the IPM training and complemented that of the collections management programme. This was successfully reinforced with the provision of IPM reports designed for relevant stakeholders within the programme, providing advice and guidance on models for reporting and strategy writing (Crossman 2019a,b; 2020a,b; Dawson *et al.* 2019). Some of the insects found are indicators of poor housekeeping procedures and lack of building management, as opposed to museum insect pests. Identification of more unusual insect pest species emphasised the need for the specialist support of an entomologist for a project of this scope. Although monitoring is beginning to identify insect species, how they behave and respond to the Myanmar environment is not known. As Myanmar has been recognised as at high risk from climate change, insect species and their behaviour need to be monitored and recorded (Overland 2017). Knowledge of pest species is only half of the puzzle – we also need to understand the collections in order to determine pest risk.

## Acknowledgements

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# The pesty business of translation: a global collaboration to bring MuseumPests.net to a wider audience

Fabiana Portoni, Laura García-Vedrenne, Silvia Manrique, Jessica Lewinsky, Beatriz Haspo, María Castañeda, Christian Untoiglich, Amparo Rueda, Sandra Joyce Ramírez, Armando Mendez, Rachael Perkins Arenstein and Paloma Mujica

**ABSTRACT** In 2007 an ad hoc group of museum and entomology professionals launched the MuseumsPests.net website. Since then, it has become one of the core online resources promoting best practice in integrated pest management (IPM) for collections and cultural heritage institutions. However, to fully benefit from the comprehensive information provided, a good command of the English language is needed. To reach a wider audience and to connect with the IPM community in other regions of the world, MuseumPests.net began a project in 2020 to translate the website, including all its training materials and resources, into Spanish. The translation project saw leaders of the MuseumPests Working Group collaborating with bilingual (Spanish–English) professionals who work in the IPM field around the world as well as APOYOnline (Association for Heritage Preservation of the Americas). These professionals volunteered to translate the site, bringing their technical knowledge and expertise. This venture is part of a comprehensive effort to expand the MuseumPests.net community by creating additional working groups to educate, inform and collaborate with colleagues in combating pest infestations in cultural heritage institutions worldwide.

**KEYWORDS** Integrated pest management; IPM; international collaboration; global collaboration; museum pests; MuseumPests in Spanish

## Introduction

The MuseumsPests.net website launched in 2007 with the aim of promoting best practice in integrated pest management (IPM) for collections and cultural heritage institutions. The website was created by a group of volunteer museum, pest control and entomology professionals who pooled their expertise to provide open-source IPM information and resources for the cultural heritage community. However, a good command of the English language is required to benefit from the extensive information provided on the site. For several years, MuseumPests.net founding members received enquiries about whether the information could be made available in Spanish, but resources were not available. The project to translate the whole site into Spanish was kick-started when Christian Untoiglich voluntarily translated a significant section of the English website. From this initial translation, MuseumPests.net en Español began to take shape, although a larger group was required to translate the entire website including all its training

**Table 1** List of countries where Spanish is an official or significant language.

| Countries where Spanish is the official language either by law or de facto (Moreno-Fernández and Otero 2008) | Countries where Spanish is a significant language but is not official |
|---|---|
| Argentina | Andorra |
| Bolivia | Belize |
| Chile | Brazil |
| Colombia | Gibraltar |
| Costa Rica | Philippines |
| Cuba | Netherlands Antilles (Bonaire and Curaçao) |
| Ecuador | United States of America |
| El Salvador | |
| Spain | |
| Guatemala | |
| Equatorial Guinea | |
| Honduras | |
| Mexico | |
| Nicaragua | |
| Panama | |
| Paraguay | |
| Peru | |
| Puerto Rico* | |
| Dominican Republic | |
| Uruguay | |
| Venezuela | |

* Puerto Rico is not officially a sovereign state but an unincorporated territory of the USA

materials and resources. The main aims of the project were to reach a wider audience and to connect with the IPM community in other regions of the world.

Spanish is spoken by nearly 580 million people, representing 7.6% of the global population. It is the second most spoken native language and the third language most used on the internet after English and Chinese (Instituto Cervantes 2019). Spanish is the official language of 21 countries and used significantly in several others (Moreno-Fernández and Otero 2008) (see Table 1). Spanish is also known as Castilian (*castellano*) in various countries. However, the Real Academia Española (RAE) uses the term Spanish when referring to the language and that is how it will be referred to within this paper. Due to the wide geographical spread of the language (see Fig. 1), it was inferred that the Spanish-speaking IPM community would be able to contribute information and knowledge for a relevant section of the world.

The translation project started in earnest in 2020, when leaders of the MuseumPests Working Group joined forces with bilingual (Spanish–English) cultural heritage professionals working in the IPM field and APOYOnline (Association for Heritage Preservation of the Americas).[1] APOYOnline is a non-profit organisation that has promoted communication, exchange and professional development in the field of cultural heritage preservation in the Americas and in Portuguese- and Spanish-speaking countries for over 33 years. In line with the previous work on the website, the project was a completely voluntary endeavour that brought together professionals with a passion for outreach and advocacy of IPM in the Spanish-speaking world.

The MuseumPests Spanish Working Group is a diverse collective of cultural heritage professionals from various Spanish-speaking countries including Argentina, Colombia, Chile, Mexico and Spain. It is complemented by members from Brazil and the United States, who contribute by sharing their IPM expertise and connections with other cultural heritage professionals in Spanish-speaking countries, especially in Ibero-America.

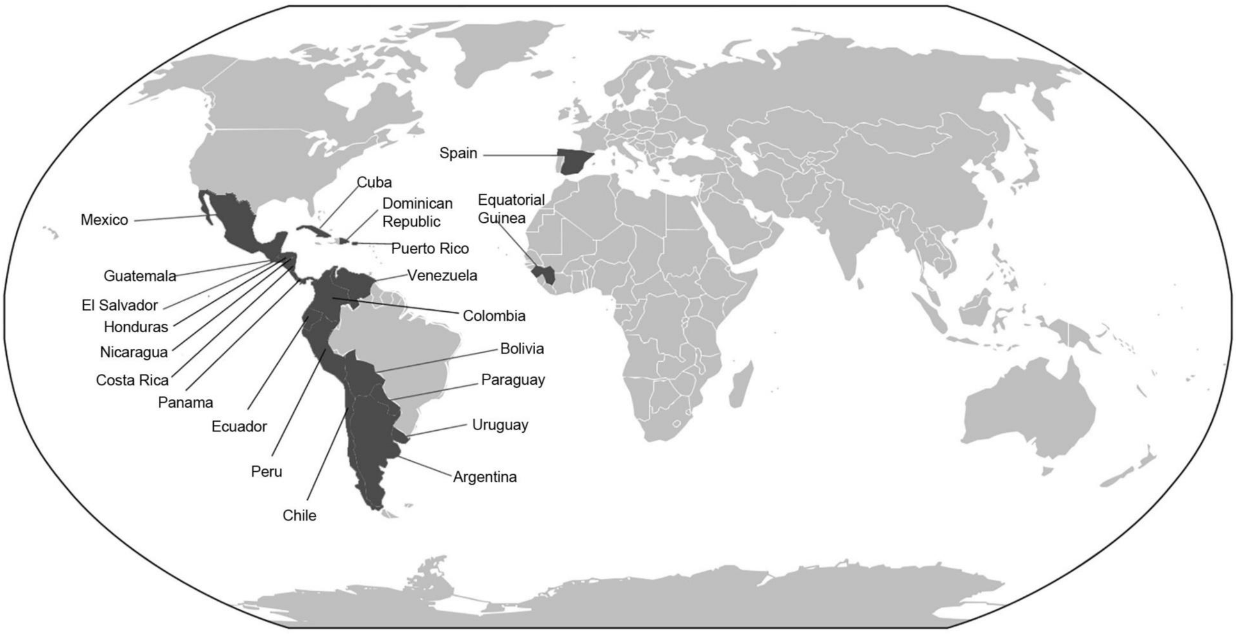


**Figure 1** Map showing countries where Spanish is an official language.

They also contribute their trained skills as translators and interpreters in Spanish, English and other languages. Several of these professionals live and work in other countries such as Canada, Israel, the UK and the US. This variety of geographical and cultural backgrounds provides members with a diverse set of skills and experiences which has been invaluable in the translation and interpretation of the website. More importantly, this assortment of backgrounds paved the way for discussions around the complex diversity of the Spanish language. These discussions highlighted the importance of careful word selection that would avoid loss or change of meaning, while including regional linguistic variants.

## Remote working around the world during the COVID-19 pandemic

In March 2020, the World Health Organization declared the COVID-19 outbreak a pandemic (*TIME* 2020). Consequently, restrictions were suddenly implemented worldwide, including lockdowns in most countries and a major shift of cultural heritage professionals to working from home. This change in working patterns provided a unique opportunity for the MuseumPests translation project. Unlike other projects which required participants to be on-site together, the translation of MuseumPests.net was well suited to be completed entirely online. Emerging technologies such as video call platforms facilitated the task as team members were based in different countries. Therefore, working remotely and communicating via online meetings was the logical way forward. Even though there were some logistical challenges – such as organising online meetings across nine time zones (see Fig. 2) – the immediacy of technology and messaging systems meant it was easy for team members to remain in contact and work together while physically apart.

Some employment challenges created by the pandemic – such as workers on furlough or the postponing of tasks that could not be completed while working remotely – meant that members of the team often had spare time that could be devoted to the translation project. This resulted in unexpected progress over the summer of 2020, and the eventual completion of the translation for most of the site in only six months (April 2020–September 2020). Throughout 2021, the group hosted periodic video meetings: some in English to liaise with the MuseumPests Working Group leaders, others in Spanish to discuss the language style and tone as well as regional variations in the mother/native language of most team members.

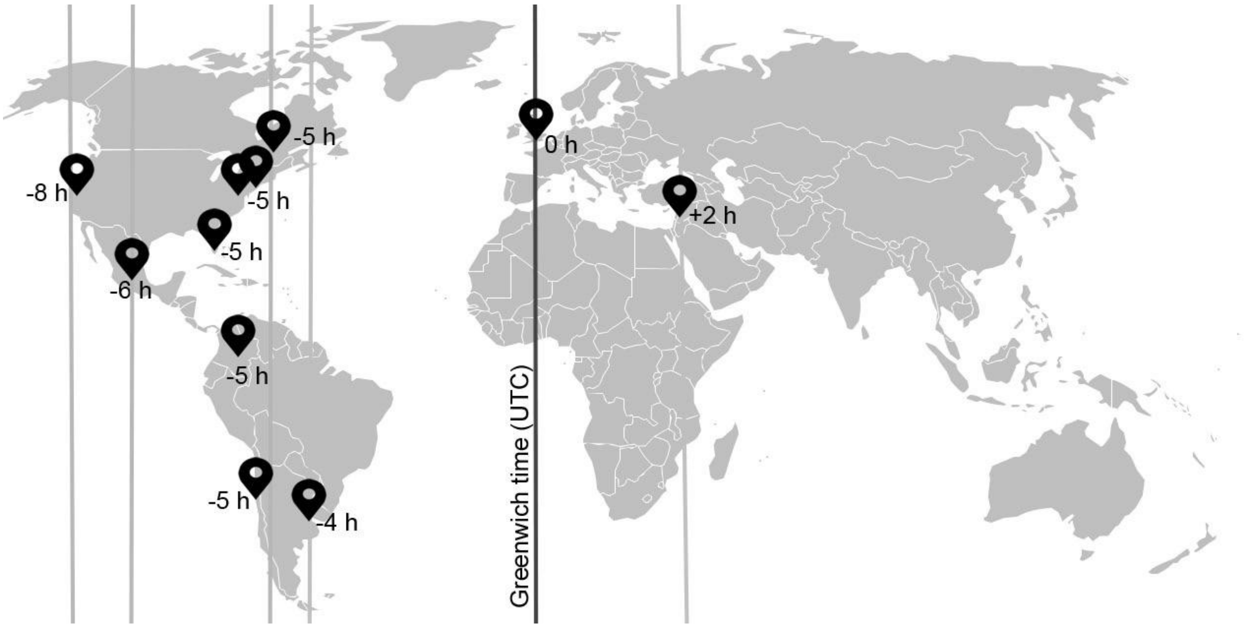


**Figure 2** Map of team members' locations and time differences.

## Translation work

> *Me parece que el traducir de una lengua en otra, es como quien mira los tapices flamencos por el revés, que, aunque se veen las figuras, son llenas de hilos que las escurecen, y no se veen con la lisura y tez de la haz. [sic]*
>
> Translating from one language to another, is like looking at Flemish tapestries from the wrong side, for although the figures are visible, they are covered by threads that obscure them, and cannot be seen with the smoothness and colour of the right side.
>
> Miguel de Cervantes Saavedra, Don Quijote (LXII, II)

Eloquently expressed by Miguel de Cervantes Saavedra, translation is complex and requires a significant amount of work and knowledge on a specific topic to convey the message from the original language in a way that works and maintains the context in another. Fortunately, the MuseumPests Spanish team has substantial knowledge of the topic of IPM and its technical terminology. Furthermore, their living and working experiences in English-speaking countries equipped them to prevent information from being lost in translation. The team organised the workload by dividing the website sections and allocating tasks so members could work simultaneously. The creation of an assignment tracker on Google Docs proved useful in allowing team members to easily record their progress and avoid duplication of effort. Introducing a proofreading step to the process required several people to read the produced texts, which helped corroborate the accuracy of the translation and unify the definitions of the terms used.

### Setting the tone

A conscious decision was made to set the tone for the Spanish website. The original MuseumPests.net is written in a friendly approachable tone which is inviting and engaging for English readers. However, writing in an informal tone in Spanish tends to veer into specific regional variations. The team agreed that, for the translation to be as neutral as possible, the language variation known as neutral or international Spanish should be used. Neutral Spanish aims to eliminate regional terminology and idioms to promote a clear understanding by Spanish speakers from any nation (Gómez Font 2012).

### Proofreading

To ensure standardised language and tone, the process of translation was divided into several steps,

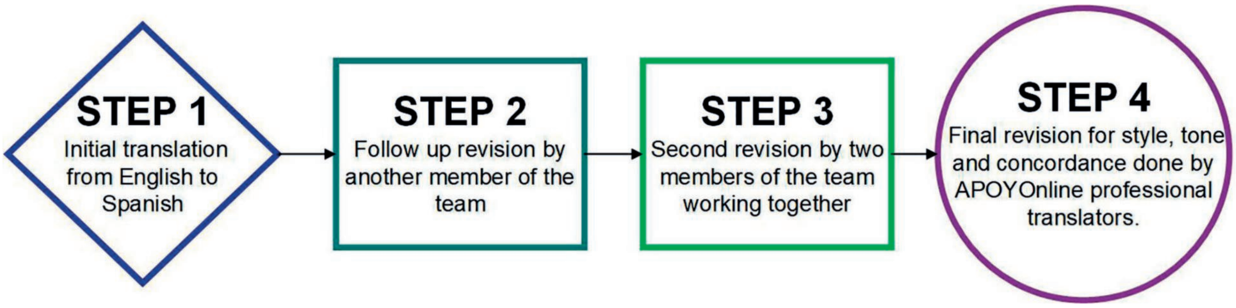


**Figure 3** Diagram of the translation and proofreading process.

carried out by different team members (see Fig. 3): (1) the initial translation from English to Spanish; (2) a follow up revision; (3) a second revision by two members of the team; (4) a fourth and final revision to ensure standardisation of style and tone across the site (4). This final step was completed by professional translators, members of APOYOnline, with previous experience in translating official documents in collaboration with many international organisations. Their translations from English into Spanish and Portuguese include collaborations with the Canadian Conservation Institute (CCI) in Ottawa, and the Institute of Museum and Library Services (IMLS) and the Smithsonian Institution, both in Washington, DC.

## IPM terminology

From the beginning of the project, the need for a clear IPM terminology across the website was highlighted. For example, the team discussed the significance of having a similar acronym in Spanish to link both languages and be easily recognisable as equivalents. Fortunately, the translation of integrated pest management to *manejo integral de plagas* means the acronym only changes order from IPM to MIP, promoting an easy correlation. As a result of these discussions, the team met to create a standardised English–Spanish glossary of terms to ensure consistent terminology and language. The glossary took into consideration regional variations in Spanish and was a useful resource during the translation work. The final goal is to make the glossary available on the website as an IPM tool for all users, correlating information between languages.

## Challenges

The complexity of working together with people based in many corners of the world, the difference in time zones and the fact that most participants had only met online, created other challenges for the teams. These included identifying regional lexicon variations, correlating insect common names, describing treatments, approaches, materials and common brands, etc., to facilitate the use of the finished text by professionals in all Spanish-speaking countries.

## Regional lexicon

As mentioned by the RAE (2016), Spanish is a diverse, yet unified language. This means that even though there are regional variations in lexicon, Spanish speakers from any of the 21 countries listed above can communicate successfully with some minor changes in terminology and idioms. Nonetheless, to ensure that the information on the website was as clear as possible, the team had to consider neutral terms that would be understood by the widest possible number of readers.

## Pest fact sheets: insect common names

MuseumPests.net hosts a set of pest fact sheets which present concise information on common museum and cultural heritage pests. These fact sheets aid professionals with pest identification by providing a useful summary including diagnostic morphology, behaviour, life cycle, and possible controls and treatments to mitigate damage. The translation of these fact sheets was a wonderful opportunity to share these useful summaries with a Spanish-speaking audience. However, it was immediately evident that several different names were used interchangeably by Spanish speakers across countries – and even regions – to refer to the same species. Significant research went into identifying these terminology variations as a first approach, although future consultations are still needed. By collating the insect species scientific names with their equivalent common names in both English and Spanish, the information has been condensed, providing a useful juxtaposition of the different terms used to name a single species across several geographic regions. Additionally, the website also has a long-term goal to add common names in other languages, such as German and Portuguese. The need to accommodate additional common names was the impetus for changing the fact sheets from a static PDF document to a dynamic, easily updatable new format in Airtable. The new platform will facilitate updates to all the pest fact sheets in English, Spanish and any future language translations.

## Launch of the MuseumPests.net website in Spanish

In March 2021, after a year of work on the translation, MuseumPests in Spanish was ready for an initial launch at the MuseumPests Working Group annual meeting. The Spanish website was launched via an online presentation session at the MuseumPests annual meeting. The launch represented an opportunity to share the Spanish site with the IPM community, provide a brief introduction to the project, and announce the working group email and social media hashtags. To date, visitors to the website are predominantly from the US, Spain, Argentina, Mexico and Colombia.

## Work in progress

The translation of the MuseumPests.net website into Spanish is just the first step of an ongoing project which aims to bring together IPM professionals from various Spanish-speaking countries. The long-term goal is to build a platform where IPM content is created and shared in Spanish, connecting IPM professionals from the Spanish-speaking world. An ongoing aim of the project is to encourage further discussion and collaboration among professionals in Spanish-speaking countries. In line with the intent of the original English website, the Spanish version is a dynamic work in progress that is regularly edited and updated. The translated site will also include important research published originally in Spanish that addresses work practices and issues drawn from local communities. This will help highlight local knowledge for a broader audience. Some of the upcoming tasks planned by the MuseumPests Spanish Working Group to further the understanding across Spanish-speaking countries include conducting a survey and hosting an IPM conference in Spanish. In addition, the MuseumPests.net community is currently reviewing the possibility of collaborating with APOYOnline to translate the website and associated materials into Portuguese.

## Conclusions

The translation of MuseumPests.net into Spanish is a step in the right direction in the effort to reach a wider audience in other regions of the world, as well as establishing connections with the IPM community in the Spanish-speaking world. This successful international collaboration highlights the importance of colleagues working together through challenging times, and demonstrates that ambitious projects can be completed over time with the right resources. The project is an example of an initiative which was not disadvantaged by the COVID-19 pandemic but quite the opposite – it benefited from the increase in web communications enabling it to be completed while working from home in any corner of the world. Nonetheless, it is important to highlight that this is an ongoing project: ultimately the site aims to continue fostering international collaborations and developing opportunities for research, training and education.

## Note

1. https://apoyonline.org/en_US/.

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# And then there were none: the successful treatment of a silverfish (*Lepisma saccharinum*) outbreak during the COVID-19 pandemic

Catherine Harris and Alexandra Walker

**ABSTRACT** December 2019 witnessed the advent of a significant outbreak of common silverfish (*Lepisma saccharinum* Linnaeus, 1758) in a publicly accessible area of the Bodleian Libraries, University of Oxford. Housekeeping and preventive conservation methods were quickly deployed to try to halt the outbreak, along with attractant traps for enhanced monitoring and control. Regular monitoring showed that these methods were not having a significant effect and so a suitable chemical treatment was researched. A newly developed product was selected: as it was not water based it would not have a detrimental effect on collections and in addition, it was long lasting with low toxicity to humans. This was deployed by an external pest controller using the Bodleian as their first site for this product. Most of the monitoring and all the treatment was carried out during the COVID-19 pandemic, mainly during the first strict UK-wide lockdown (23 March–23 June 2020). This resulted in some advantages such as no public access and the possibility of increased trapping, but also challenges including remote working and staff unable to work together. These were successfully overcome to produce a satisfactory outcome, providing a template for best practice should this type of pest infestation occur again.

**KEYWORDS** Integrated pest management; IPM; library; silverfish; *Lepisma saccharinum*; gel bait; clothiandin; Maxforce Platin

## Introduction

The Bodleian Libraries is the library service for the University of Oxford. Comprising 28 separate libraries, it is the largest academic library service in the UK, holding more than 13 million printed items (Bodleian Libraries 2021). Central to this is the Weston Library, completely refurbished between 2010 and 2014 and the home of the libraries' special collections and associated reading rooms, events, social and retail spaces.

The Weston Library has maintained a comprehensive integrated pest management (IPM) programme since its reopening in 2015, with over 100 individual insect pest trap locations. The preventive conservation team manages this programme, deploying a mixture of cardboard blunder traps, rigid plastic traps and webbing clothes moth (*Tineola bisselliella* (Hummel, 1823)) pheromone traps, which are checked on a quarterly basis. The programme is well integrated into the structure of the library, with support from facilities and cleaning teams as well as active reporting of pest issues from library staff members. Regular updates are included in the staff newsletter and incorporated into internal Preventive Advice for Library Staff training sessions.

The library is effectively a new building given the comprehensive nature of the recent refurbishments

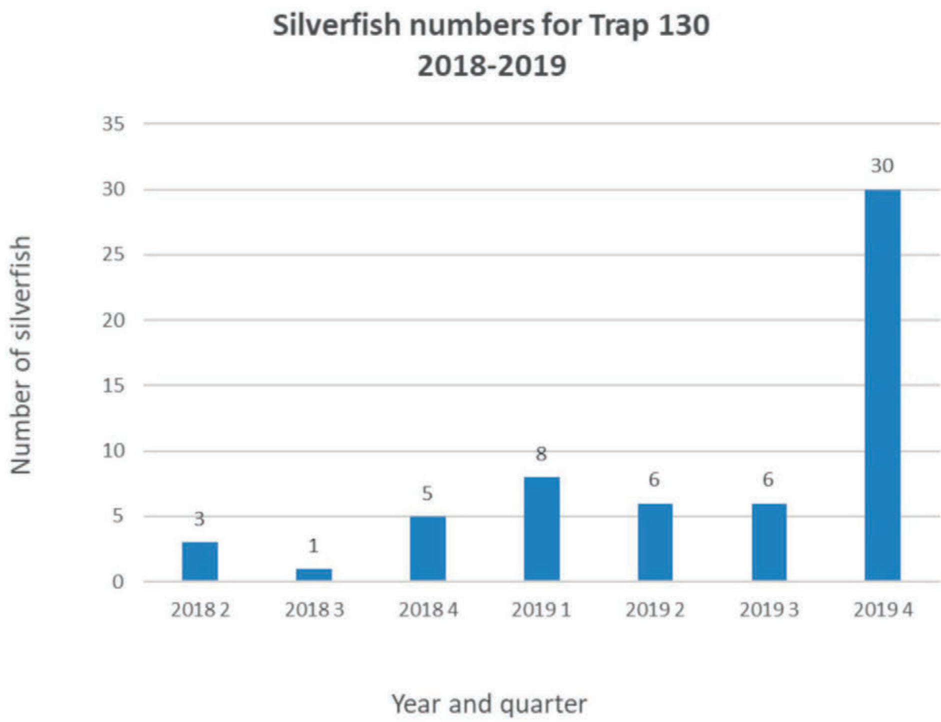


**Figure 1** Silverfish numbers for Trap no. 130, 2018–2019.

with a new air handling system designed to BS5454:2000 specifications (British Standards Institution 2000), a collections care-focused food and drink policy, and a revised IPM policy. Background numbers of insect pests such as booklice and silverfish are present throughout the building, but at levels which are not generally considered a cause for concern (Querner 2015). In December 2019, however, routine monitoring in a publicly accessible space revealed a significant increase in common silverfish (*Lepisma saccharinum* Linnaeus, 1758)), necessitating an increase in monitoring and an investigation into the source of the outbreak. Unfortunately, while these investigations were ongoing, the library went into lockdown as part of the UK's COVID-19 response, which had both advantages and disadvantages for the investigation and treatment of the outbreak.

## Context

The space where the outbreak was discovered (which is dry mopped daily when the library is open) has a solid floor with an area of 120 $m^2$ and contains no specific insect pest risks (e.g. food and drink, toilets, highly vulnerable collections, external openings, obvious harbourages etc.). Temperature and relative humidity (RH) are monitored at a central point by an Ellab Monitoring Solutions (formerly Hanwell) monitoring system, which recorded an average temperature of 20 °C and an RH of 48.2% for the period December 2018–December 2019. A single rigid plastic floor trap, Trap no. 130, is usually deployed in this space. A low background population of silverfish had previously been trapped in this location but it was clear from the December 2019 catch that a significant increase in population had occurred (Fig. 1).

The preventive conservation team and colleagues responded by checking the environmental parameters and placing an additional RH data logger at floor level. Silverfish thrive at high RH, developing and reproducing most effectively at a temperature of 22–27 °C and an RH of 75–97% (Sweetman 1939). No area of higher RH was found, with the data logger recording an average of 49% RH for the one month period for which it was deployed. The space was deep cleaned and a detailed inspection carried out to identify any possible harbourage or food sources, including support from facilities to look for cable runs, risers or any other harbourage locations but none was identified. Monitoring was then increased to try to pinpoint the source of the outbreak.

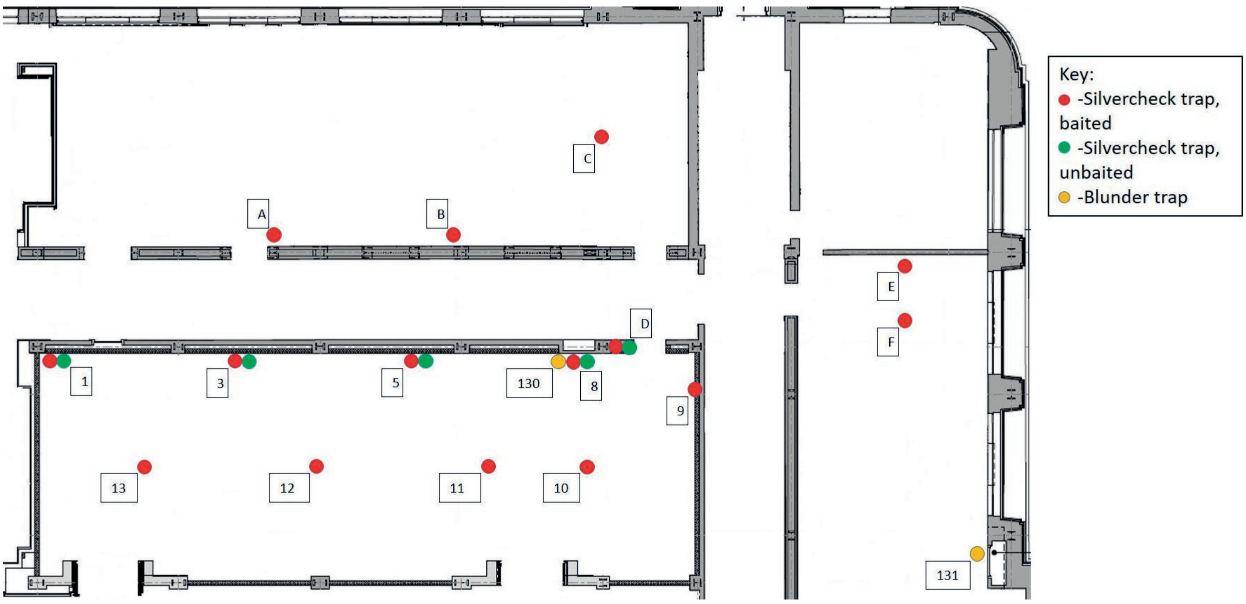


**Figure 2** Silvercheck and blunder trap locations in and close to the affected space.

## Monitoring methodology

Monitoring was carried out using Silvercheck baited silverfish traps. These traps are designed to attract silverfish using a combination of physical design and a 'multi-food attractant' composed of 63–69% protein, 17–19% fat and 2% carbohydrate (Russell IPM 2018). The manufacturer's website claims that they catch three times as many common silverfish (*Lepisma saccharinum*) and grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) compared to a range of commercial traps tested (Russell IPM 2020) although no evidence is offered to support this. An attempt was made to assess the traps' efficacy as they had not previously been used at this site. Pairs of traps were placed next to each other at locations 1, 3, 5 and 8 (Fig. 2), with one having the bait applied and one being left to function as a blunder trap.

The manufacturer recommends placing one trap every 25 m$^2$ or more if trying to locate the source of an infestation. After the four pairs of traps were initially placed, it quickly became clear that the outbreak was more severe than realised. A further six locations (4, 10, 11, 12, 13) were then added in order to narrow down the source of the outbreak and attempt a degree of control, as mass attractant trapping for insect population control has been shown to be effective in some circumstances (El-Sayed *et al.* 2006). Additional traps (9, D) were placed in voids behind walls suspected to be potential harbourages.

In total there were 14 traps in the space by the beginning of March, plus traps A, B, C, E and F in adjacent rooms to rule out the source of the infestation being elsewhere. Four months were allowed to assess whether the traps were controlling the population sufficiently before moving on to chemical treatment. To make measurements easier, traps were replaced each time they were checked unless no insects were present.

## Results

In total, 38 traps were placed and checked between 7 February and 18 June 2020. During this period, 1,580 silverfish were trapped, giving an average of 41 individuals per trap or 1.6 per trap per day. Some patterns in the concentrations of silverfish were observed, with locations 12, 10 and 5 showing the highest numbers with an average catch per day of 4.5, 2.8 and 2.1 respectively. No insects were trapped in the suspected harbourages behind the walls and no catches were observed on the traps in the adjacent rooms.

During the four-month monitoring period, intensive trapping was seen to be having some effect. Although the numbers of individuals continued to increase, the numbers per trap per day were falling somewhat (Table 1). There were also some signs that the silverfish population was not stable (Aak *et al.*

**Table 1** Average numbers of silverfish caught per trap per day by month.

| Month checked | Total silverfish trapped | Average catch per active trap per day |
|---|---|---|
| February | 38 | 2.5 |
| March | 427 | 2.5 |
| April | 470 | 1.2 |
| June | 645 | 1.2 |

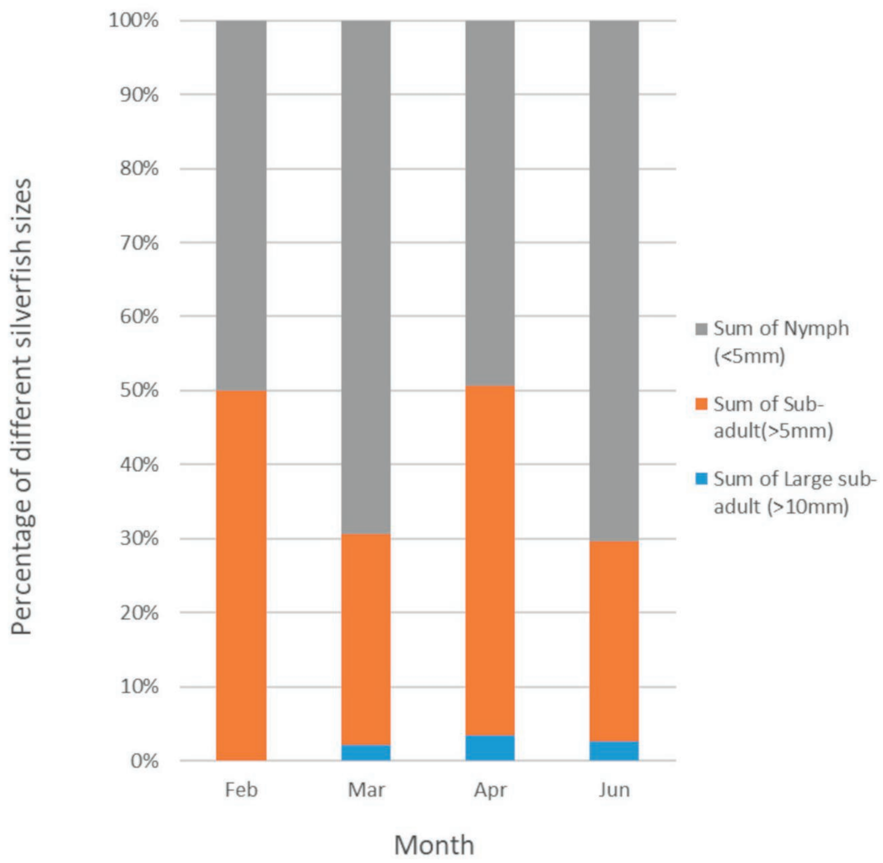


**Figure 3** Silverfish sizes trapped per month.

2020a), as most of the individuals trapped were not of reproductive age and the majority were nymphs of below 5 mm in length (Fig. 3). As the effect was clearly insufficient and no source was found for the outbreak, it was decided to move on to chemical treatment.

## Chemical treatment

The Bodleian's pest controllers were asked to apply a suitable product. The preventive conservation team researched treatments that had been tested in Norway where the grey silverfish (*Ctenolepisma longicaudatum*) is a significant public health nuisance (Aak *et al.* 2019). One of these was Maxforce Platin, containing clothianidin, a neurotoxin and activator of post-synaptic acetylcholine receptors (Aak *et al.* 2020a), plus a proprietary attractant technology. Data showed that Maxforce Platin was highly effective in controlling and eliminating grey silverfish in laboratory trials (Aak *et al.* 2020b) as well as common silverfish in field trials (Aak *et al.* 2020a). Although Advion Cockroach Gel, with its active ingredient of

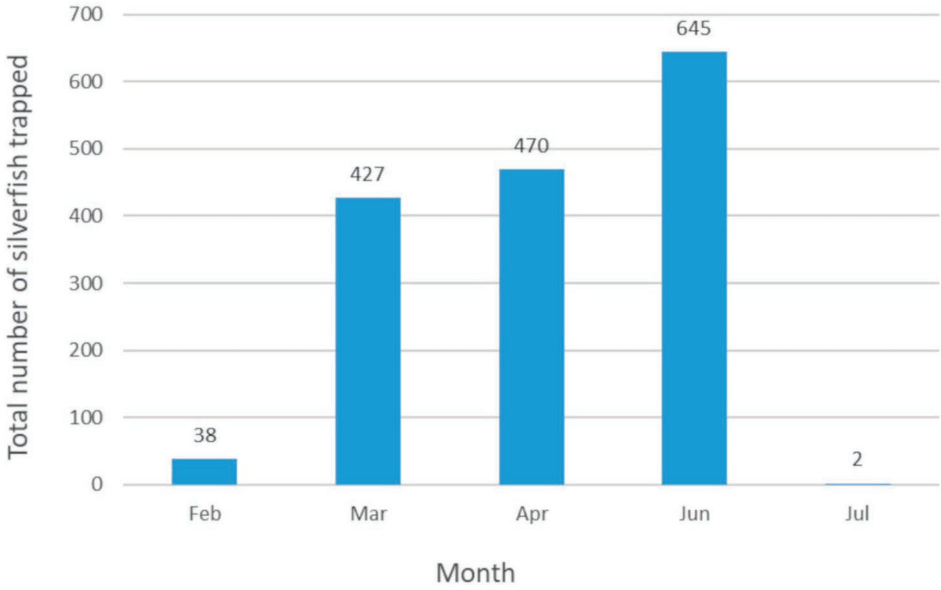


**Figure 4** Total silverfish trapped per month.

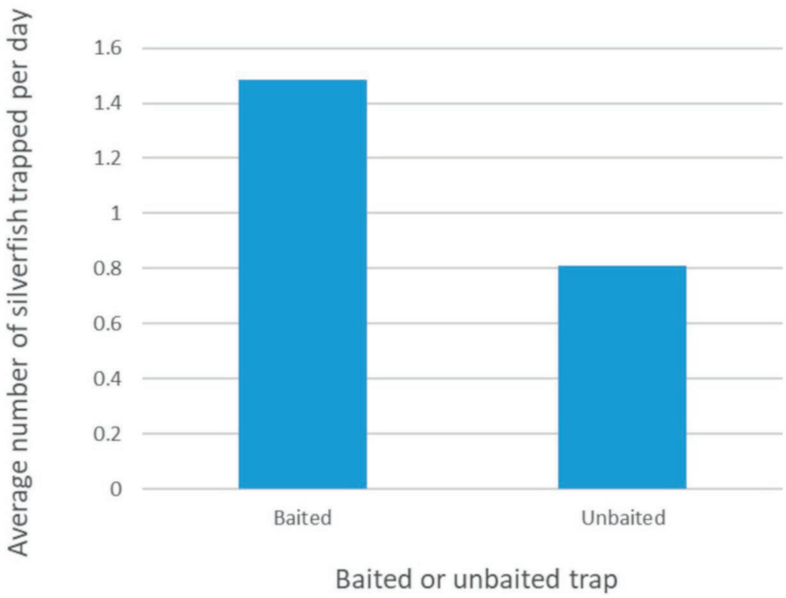


**Figure 5** Average numbers of silverfish caught per day on baited and unbaited traps.

indoxacarb, achieved slightly better results under laboratory conditions and had a stronger secondary poisoning effect (Aak *et al.* 2020b), silverfish are not a target species on the product label so it could not be used to treat a silverfish infestation under UK regulations (British Pest Control Association 2020). Maxforce Platin was new to the UK market and seemed a good choice as its gel-based formulation has active ingredients that are long lasting (Aak *et al.* 2020b), of very low toxicity to mammals and applied only in tiny droplets (2 mm) in areas where silverfish hide and live (European Chemicals Agency

2019). This meant that no moisture would be introduced into the space, no risk of toxicity to users of the space and little likelihood of the product being removed through cleaning.

The space was cleaned once more before application and the Silvercheck traps removed to avoid providing a competing food source for the silverfish. The treatment was carried out in two sessions, two weeks apart. It was applied widely around the outside walls and internal fixed structures, as no specific source of the outbreak had been identified. After the second application (on 18 June), new Silvercheck traps were placed to allow monitoring to resume. An informal visual check of the traps on 7 July revealed a remarkable improvement, with only one silverfish observed. A complete check of the traps was made and recorded on 30 July, the results of which can be seen in Figure 4.

The treatment resulted in an almost complete eradication of the population within the first six weeks. Monitoring has since continued and no evidence of silverfish has been found. At the time of writing, no silverfish have been observed for a full calendar year, indicating that the treatment has been successful and that the reduction in numbers is not simply due to seasonal fluctuations in population.

## Discussion

This was a large, sustained and challenging silverfish outbreak. Many strategies were employed to tackle it, including investigation, cleaning, RH monitoring and mass trapping, all of which took place against a backdrop of building closure, limited staff access and communication challenges due to the pandemic. COVID-19 restrictions resulted in difficulty accessing the building and communicating between staff members working from home. The numbers of traps replaced each time were not always consistent and traps were down for variable amounts of time before being checked. Building closure, however, meant that many more traps could be placed in less discreet locations than would usually have been possible. Clearer trapping schedules and floor plans would have helped data to be collected more consistently although ultimately this did not affect the outcome.

Although a definitive source of the infestation was not found, a sweet (confectionary item), presumed to be gelatine and sugar based, was found pushed beneath a ledge close to Location 12 (Fig. 2), where the highest concentration of silverfish numbers was found. It was heavily 'grazed' to the point that the original shape was not identifiable, therefore it was assumed that this had been caused by silverfish. Carbohydrates are an important food source to this species (Sweetman 1937) and according to Devries and Appel (2014), at 20 °C and in the absence of any other food sources, the consumption of carbohydrate (specifically sucrose) averages approximately 0.05 mg per adult silverfish per day. A sweet weighing approximately 6.6 g, such as a Jelly Baby containing 78% carbohydrate and 3.5% protein, could therefore theoretically support in excess of 100,000 silverfish. Although there is no strong evidence that this sweet was the cause of the outbreak and silverfish numbers did not reduce substantially when it was removed, it highlights the vital importance of clear and well-enforced food and drink policies in cultural heritage institutions.

With regard to the effectiveness of the Silvercheck traps, it appears that the baited traps were attracting more individuals, with an average of 1.5 per trap per day for the baited traps compared with 0.8 per trap per day for the unbaited traps (Fig. 5). However, there were 25 baited trap observations versus 13 unbaited, and the traps were placed for variable periods of time, making the data unreliable. Further investigation would be interesting.

## Conclusions

Ultimately, despite diligent preventive conservation and housekeeping, it was the use of Maxforce Platin with its new attractant technology and active ingredient of clothianidin which provided a swift and effective resolution to the silverfish outbreak. This had sustained effects over the following year, with no risk to people or collections. We now have a template for action should a similar infestation occur, with preventive conservation aspects remaining essential to allow chemical treatment to work effectively and help prevent recurrence where a source cannot be identified.

## Acknowledgements

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## Materials and suppliers

- Advion Cockroach Gel Bait (0.6% indoxacarb): Syngenta International AG, Basel, Switzerland
- Ellab environmental monitoring system: Ellab Monitoring Solutions Ltd, Letchworth, Hertfordshire, UK
- Maxforce Platin (0.5% clothianidin): Bayer AG, Leverkusen, Germany
- Silvercheck: Russell IPM Ltd, Deeside, Flintshire, UK

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# Grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) at the National Gallery, London: the importance of monitoring and advocacy in IPM

Kristina Mandy and Sarah Coggins

**ABSTRACT** Like many other institutions, the National Gallery (NG) in London has been faced with the challenge of maintaining its integrated pest management (IPM) programme during the COVID-19 pandemic. With lockdowns, darker hours and lack of human activity, pest numbers have escalated. The grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) was first identified at the Gallery in 2018, since then numbers have increased. During 2020 and 2021, the NG trialled three treatment options to investigate their effect on the population. The importance of advocacy and communication across the NG was highlighted by experiences of working on IPM tasks throughout the pandemic. The Preventive Conservation Working Group, established in 2016, has been vital to cross-departmental communication, spreading the message of the importance of IPM and reducing pest numbers.

**KEYWORDS** Grey silverfish; silverfish; booklice; treatment; advocacy; pandemic

## Introduction

Pest management has been practised at the National Gallery (NG) in London for many years but an integrated approach has only recently been promoted. Old master paintings are not at high risk from many of the pests considered damaging to cultural heritage collections, and until recently insect pest management had not been a high priority. Increased visitor numbers, with no corresponding increase in cleaning practices and coupled with sporadic insect pest monitoring programmes, undoubtedly led to an escalation in certain pest populations. Alongside an increase in events and exhibitions at the NG in the last few years, there was a growing concern that novel uses for galleries by staff members with no knowledge of the danger posed by pests could expose the collection to further risks. The COVID-19 pandemic and increasing levels of pest species of concern compounded the problem.

The Preventive Conservation Working Group (PCWG), which formed in 2016 of key stakeholders, meets regularly to raise awareness and mitigate risks to the collection, encourages cross-departmental collaboration to better manage risk, and creates and establishes guidelines and policy documents for activities taking place in proximity to the collection (Harrison *et al*. 2018). Improved collaboration between departments has been crucial in maintaining knowledge and communication on integrated pest management (IPM) concerns, especially during the pandemic. During the lockdowns of 2020 and 2021, reduced staff and visitor presence, and curtailed IPM tasks, led to numbers of certain pests increasing, especially the grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905). Encouragingly, the closure period freed up time to concentrate on eradication treatment options.

**Figure 1** A National Gallery conservator checking a pheromone lure trap under a painting in room 29 (© The National Gallery, London).

## IPM at the National Gallery

The National Gallery collection comprises over 2300 paintings, as well as paper, book and photographic archives and a historical collection of furniture. IPM duties are divided between the operations and the conservation departments. The operations department is responsible for the management of rodent and larger pests and for pest management of non-collection areas, with pest control measures provided through a contractor. The conservation department is responsible for monitoring insect pest populations in collection areas (Fig. 1).

Insect pest monitoring is carried out by two conservators on a part-time basis, so continual monitoring of all the collection areas cannot be maintained. A full survey of collection areas is carried out every five years using 110 blunder and pheromone traps. In the intervening years, a reduced monitoring programme with 54 traps checks areas that are either vulnerable or have a high presence of pests. Pheromone traps are deployed on the ground in many spaces with a dual purpose, as lures for webbing clothes moths (*Tineola bisselliella* (Hummel, 1823)), the most common pest species found at the NG, and as blunder traps to catch crawling insects. All traps are replaced on a quarterly basis.

## IPM and COVID-19

The NG has been challenged with maintaining its IPM programme during the COVID-19 pandemic. It was forced to shut its doors to the public for two periods: 19 March–8 July 2020 and 4 November 2020–17 May 2021. Staff access was limited to essential tasks during these periods, therefore colleagues unfamiliar with IPM duties were sometimes responsible for lifting and replacing traps. Consequently, the trap checks were disrupted, with some traps difficult to locate and others deployed without the backing removed. The moth number checks for April and May 2020 were missed and the June 2020 traps were swapped late. Pest identification was achieved in less-than-ideal working from home environments without good lighting or magnification (Fig. 2).

During the lockdowns, the number of certain pest species increased, especially booklice (*Liposcelis* and *Lepinotus* spp.), webbing clothes moths (*Tineola bisselliella*), silverfish (*Lepisma saccharinum* Linnaeus, 1758), grey silverfish (*Ctenolepisma longicaudatum*) and plaster beetles (*Adistemia watsoni* Wollaston, 1871). Compared to the data for 2018–2019, the data for 2019–2020 showed a surge in each of the most prevalent pest species. The data for 2020–2021 so far seem to continue that trend with the exception of silverfish numbers (Table 1).

After attending IPM meetings and courses over 2020, it became clear that other institutions around the UK were experiencing an increase in pest numbers during lockdowns. Pests thrived when it was quieter and darker with reduced human activity and air flow. With many NG contractors on furlough during lockdowns, there were also reduced resources for the contracted cleaning services.

## Grey silverfish at the National Gallery

Grey silverfish were first identified at the NG in March 2018, and numbers have since grown. It is


**Figure 2** (a) Checking a blunder trap at home with 5× magnification optivisors, January 2021 (© Kristina Mandy). (b) Checking blunder traps with the right equipment at the NG, June 2021 (© The National Gallery, London).

**Table 1** Pest species counts September 2018–June 2021 showing the rise in certain pest species over the pandemic and lockdown periods.

| Date | | Booklouse (*Liposcelis, Lepinotus* species) | Winged booklouse | Webbing clothes moths (*Tineola bisselliella*) | Plaster beetle (*Adistemia watsoni*) | Grey silverfish (*Ctenolepisma longicaudatum*) | Silverfish (*Lepisma saccharinum*) | Firebrat (*Thermobia domestica*) |
|---|---|---|---|---|---|---|---|---|
| Sept–Dec | Total for quarter 1 | 141 | 66 | 264 | 21 | 3 | 57 | 51 |
| Dec–Mar | Total for quarter 2 | 125 | 22 | 258 | 4 | 0 | 25 | 10 |
| Mar–Jun | Total for quarter 3 | 195 | 99 | 332 | 11 | 14 | 78 | 12 |
| Jun–Sept | Total for quarter 4 | 211 | 132 | 507 | 49 | 8 | 104 | 11 |
| 2018–2019 | **TOTAL FOR 2018–2019** | **672** | **319** | **1361** | **85** | **25** | **264** | **84** |
| Sept–Dec | Total for quarter 1 | 316 | 178 | 265 | 30 | 30 | 85 | 17 |
| Dec–Mar | Total for quarter 2 | 226 | 63 | 239 | 6 | 3 | 97 | 10 |
| Mar–Jun | Total for quarter 3 | 252 | 60 | 487 | 60 | 37 | 232 | 27 |
| Jun–Sept | Total for quarter 4 | 599 | 145 | 897 | 144 | 12 | 115 | 33 |
| 2019–2020 | **TOTAL FOR 2019–2020** | **1393** | **446** | **1888** | **240** | **82** | **529** | **87** |
| Sept–Dec | Total for quarter 1 | 315 | 272 | 372 | 62 | 31 | 80 | 27 |
| Dec–Mar | Total for quarter 2 | 540 | 95 | 478 | 36 | 95 | 46 | 12 |
| Mar–Jun | Total for quarter 3 | 329 | 60 | 391 | 147 | 106 | 26 | 16 |
| Jun–Sept* | | - | - | - | - | - | - | - |
| 2020–2021** | **TOTAL FOR 2019–2020** | **1184** | **427** | **1241** | **245** | **232** | **152** | **55** |

*The data for June–September 2021 had not been gathered at time of writing, therefore **these data are missing from the totals for 2020–2021.

possible that this species was present before 2018, but assistance from David Pinniger allowed us to make an identification of grey silverfish on traps from this date. Identification was difficult due to initial confusion between grey silverfish, common silverfish and firebrats (*Thermobia domestica* Packard, 1873),

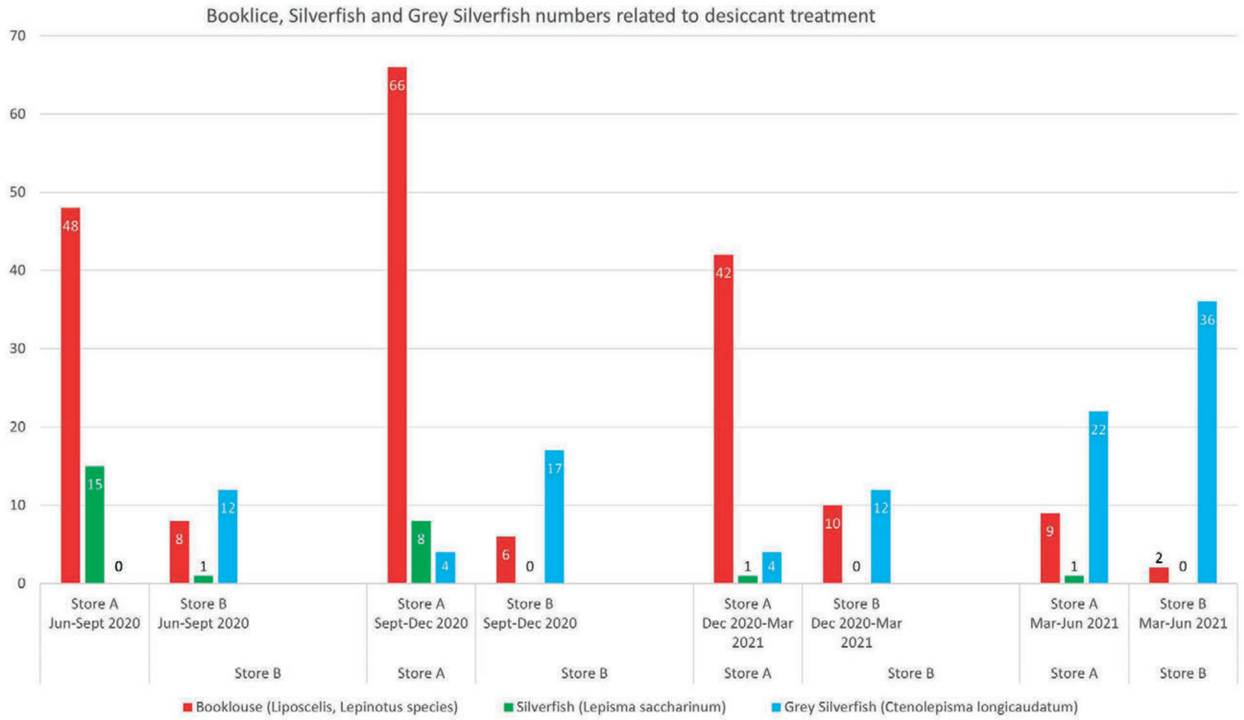


**Figure 3** Booklice, silverfish and grey silverfish numbers for two stores from June 2020 to June 2021, to track the effect of a Vazor DE desiccant application in October 2020.

especially in their nymph stages. Grey silverfish have become more common in London museums having first been identified at the Museum of London in 2015 (Moore and Steer 2017). Their spread to the UK from mainland Europe is linked to global trade and climate change, as the species prefers warmer, more humid climates (Goddard *et al*. 2016).

## Vazor DE powder treatment trial

In October 2020, the NG began trialling an amorphous silica desiccant, Vazor DE powder, to assess its effect on reducing the numbers of booklice, common silverfish and grey silverfish. It is made from diatomaceous earth, a fine powder that causes the cuticle of the insect to dry out thereby killing it. Vazor DE was trialled in an archive and two painting stores and seemed to slightly reduce booklice populations in stores A and B, and possibly the silverfish numbers in store A (Fig. 3).

There seemed to be no effect on the grey silverfish population, possibly because of limitations with the application method. Vazor DE is sprayed on with a solvent carrier that facilitates good application onto flat floor areas but is less effective for flooring with small cracks and crevices where this species likes to hide. Also, despite extensive signage and notification, some treatments were removed by cleaning.

Published information regarding the mortality rates of grey silverfish with desiccant dust is limited (Aak *et al*. 2019: 29). Experiments have shown good results with reducing common silverfish numbers because this species is more dependent on moisture (Faulde *et al*. 2006). However, grey silverfish's resilience in lower humidity may render this treatment less effective (Pinniger and Lauder 2018: 53–4, 89).

Closure of the NG to the public but increased staff presence in early 2021 made it possible to conduct trials of other pest treatments. After research and consultation with our external pest contractors, we trialled one spray treatment, Dethlac insecticidal lacquer, in February, and one gel treatment, Maxforce Platin, in April. Key considerations were for any pest treatment in display galleries to be safe for the surrounding paintings and as inconspicuous as possible.

## Dethlac treatment trial

Dethlac is sold for amateur and professional use against small crawling insects. It contains the pyrethroid ester insecticide deltamethrin and the natural insecticide

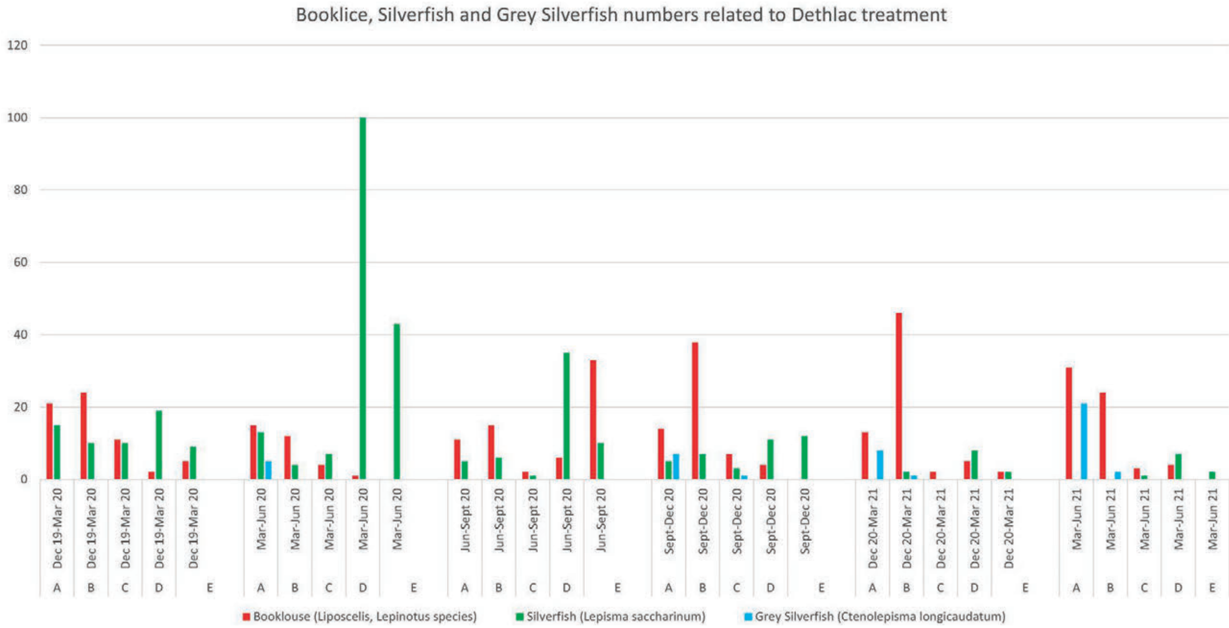


**Figure 4** Booklice, silverfish and grey silverfish numbers for galleries (A and B) and back of house areas (C, D and E) from December 2019 to June 2021 to track the effect of a Dethac lacquer spray application in February 2021.

pyrethrum. It can be sprayed on firm, non-absorbent surfaces and it dries to a lacquer finish in 15 minutes, after which the area can be cleaned with no reduction in the material's efficacy. A coating application lasts six to eight months. As only a small amount of solvent is released with the spray application and the galleries have sufficient ventilation, this material could be tested in those galleries where the specific type of flooring meant the lacquer would not be visible and would not need to be removed (A and B); it was also trialled in back of house areas (C, D and E).

In some spaces, analysis following the Dethlac treatment suggested a reduction in silverfish numbers beginning around February 2021, especially when compared to the data from the first lockdown in March–July 2020 (Fig. 4). There may also be reduced grey silverfish numbers in some of these spaces, but this is unclear as the numbers recorded of this pest were lower and more sporadic at the start.

## MaxForce Platin treatment trial

Some galleries have black marble flooring, where the lacquer spray treatment is noticeable and its removal an issue, so an alternative was sought. A Norwegian Institute of Public Health report showed success in reducing grey silverfish populations with insecticidal bait (Aak *et al*. 2019: 41). Our external pest contractor recommended the use of the product Maxforce Platin, which had been used successfully in the Netherlands and Germany against grey silverfish (Gutsmann 2019). A gel bait developed for the control of cockroaches and grey silverfish, it contains clothianidin, a neonicotinoid insecticide. It should be applied by professional operators and placed as multiple, small, evenly distributed droplets of bait to increase the probability of contact and therefore ingestion by the grey silverfish (Aak *et al*. 2019: 28). The gel was trialled in those galleries where it could be applied using an injector into crevices along the wall-to-floor join. The location for these droplets was focused around the location of the trap in each space. The trial was conducted in April 2021 in galleries F–I, which were easier to access during closure rather than the back of house areas where grey silverfish numbers were higher (Table 2). At the time of writing, the only results available are for June 2021 and so far, the data appear inconclusive, but there are suggestions of a decrease in silverfish numbers. The trial will continue and, if successful, will be expanded to further areas.

## The importance of advocacy

The PCWG advocates for IPM activities across the National Gallery and is a point of contact for anyone

**Table 2** Pest species counts for specific rooms February 2020–June 2021 to track the effect of a Maxforce Platin gel treatment in April 2021. Note: there are no results from room H for two quarters (July–December 2020), but a presumed lost trap from that space was discovered in April 2021 covering the entire period July 2020–April 2021.

| **Location** | **Date** | **Booklouse (*Liposcelis, Lepinotus* spp.)** | **Silverfish (*Lepisma saccharinum*)** | **Grey silverfish (*Ctenolepisma longicaudatum*)** | **Comment** |
|---|---|---|---|---|---|
| F (pheromone) | Mar–Jun 20 | 2 | 3 | 0 | silverfish are nymphs |
| G (blunder) | Mar–Jun 20 | 9 | 3 | 8 | grey (?) silverfish are nymphs |
| H (pheromone) | Mar–Jun 20 | 0 | 3 | 0 | silverfish are nymphs |
| I (pheromone) | Mar-Jun 20 | 1 | 0 | 0 | |
| F (pheromone) | Jun–Sept 20 | 4 | 3 | 0 | silverfish are nymphs |
| G (blunder) | Jun–Sept 20 | 19 | 7 | 0 | silverfish are nymphs |
| I (pheromone) | Jun–Sept 20 | 1 | 1 | 0 | silverfish is a nymph |
| F (pheromone) | Sept–Dec 20 | 2 | 0 | 0 | |
| G (blunder) | Sept–Dec 20 | 3 | 3 | 0 | 2 silverfish are nymphs |
| I (pheromone) | Sept–Dec 20 | 1 | 1 | 0 | |
| F (pheromone) | Dec 20–Mar 21 | 3 | 4 | 0 | |
| G (blunder) | Dec 20–Mar 21 | 10 | 0 | 7 | |
| H (pheromone) | Jun 20–Apr 21 | 10 | 11 | 0 | |
| I (pheromone) | Dec 20–Mar 21 | 1 | 2 | 0 | 1 silverfish is a nymph |
| F (pheromone) | Mar–Jun 21 | 5 | 0 | 1 | grey silverfish is a nymph |
| G (blunder) | Mar–Jun 21 | 1 | 0 | 3 | 1 grey silverfish is a nymph |
| H (pheromone) | Apr–Jun 21 | 0 | 0 | 0 | |
| I (pheromone) | Mar–Jun 21 | 1 | 0 | 3 | |

requiring information concerning pests. The group's support for trialling novel treatments against the grey silverfish population cannot be understated. Pest infestations and treatments are a regular topic of discussion and opportunities for collegial collaboration are frequently identified. When a rise in numbers of webbing clothes moth was recorded in the 2017–2018 monitoring period, members of the PCWG identified high level ledges and floor grilles in galleries as possible breeding locations for the moths and a schedule of cleaning of these spaces was implemented.

Following discussions at the PCWG, deep cleaning of back of house areas, high level cleaning in galleries, and dusting the backs of paintings and frames when they are rehung are now a regular occurrence. Staff from the operations, conservation and art handling departments collaborate on these activities, thereby drastically reducing the amount of accumulated dust and likelihood of infestations. A comprehensive review and streamlining of the IPM policy is also being undertaken.

In the case of the rising number of grey silverfish, the PCWG has been instrumental in raising awareness across the NG and acts as a sounding board for ideas. Various treatments for the grey silverfish population were discussed with group members. Scientists, conservators, operations and building and facilities staff met to discuss the health and safety implications, areas that could be treated, and whether the treatments would pose a risk to the collection. These discussions were recorded in the minutes of the meetings. The trials in collection areas were aided by the fact that all staff members were made aware early on of infestations and treatment requirements through the PCWG.

The National Gallery has recently completed a major building project in the heart of its main building: two light wells were converted to staff office space. Conservation staff worked closely with the building project team to protect the collection and incorporate IPM practices in the new office space because of its proximity to the galleries. The regular PCWG meetings provided the opportunity to establish appropriate IPM procedures, such as the use of lidded bins, food only allowed in designated areas and a cleaning contract that removes food waste every evening. These procedures were included in costings for running the new space and ways of working were incorporated into a staff handbook.

## Conclusions

The COVID-19 pandemic has presented challenges but also opportunities in managing pest numbers at the National Gallery. Repeated closures created a tranquil, dark environment for emerging pests such as the grey silverfish that was quietly becoming established before the pandemic. However, the lockdowns have also allowed time to analyse data from the desiccant trial, research and trial two alternative treatments and carry out additional deep cleaning. All three treatments trialled are easy to apply in a targeted fashion and take account of the different materials in these spaces. Advocacy and increased communication, also a result of the pandemic, are unquestionably effective in the fight against insect pests. In time, it is hoped that the results will show that these new treatments, with continued collaboration and communication with staff, can fight back against the threat of these new pests.

## Acknowledgements

We are very grateful to the following for their help with IPM work and this paper: Lynne Harrison, David Peggie, Catherine Higgitt, Joe Padfield, Charlotte Newton, Jack Coleman and Rachel Billinge.

## Materials and suppliers

- Vazor DE powder, an amorphous silica desiccant (originally purchased from Historyonics but no longer available), can be purchased from Pest Control Warehouse. A similar product from Insectosec is available from Historyonics
- Dethlac spray, and insecticidal lacquer containing deltamethrin and natural pyrethrum, is available from Amazon
- Maxforce Platin gel, a toxic bait gel containing clothianidin, was sourced via our external pest contractor and available from Pest Control Direct

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# The use of Advion Cockroach Gel Bait against the grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) in museums in Austria

Pascal Querner

**ABSTRACT** The grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) is an important museum pest that is spreading across Europe. At the last Pest Odyssey conference in 2011, it was not reported as a major museum pest but today it is thriving in new museum buildings, storage depositories and apartments. Many photographic, graphic and contemporary art collections, as well as archives and libraries, are increasingly concerned. Damage on objects has been reported by different authors and institutions across Europe and only a few treatment methods can be used against silverfish infestations. As these insects hide during the day in cracks and dead spaces inside a building (not in/on the objects themselves), the room needs to be cleaned, gaps sealed or desiccant dust applied. An object treatment is not normally the method of choice. The Advion poisonous gel bait, originally developed for ants and cockroaches, was tested against the grey silverfish in four institutions with a high infestation. Good results were achieved with a significant reduction of the infestation/activity recorded with traps. Strong secondary poisoning by animals feeding on the dead poisoned silverfish is believed to be one of the keys to this success, however, the application of Advion gel is only recommended in areas with a high infestation.

**KEYWORDS** Advion gel; poisonous bait; grey silverfish; *Ctenolepisma longicaudatum*; IPM

## Introduction

The grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905), an important museum pest, thrives in new museum buildings, storage depositories, apartments and office buildings. The risk posed by this pest is of particular concern to many photographic, graphic and contemporary art collections, archives and libraries. It is an introduced species, originating from southern Africa where it was found for the first time. It had already been reported in high numbers and as a pest from Australia in the 1940s by Lindsay (1940). For many years it was not mentioned in integrated pest management (IPM) textbooks and was rarely found or correctly identified across the world: at the last Pest Odyssey conference in 2011 it was not reported as an important museum pest. Numbers have increased significantly since, leading to the damage of paper objects, photographs and graphics in Austria, Germany and the Netherlands with tissue and glassine paper a particular food source (Fig. 1). The grey silverfish is still spreading across museums and buildings in Europe, with the first reports coming from the Netherlands (Beijne *et al*. 2002; Schoelitsz and Brooks, 2014), Austria (Christian 2002; Querner 2015; Querner and Sterflinger 2021; Querner *et al.* 2017; Brimblecombe and Querner 2021; Pinniger *et al*. 2016) and Belgium (Lock 2007). For a number of years now *C. longicaudatum* has regularly been recorded in museums

**Figure 1** Damaged tissue paper in a museum store in Vienna (© Pascal Querner).

in Germany (Sellenschlo 2007; Meineke and Mengs 2014; Pinniger *et al.* 2016), the UK (Moore *et al.* 2019; Goddard *et al.* 2016), Norway (Aak *et al.* 2019, 2021; Mattsson 2014, 2018), in the Faroe Islands (Thomsen *et al.* 2019) and in the Czech Republic (Kulma *et al.* 2018). This pest presents a new challenge for pest prevention and IPM.

Few treatment methods can be used against silverfish problems. They are found below floorboards, in cable shafts and technical facility rooms containing air-conditioning systems for example. This requires the room to be cleaned (vacuumed), gaps sealed, desiccant dust applied (Fig. 2) and/or bait gels placed. Generally, most silverfish bait currently available has a low efficiency.

**Figure 2** Desiccant dust and dead grey silverfish in a museum store in Vienna (© Pascal Querner).

## Material and methods

Recently, Advion Cockroach Gel Bait (chemical substance indoxacarb), originally developed for ants and cockroaches, has been used against the grey silverfish in Norway (Aak *et al.* 2019, 2020). In Europe, the application of the Advion gel is only registered for professional use by a certified pest contractor. It is, however, less toxic than many other biocide products registered for domestic application under the EU biocide regulation. The Advion poisonous bait was tested against *C. longicaudatum* in four locations, three museum stores and one museum (including exhibition spaces, offices and small storage) in Austria:

- Site 1, Vienna: an art store in a basement containing mainly objects and paintings, but also a large collection of graphics and other paper-based materials.

Figure 3 Application of the Advion gel drops along a wall in a museum store (© Pascal Querner).

Figure 4 Advion gel drops onto a tape on the floor (© Pascal Querner).

- Site 2, Lower Austria: a large museum store containing different object types, materials and paper
- Site 3, Salzburg: a museum store for stone objects and furniture in the basement of a football stadium.
- Site 4, Vorarlberg: a historic museum building connected to a new modern building via a gap of about 15 cm

In all locations, in the rooms with high *C. longicaudatum* numbers, very small bait drops of the gel were applied (10–20 mg) every 50 cm along the walls, next to doors and in corners (Fig. 3). In some cases, areas outside the store or exhibition rooms were also treated if insect pest monitoring confirmed a high activity, for example in hallways and staircases. These are important areas that allow the animals to move easily from one room to another. At a later stage the bait drops are applied on a tape which is more visible and can be removed after treatment (Fig. 4). Monitoring with insect traps (blunder traps, pheromone traps for moths placed on the floor and live traps) were used in all the locations to record the pest population and activity before and after the treatment. Following the bait application it was used to evaluate its success.

## Results

In all locations a significant reduction in the number of pests was observed 8–12 weeks after the application (see Table 1). Dead insects were found lying next to the bait drops (Fig. 5), evidence that the treatment was successful. Monitoring carried out over the next months and years showed a much lower abundance/activity of the grey silverfish, but individuals were still found on traps from time to time. The combined results presented in Table 1 show the data from all traps over a complete 12-month period (traps were replaced twice and checked 4–6 times per year). At the time of writing, the number of grey silverfish remains very low and the areas have not been treated again. The bait points will be left in place as long as insects are present.

## Discussion

Insect pests in museums can be eradicated using different chemical and non-chemical methods (see Querner and Kjerulff 2013 for an overview of treatment methods used in museums). Non-chemical methods are preferred in museums today: they do not damage the objects, harm the environment or compromise the health of museum staff (Strang and Kigawa 2009; Pinniger 2015). Physical treatments are achieved by freezing or humidity-controlled heating. For delicate objects and mixed materials, anoxic treatments are preferred: in Austria, the favoured option is nitrogen fumigation in chambers or tents (small objects can be treated with oxygen absorbers in small tents).

In the past DDT, methyl bromide and hydrogen cyanide were used in Austrian museums as chemical

**Table 1** Results of the monitoring with traps for the grey silverfish 2015–2020.

| | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
|---|---|---|---|---|---|---|
| Site 1, Vienna | | 441 | 157 | 253 | 319 -> **ADV** | 27 |
| Site 2, Lower Austria | 108 | 166 | 289 | 572 | 351 -> **ADV** | 109 |
| Site 3, Salzburg | | 61 | 259 | 433 -> **ADV** | 182 | 135 |
| Site 4, Vorarlberg | | | | | 747 -> **ADV** | 120 |

**Figure 5** Dead grey silverfish after the application of Advion gel drops in a museum store (© Pascal Querner).

pesticides, but these products are now banned. Pyrethroid fumigations are not an option today as they do not kill all insect stages (e.g. larvae inside objects). Success in killing 100% of insects of all stages can be achieved with toxic gases, but these also have their limitations in museums and within densely populated cities. Phosphine and sulfuryl fluoride are the only two toxic gases registered for use in Austria, but both are rarely used. Few museums in Austria today use pesticides against insect pests as the non-chemical treatment methods mentioned above offer very good alternatives.

As silverfish live inside the room (Brokerhof 2007), hiding in cracks and other small spaces during the day, they cannot be eradicated by treating the objects themselves.[1] Brokerhof suggests deep cleaning the room, the application of desiccant dust or adapting the climate by reducing the humidity. This might work for the silverfish species, *Lepisma saccharinum* Linnaeus, 1758, but experiences in Austria in the last years have shown that this method will not prevent an infestation of grey silverfish.[2] Adult animals can survive at lower humidity for quite some time while spreading and moving within a large museum building. Vacuuming and the application of desiccant dust did reduce their numbers but in highly infested buildings this was not sufficient to control the populations, spread and damage to paper and objects. Therefore, an alternative method for treating the building was needed.

The Advion poisonous bait has been used against the grey silverfish in Norway (Aak *et al.*

2019, 2020) in apartments, offices, kindergartens and also museums. Strong secondary poisoning by grey silverfish feeding on the poisoned silverfish is believed to be one of the keys to success (Aak *et al*. 2020). The results presented for the four museums and storage facilities in Austria show very similar, good results. The abundance of the grey silverfish is now at a relatively low level and no damage to objects was observed. It is assumed that new individuals are occasionally introduced with packaging material and other incoming objects, so the population in a building is very hard to eradicate completely.

For a successful application many, but very small, bait drops need to be applied every 50 cm along the walls. This makes the application in large museum buildings and storage depositories very time consuming. However, it is not suggested for a museum environment in order to reduce the application of biocides in these buildings – the use of poison bait in a museum is only recommended for areas with a high infestation. A good monitoring programme with traps to locate these hotspots inside the building is an essential first step.

As already mentioned, in Europe the application of Advion gel is only allowed by a certified pest contractor. Before using the gel there are several factors to consider: an experienced practitioner needs to evaluate the extent of the grey silverfish infestation and locate the problem areas within the building before applying the gel correctly at sufficient points.

## Conclusions

Initial results indicate that Advion Cockroach Gel Bait may be an effective treatment for high infestation levels of the grey silverfish (*Ctenolepisma longicaudatum*) which is resistant to non-chemical treatments. Traditionally, it has been used to effectively deal with other silverfish species infestations including *Lepisma saccharinum.* How the surface of objects react to the gel and materials in museums should be tested in the future to prevent damage, but direct application onto tape reduced this problem to some extent.

## Acknowledgements

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## Notes

1. For treating the objects see Wagner 2019 and the paper by Wagner *et al*. in this volume for three treatment methods that can be used against the grey silverfish.
2. For the biology of the grey silverfish see Lindsay 1940 and Aak *et al*. 2019, 2021.

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# First occurrence of *Oligomerus ptilinoides* (Coleoptera: Ptinidae) in domestic premises in the UK

Matthew Paul Davies and Jonathan Binge

**Figure 1** *O. ptilinoides* from a loft of a domestic property in Kent, during August 2020 (© Jonathan Binge, Killgerm Chemicals Ltd).

## Introduction

In 2020 the Mediterranean furniture beetle, *Oligomerus ptilinoides* (Wollaston, 1854), was identified in two domestic properties in the UK. These records are believed to represent the first identifications of *O. ptilinoides*, in the UK, outside of the museum and cultural heritage sector. These findings add to an existing UK record of *O. ptilinoides* at Hampton Court Palace from 2015, which has since been eradicated. The beetles were found in alder plywood flooring and a hazel branch from a storeroom and were eradicated in 2018 by freezing and removal of affected items (Higgs *et al*. 2019). No previous reports of *O. ptilinoides* are known from domestic premises in the UK.

## Methods

Samples were submitted by public health pest control operators to the insect identification service at Killgerm Chemicals Ltd. They were identified by Killgerm entomologist Jonathan Binge via microscopy and dichotomous key (Zahradník 2013) with assistance from David Pinniger (DBP Entomology Ltd) and Darren Mann (Oxford University Museum of Natural History).

## Results

The first identification of *O. ptilinoides* was in late June 2020 from the first-floor bedroom of a domestic premises in Cranleigh, Surrey, where two adult beetles and flight holes were noted in a wooden bedframe. A further incidence of activity was reported in a loft of a domestic property in Kent during August 2020, with approximately 37 adult beetles found (Fig. 1).

## Discussion

The potential for misidentification of *O. ptilinoides* is noted due to superficial similarities with *Stegobium paniceum* (Linnaeus, 1758) and *Anobium punctatum* De Geer, 1774. However, at up to 7.5 mm, *O. ptilinoides* is larger (Fig. 2). Identification features include

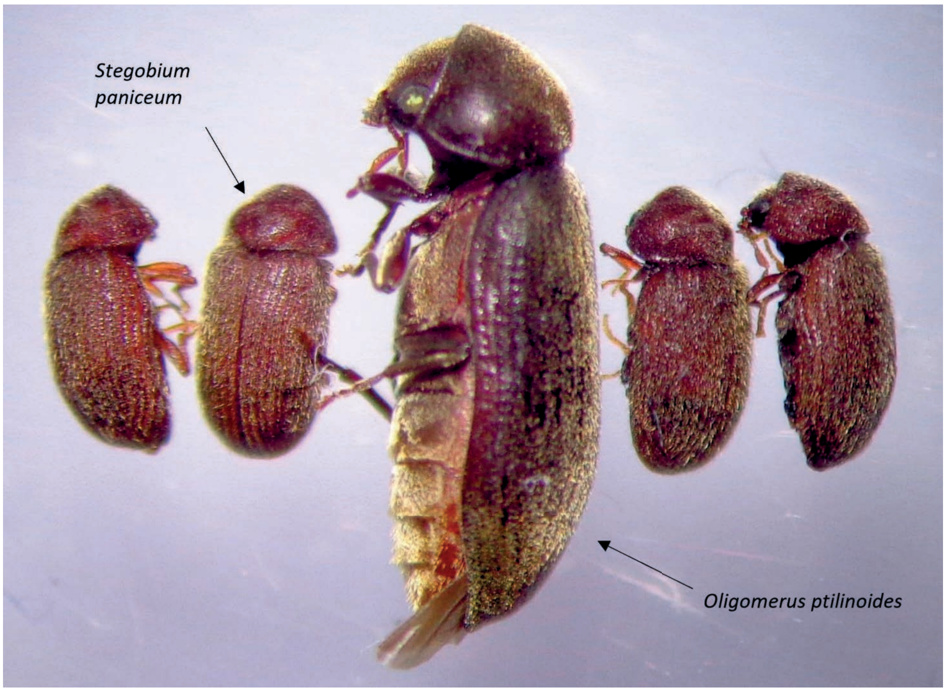


**Figure 2** *O. ptilinoides* and *S. paniceum* (© Jonathan Binge, Killgerm Chemicals Ltd).

antennae of 11 antennomeres with the terminal three elongate. Eyes have sparse, long, erect hairs. The pronotum is convex with no central elevation like *A. punctatum*. Exit holes are circular and 1.3–3 mm in diameter in comparison to *A. punctatum*, which are 1.5–2 mm, and *Xestobium rufovillosum* (De Geer, 1774) at 3 mm. Frass is peanut-shaped and circular in diameter. Adults fly from early March to September which is when sightings may be made.

*O. ptilinoides* develops in dead wood of broad-leaved trees such as lime (*Tilia* spp.), poplar (*Populus* spp.) and oak (*Quercus* spp.). It develops in timbers with moisture contents of 11–16%, which includes hardwoods and well-seasoned softwoods. It is also recorded in pallets and crates. Extensive damage can be caused to furniture, statues, wooden art, easel painting stretchers, paints on wood and roof timbers. Control measures involve the removal and treatment of affected items with a suitable woodworm fluid insecticide, thermal humidity chambers and freezing. Cultural heritage institutions and public health pest control operators are alerted to these findings, requested to seek appropriate identification, and encouraged to exercise vigilance.

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# Battling booklice in Scottish galleries, libraries, archives and museums

Jeanne Robinson, Joseph C. Jackson and Ashleigh L. Whiffin

## Introduction

The aim of this poster presentation is to aid in the identification of winged booklice such as *Dorypteryx domestica* (Smithers, 1958) (Fig. 1), and to raise awareness of the spread of *Dorypteryx longipennis* Smithers, 1991 (Fig. 2) across Scotland and to provide a way of identifying the species. Booklice are all too frequently encountered in galleries, libraries and museum stores, and the arrival of new species of booklice can be an indicator that integrated pest management (IPM) is failing in a particular area. It is important to be able to recognise booklice in all their forms, as winged booklice may not be recognised as booklice at all. The environmental conditions favoured by the various synanthropic or domestic booklice are generally unfavourable for collections storage, so recognising increases in any of their populations can highlight when environmental controls are suboptimal.

In Britain there are 98 Psocoptera or psocid species, including barklice and booklice, four of which are encountered in galleries, libraries and museums: *Dorypteryx domestica* (Smithers, 1958) (Fig. 1), *Liposcelis bostrychophila* Badonnel, 1931 (Fig. 3), *Lepinotus reticulatus* Enderlein, 1904 (Fig. 3) and *Badonnelia titei* (Pearman, 1953) (Fig. 3). There is however, a fifth species which is a more recent arrival to Scotland, *Dorypteryx longipennis* Smithers, 1991 shown in Figure 2 (a winged booklouse). After originally being discovered in Luxembourg in 1988, Dublin in 2004 and Leeds in 2010, *D. longipennis* has earned the title of an accomplished traveller. The first record of this species in Scotland was in 2016, where it was discovered on blunder traps in Summerlee Museum of Scottish Industrial Life, Lanarkshire. Populations had spiked after a failing in the environmental controls (Robinson 2017). Examples of *D. longipennis* and *B. titei*, present in collections in Aberdeenshire since 2012 and in Edinburgh at the National Museums Collection Centre since 2019, have subsequently been identified, albeit at low levels. These species are often more widespread but overlooked.

A simple identification tool could prove invaluable in helping museum staff raise awareness of the different types of booklice in areas housing collection items. The latest Royal Entomological Society (RES) Psocoptera Handbook (New 2005) does not include *D. longipennis* and there is currently no resource specific to museums, galleries and libraries which includes it. Due to its similarity to *D. domestica*, it is likely that even when institutions are able to identify their booklice to species, it has been overlooked. As this species has now made its way into numerous Scottish institutions, we hope this guide will assist in mapping the spread of *D. longipennis*.

Booklice are often so commonplace in collections storage areas, colonies can arise consisting of multiple species making it difficult to relate damage to a specific species. Although *D. longipennis* is not considered a collection pest, little is known about its ecology. It will be interesting to see how the booklice fauna changes in quantity and diversity with climate change and if there are accompanying changes in types and frequency of collection damage.[1]

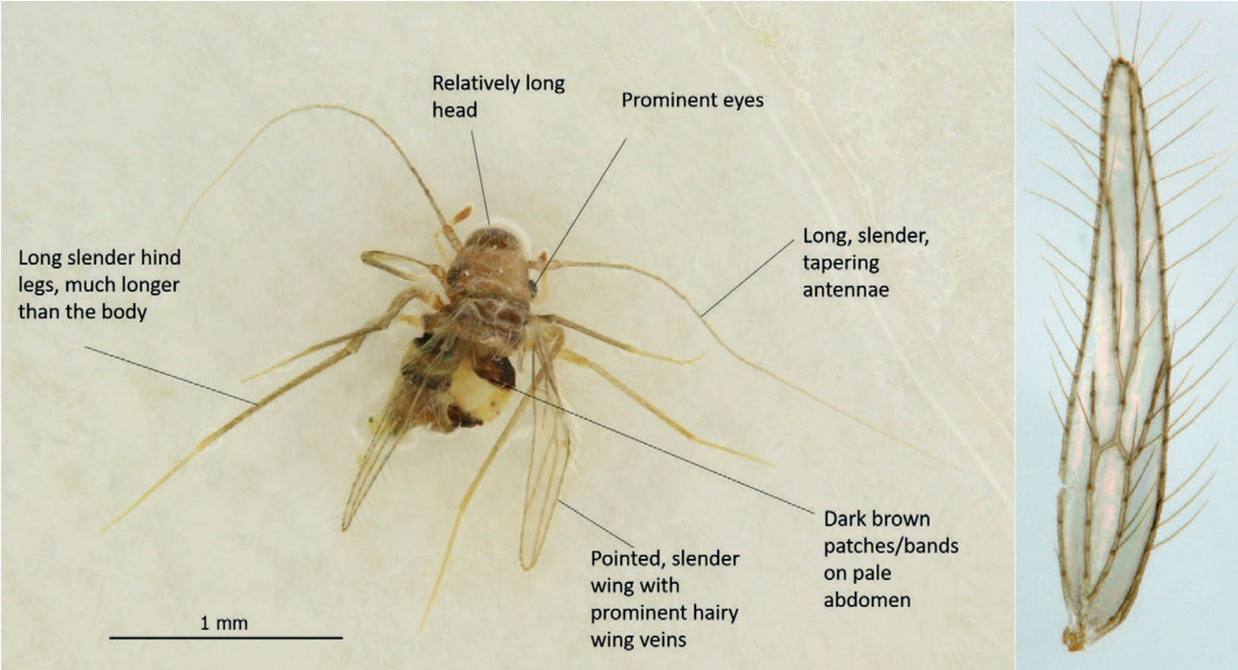


**Figure 1** *Dorypteryx domestica* (© Ashleigh Whiffin, National Museums Scotland).

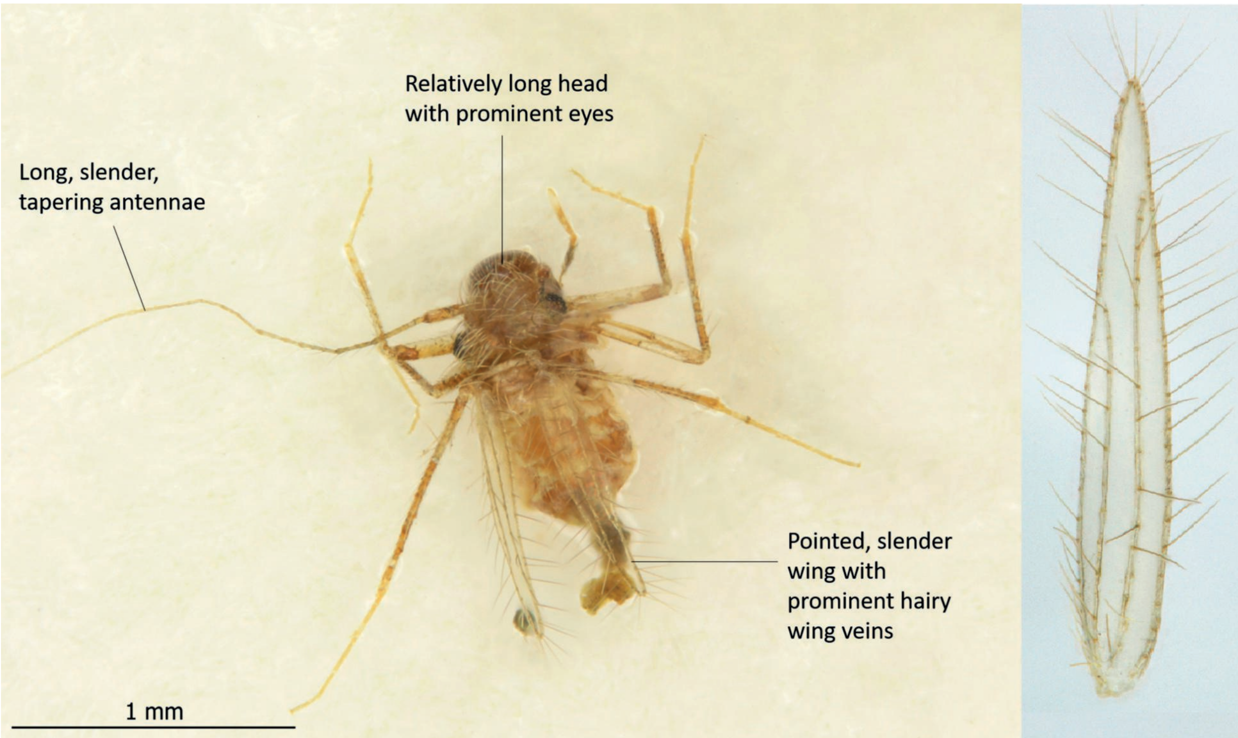


**Figure 2** *Dorypteryx longipennis* (© Ashleigh Whiffin, National Museums Scotland).

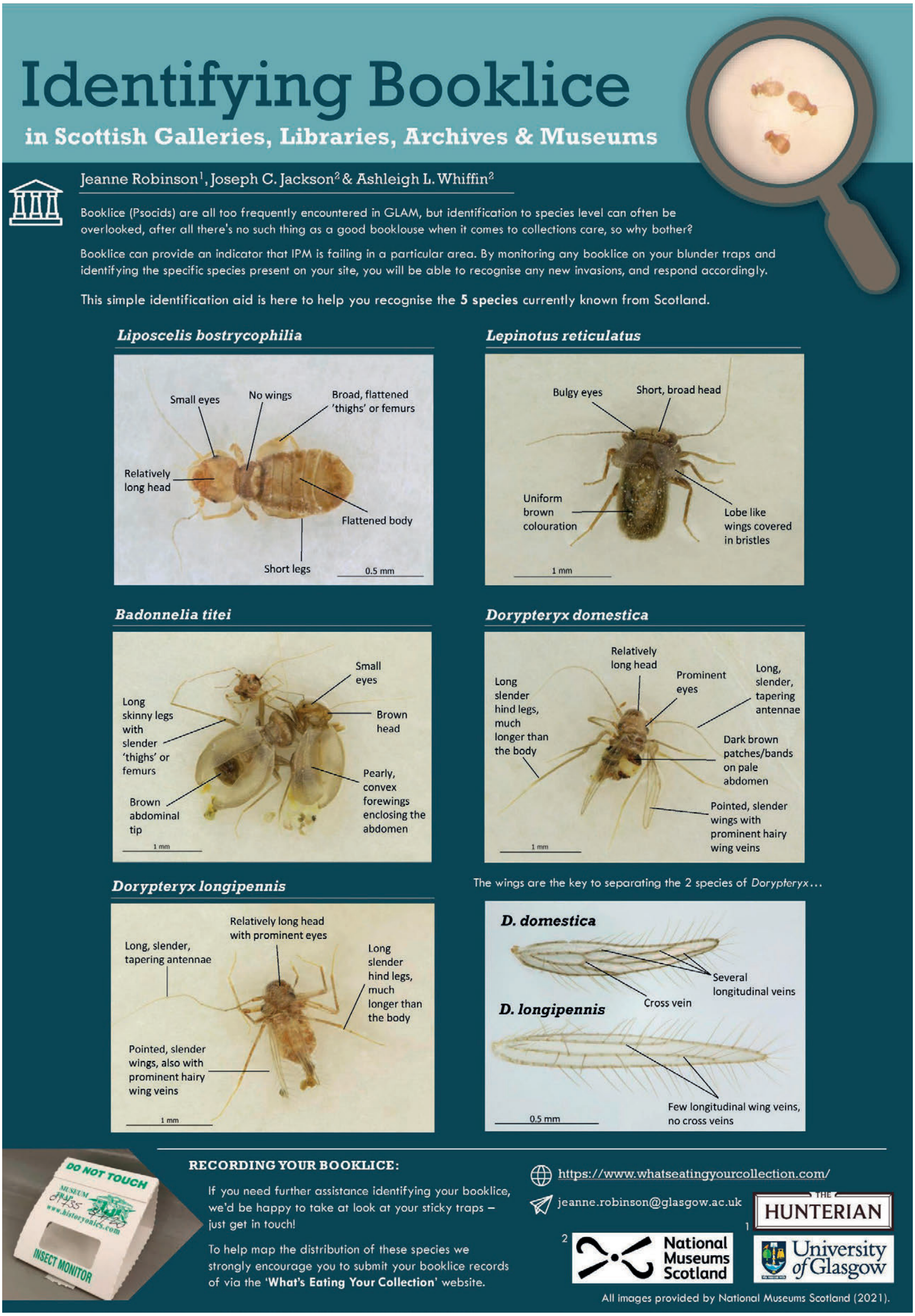


**Figure 3** Identification poster (© Ashleigh Whiffin, National Museums Scotland).

## Note

1. To help map the spread of this species we strongly encourage people to submit their booklice records via ‘What’s Eating Your Collection?’: https://www.whatseatingyourcollection.com/.

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# Seasonal changes in the distribution of head capsule size of a silverfish species

Hiroki Watanabe, Rika Kigawa and Tom Strang

## Introduction

Silverfish occurring in museums can be harmful to collections made from organic materials including paper. Ecological data of insect pests such as population dynamics can be useful to control harmful pests in museums. Age- or stage-structured models are often used to describe the growth of populations. In this study, we collected and analysed data regarding the seasonal changes in the frequency distribution of head capsule width (HCW) of a silverfish species (Fig. 1) found in Japan. HCW is used to differentiate instars of insects (Dyar 1890) and here, it is used as an alternative to age/stage.

## Materials and methods

The monitoring of the silverfish population was conducted in a certain section of a building. The test site had no air-conditioning system and the temperature reflected the outside seasonal changes (20–30 °C). The test site had a concrete floor with an approximate area of 230 $m^2$ and was surrounded by walls approximately 160 m long in total. A pyrethroid insecticide was applied on the floor along the wall and approximately 50 adhesive traps (428 × 44 mm) were set along the wall. The silverfish individuals lying dead on the floor or captured by the traps were collected monthly and the HCW of each individual was measured under a microscope (Fig. 1). The sets of HCW data were represented in histograms with 0.1 mm intervals to analyse the population's size structure.

## Results and discussion

Figure 2 shows the monthly changes in the number of silverfish individuals collected in the test site. The graph suggests that the population size grew in summer and autumn, becoming the largest in November and then declining in winter. The HCW distribution indicated that, from winter to spring, the mid-size individuals, belonging to 0.7 mm and 0.8 mm classes, were the most dominant. An example in April 2020 is shown in Figure 3a. In July, a new peak appeared in the 0.5 mm class (Fig. 3b), suggesting that a new generation of early stage larvae had emerged. These larvae were estimated to have hatched from eggs that were laid in April–May. The 0.5 mm class was most dominant until October–November, suggesting that the addition of early stage larvae to the population continued. In December, the peak shifted to the 0.7 mm class (Fig. 3c). This implied that oviposition of the year had ended, causing fewer individuals to be added to the population, and that the body size of previously born individuals had grown.

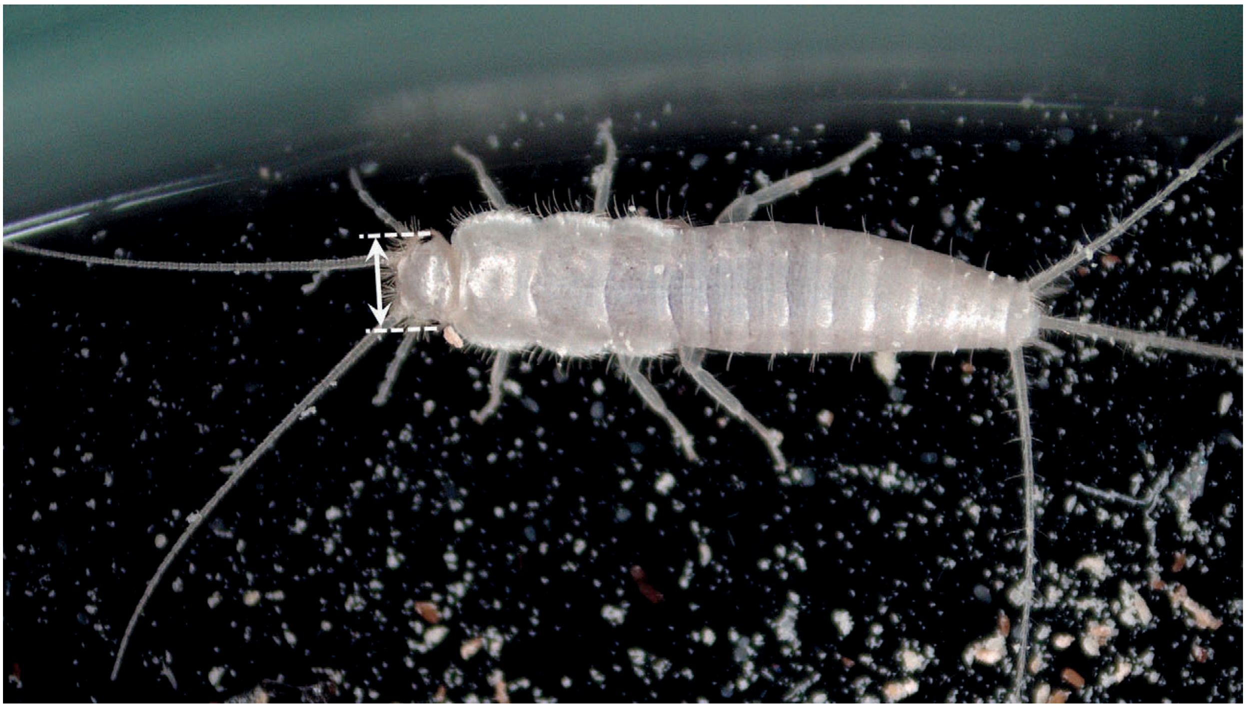

**Figure 1** Photograph of a silverfish. It should be noted that the species has not yet been identified and investigations are ongoing. The arrow represents the head capsule width (© H. Watanabe 2021).

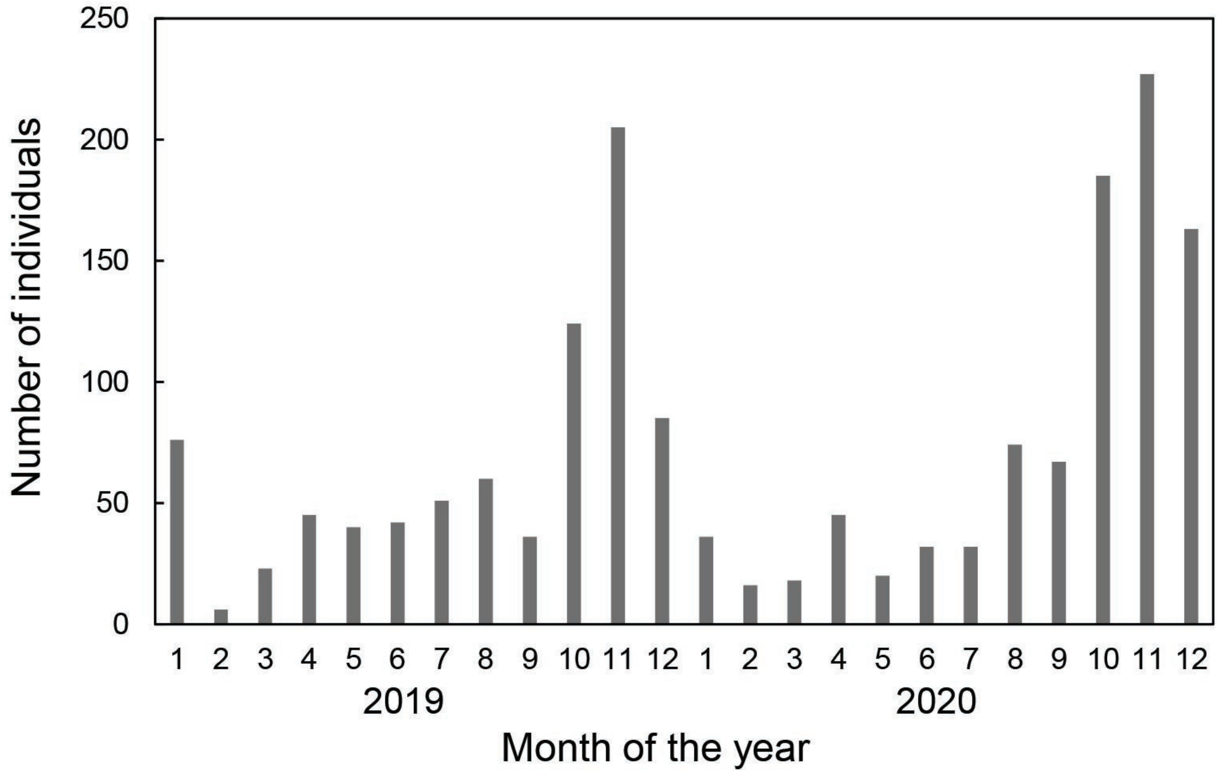


**Figure 2** Number of silverfish individuals collected monthly in the test site. (© H. Watanabe 2021).

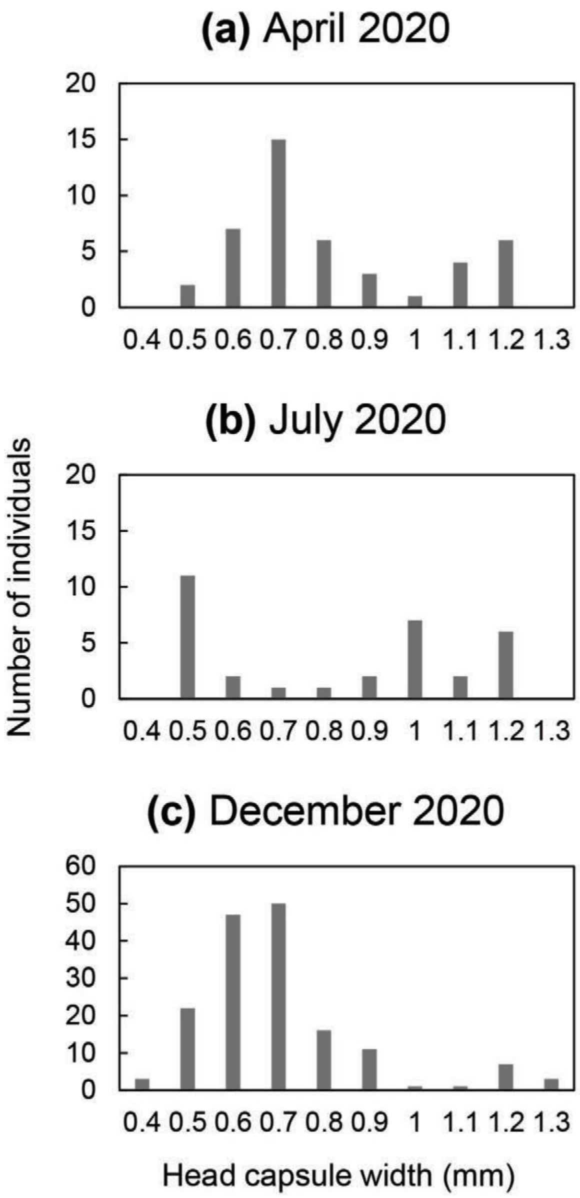


**Figure 3** HCW distribution of silverfish collected in April, July and December 2020 (© H. Watanabe 2021).

## Conclusions

The monthly distributions of HCW appeared to reflect the reproduction and development of the silverfish in an indoor environment, information that is important for building population dynamics models of this species. Such models could be used for examining the consequences of pest management programmes in exhibition halls or collection storage rooms in museums.

## Acknowledgements

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# Mice and moths: from one infestation to another

Greg Fee

## Introduction

This poster presentation looks at how controlling rodent pests may lead to an insect pest infestation. An observation which we and integrated pest management (IPM) practitioners have previously noted is an undeniable correlation between increasing numbers of clothes moth (*Tineola bisselliella* (Hummel, 1823)) following the control of house mice (*Mus musculus* Linnaeus, 1758). Effective control of mice often includes the use of rodenticides but there are downsides, one of which is the lack of control over where poisoned mice die. This is often in inaccessible areas such as under floors or inside wall and ceiling voids. The bodies of the mice can then lie host to a range of insect pests. With each dead mouse the concentration of insects found appears much higher than we would normally expect to see on an infested textile, for example (Figs 1–3). Figure 4 shows a mouse which was placed in a floor void for a 5-month period; on close inspection *T. bisselliella* larvae can be seen on the body. We also noted a number of adult moths on the wing in the test area. Figure 5 illustrates a mouse caught on a long-forgotten physical trap together with large numbers of cast skins of the larvae of the brown carpet beetle (*Attagenus smirnovi* Zhantiev, 1973), another very significant pest affecting museum and cultural heritage sites. Again, the high concentration of insects from only one dead mouse is evident.

**Figure 1** Mouse carcass with adult common clothes moth (© Greg Fee 2021).

**Figure 2** Close-up of common clothes moth larvae feeding on a mouse carcass (© Greg Fee 2021).

These examples show how the detection of either a rodent or insect infestation can indicate a potential secondary unseen pest infestation. It also highlights how the control of rodents with rodenticides has the potential for far-reaching and long-lasting unseen negative effects by contributing to increased insect pest activity. Although we believe that the use of rodenticides is still a vital tool in the effective control of mice (especially in inner city environments), it does put an emphasis on the use, where possible, of other control measures such as physical trapping to remove the controlled rodent carcasses.

Other factors such as proofing should also be a primary consideration to help prevent rodent ingress in the first instance. When rodent activity is discovered, a planned approach should be used to fully investigate the area in order to identify and eliminate potential points of ingress.

**Figure 3** This epicentre of activity creates a bomb-like effect with the high concentration of insects ready to dissipate to the surrounding area once the available food source has been depleted.

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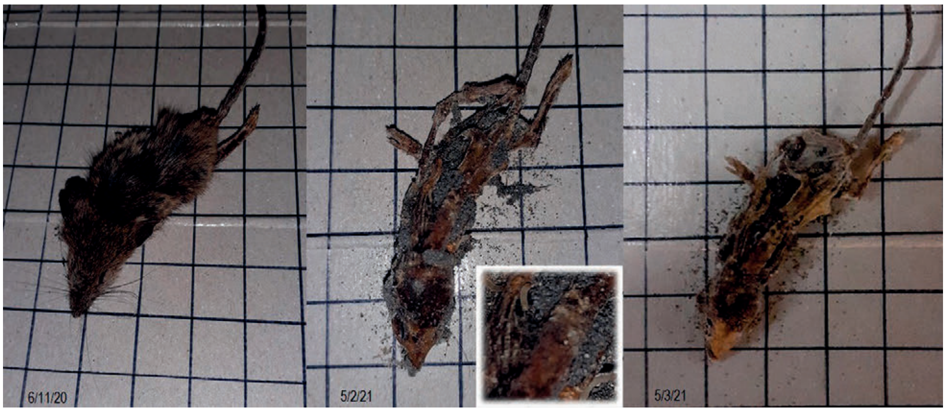


**Figure 4** Image of a mouse carcass over a 5-month period (© Greg Fee 2021).

**Figure 5** Image of a mouse carcass in a physical trap (© Greg Fee 2021).

# New adventures in IPM quarantine: still work in progress

Volker Hingst

## Introduction

In July 2017, grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) was detected for the first time in our work area. Therefore, a quick and easy method was needed to create quarantine areas and rooms. The fastest solution was achieved by sticking a double-sided pressure-sensitive adhesive tape around a stack and palette respectively (Fig. 1) or on the threshold.

**Figure 1** Typical quarantine area. Sticky traps are placed on and under plastic pallets for monitoring. Yellow double-sided adhesive tape surrounds the pallets (© Volker Hingst 2021).

## Adhesive tape

The first double-sided tape used proved to have a good catch rate, but only for larger nymphs and adult insects. Early nymph stages were not caught on this tape. When removing, the adhesion was so strong that it could only be removed by heating and peeling off. Therefore, it was necessary to find a more suitable adhesive tape with certain requirements.

- The adhesive tape width is at least 50 mm and has two sides with different adhesion forces.
- The bottom side has a relatively weak adhesion but adheres securely to different floor coverings.
- The top side has very strong adhesion so that even small or light insects adhere securely to the adhesive.
- The supporting material is tear-resistant, flexible, conformable, and strikingly yellow in colour.

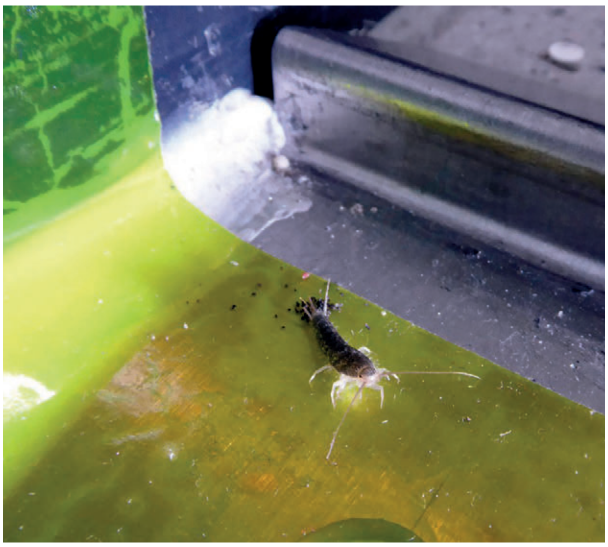

**Figure 2** Grey silverfish caught on the adhesive tape. An adult female *Ctenolepisma longicaudatum* sticks to the yellow adhesive tape inside the rigid stainless steel barrier (© Volker Hingst 2021).

**Figure 3** View into the quarantine room. The M-style barrier is fixed permanently to the floor on the threshold with the yellow adhesive tape inside the barrier. Quarantine racks are surrounded by the double-sided adhesive tape (© Volker Hingst 2021).

- The adhesive tape can be removed easily in one piece without leaving any residue at the end of the quarantine measure.

Even the best double-sided pressure-sensitive adhesive tape such as the yellow double-sided adhesive tape from allbuyone-Grip Tape GT 702 or the obvious identical product from 3M-9195 (Fig. 2) is not a permanent solution for door areas that are subject to a high frequency of use like the quarantine room. A sufficient solution as a secure and rigid barrier is needed.

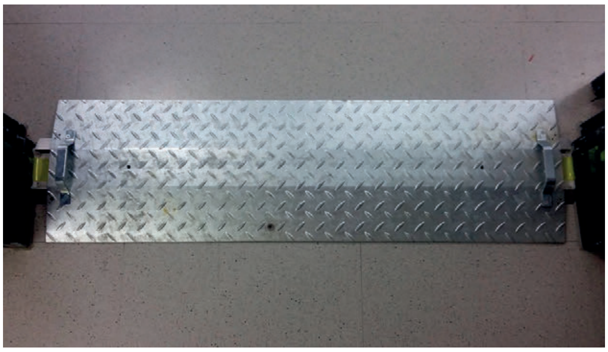

**Figure 4** New cover plate. The prototype made of galvanised sheet steel fits perfectly into the M-style barrier, which is located below. Handles on the left and right side provide easy handling (© Volker Hingst 2021).

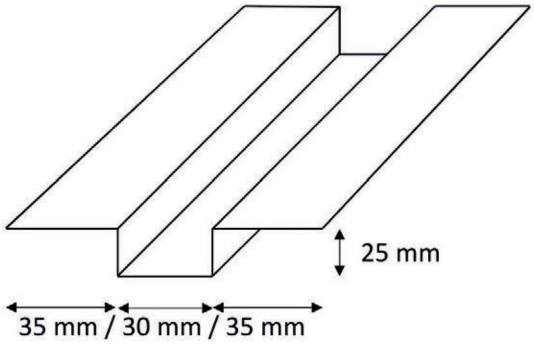


**Figure 5** Sketch of a U-style barrier (© Ines Unger, Museum Wiesbaden, Germany).

## Rigid barrier and new cover plate

After some consideration, the idea of a cable bridge made from stainless steel was suggested (a cable bridge from Julius Zapp GmbH, Lemgo in two different width versions, distributed by Projekt Rheinland, Cologne). This is fixed permanently to the floor on the threshold. The double-sided adhesive tape together with the rigid M-style barrier (Fig. 3) prevents contamination by crawling insects such as *Ctenolepisma longicaudatum* excellently. The barrier protects against the undesired contact with the adhesive tape and protects the adhesive from dust and dirt, so the tackiness from the adhesive tape will last for about four weeks. An obstacle of approximately 15 mm height must be overcome because the steel barrier is assembled above the floor level. Especially for heavy trolleys etc. this is problematic and can damage the thin steel.

Due to the disadvantages recognised in this barrier design, it was necessary to manufacture a new cover plate made of stronger material and with a flat crossing angle for the short-term covering of the barrier (Fig. 4). Now even heavy trolleys can easily be pushed over. Future versions should be made of aluminium to reduce the weight.

## Further development

The quarantine barrier will be further developed by cutting a slit in the screed to insert a U-style barrier (Fig. 5) in order to create an easier and better way of overcoming the barrier with trolleys.

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# Targeting grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905): implementing an effective IPM programme in a small to mid-sized institution on a limited budget

Antonia Reime Aabø


**Figure 1** Quarantining in the repository (© Reime Aabø).

**Figure 2** Specimen contained by tape (© Reime Aabø).

## Introduction

The regional archive for east Norway has 6000 m of archival records in its care. In the Nordic cold, dry climate, insects were seldom an issue in archives and libraries, but in 2017 an infestation identified as grey silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) was detected, requiring a fresh approach to pest management.

## Challenges

High staff workload and budgetary restrictions forced us to find time and cost-effective pest management measures, while a critical lack of space ruled out separate quarantine areas. Additionally, the integrated pest management (IPM) model was not commonly used in Norway, so staff pursued training abroad via institutions with well-established IPM programmes.

## Methods

Using blunder traps, we prioritised confident identification of *Ctenolepisma longicaudatum.*

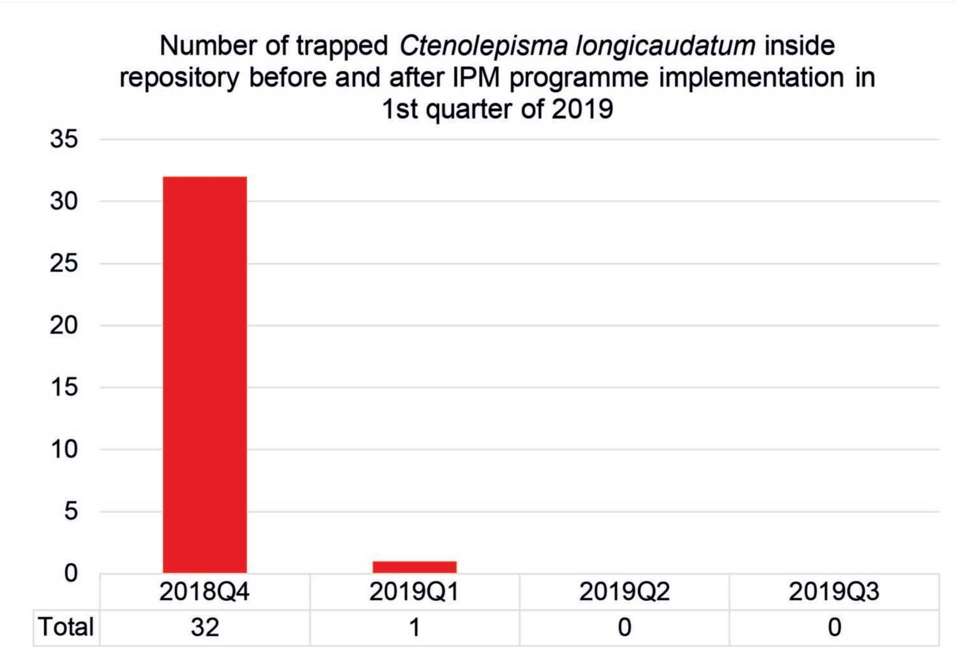


**Figure 3** Results from blunder trap monitoring.

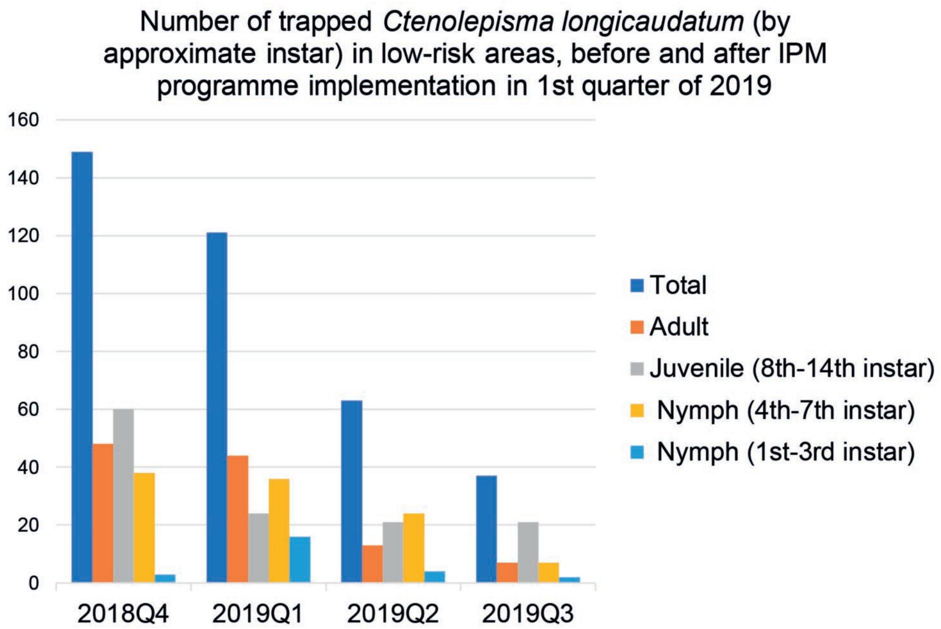


**Figure 4** Recording age diversity within the population provided useful data for targeted treatment as well as for assessing the overall impact of the measures.

Monitoring revealed both distribution and routes of ingress – namely packing materials, with corrugated cardboard a particular problem. Protocols were established to manage all deliveries entering the building and quarantining them within designated areas. Packing material was disposed of immediately. Low-temperature treatment was included in accession procedures as standard. Using household freezers, core temperature was monitored to –20 °C in accordance with species mortality data: –0 °C for hatched insects and –15 °C for eggs (Mattsson 2018). In the repository, ambient conditions were lowered from 20 °C/50% RH to 15 °C/43% RH to inhibit *Ctenolepisma longicaudatum* activity (Aak *et al.* 2019; Moore *et al.* 2019). Accessions awaiting treatment stored on plastic pallets were isolated using high-adhesive double-sided tape on the floor to contain specimens (Fig. 1) while being closely monitored for pest activity (Fig. 2).

## Outcome

Ongoing monitoring using blunder traps and staff observations has indicated eradication of *Ctenolepisma longicaudatum* in repositories (Fig. 3) and an overall decrease in non-storage areas by 76% over the period of a year (Fig. 4).

## Conclusions

In identifying key measures, we implemented an effective IPM programme on a restricted budget, while at the same time ensuring collection safety and maintaining efficient workflows. Extensive use of quarantine zones in a 15 °C environment contained and inhibited pest movement. Efficient procedures for the disposal of waste packing material and preventive low-temperature treatment of all accessions eliminated *Ctenolepisma longicaudatum* in high-risk areas. These measures will continue to inform IPM routines for our new storage facility currently under construction, enabling our institution to receive and preserve 40,000 m of archives.

## Acknowledgements

I am indebted to Johan Mattsson, Mycoteam, Norway; Armando Mendez, Natural History Museum, England; Amy Sampson, The National Archives, England; and Tom Strang, Canadian Conservation Institute, Canada.

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# Selective feeding on paper and cardboard and limited dispersal of the long-tailed silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) in archives

Volker Busch, Sabine Prozell and Matthias Schöller

## Introduction

The long-tailed silverfish (*Ctenolepisma longicaudatum* Escherich, 1905) is an emerging pest in Germany and has been recorded in six sites at Akademie der Künste (Academy of Arts) in Berlin. In order to evaluate potential damage, semi-field trials were conducted in four archive rooms.

## *Ctenolepisma longicaudatum* feeding choice trial

Sixteen different types of paper and cardboard (pieces measuring 10.5 × 7.0 cm) (Fig. 1) were exposed in choice trials to the naturally occurring silverfish population for 18 months starting in November 2019. This set-up was placed in one room with chemical control using toxic gel baits and in another room without control measures. Monitoring sticky traps were placed. Significant differences in damage were observed. About 60% of a glassine paper was consumed. Slight damage of this paper was observed in June 2020 and severe damage one year later (Fig. 2A). Some types of cardboard such as archive boxes were superficially eaten (Fig. 2B), while others were still intact at the end of the observation period (Fig. 2C).

In two different rooms, the same types of paper were damaged or not damaged, respectively, i.e. the identical result was repeated in two different sites. Less damage and lower trap catches were recorded in the room with chemical control. This result indicates different threats by silverfish for different types of paper and cardboard. Future studies are needed to elucidate the reasons for acceptance or rejection of paper as food by silverfish such as analysis of paper chemistry concerning digestible, repelling or toxic compounds. This could also help in choosing resistant paper for practice in future.

## Activity on shelves field trial

In a second field trial, silverfish activity was monitored with sticky traps on the floor versus on shelves in archive rooms. The following set-up was installed in three rooms: three sticky traps were placed on the floor and an additional three traps on smooth metal shelving close to the traps on the floor (Fig. 3). In another room, three traps were placed on pallets and three on the floor. The traps were observed every three months over a period of two and a half years. In all three sites, silverfish were present but not a single silverfish was caught on the shelves or the palettes. However, the number of silverfish caught decreased during the observation period, presumably due to more frequent cleaning of the floor and chemical control with gel baits (Fig. 4).

This result indicates limited dispersal and reduced potential for damage by long-tailed

**Figure 1** Choice trial design with 16 different types of paper and cardboard (© Matthias Schöller 2021).

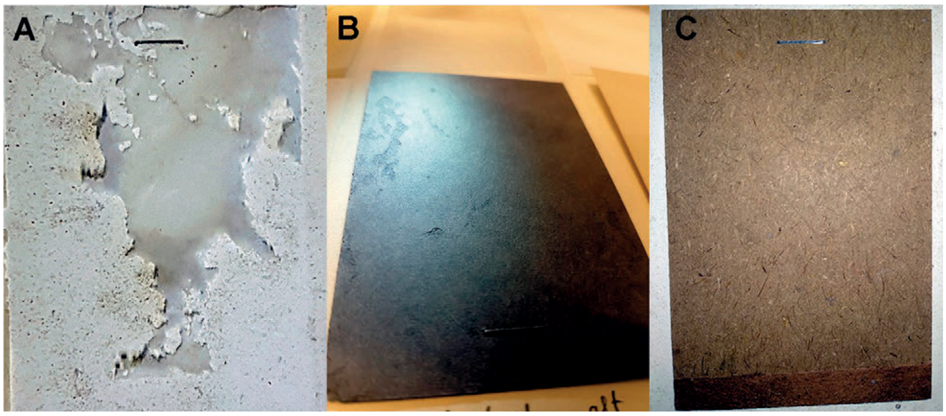


**Figure 2** Quality of paper and cardboard after exposure to *Ctenolepisma longicaudatum* for 18 months in the semi-field choice trial: (A) glassine paper (B) thin cardboard for archive packaging (C) straw cardboard (© Matthias Schöller 2021).

**Figure 3** Field trial on dispersal of *Ctenolepisma longicaudatum* in the archive room: two sticky traps on the shelf, one sticky trap on the floor and gel bait station visible (© Matthias Schöller 2021).

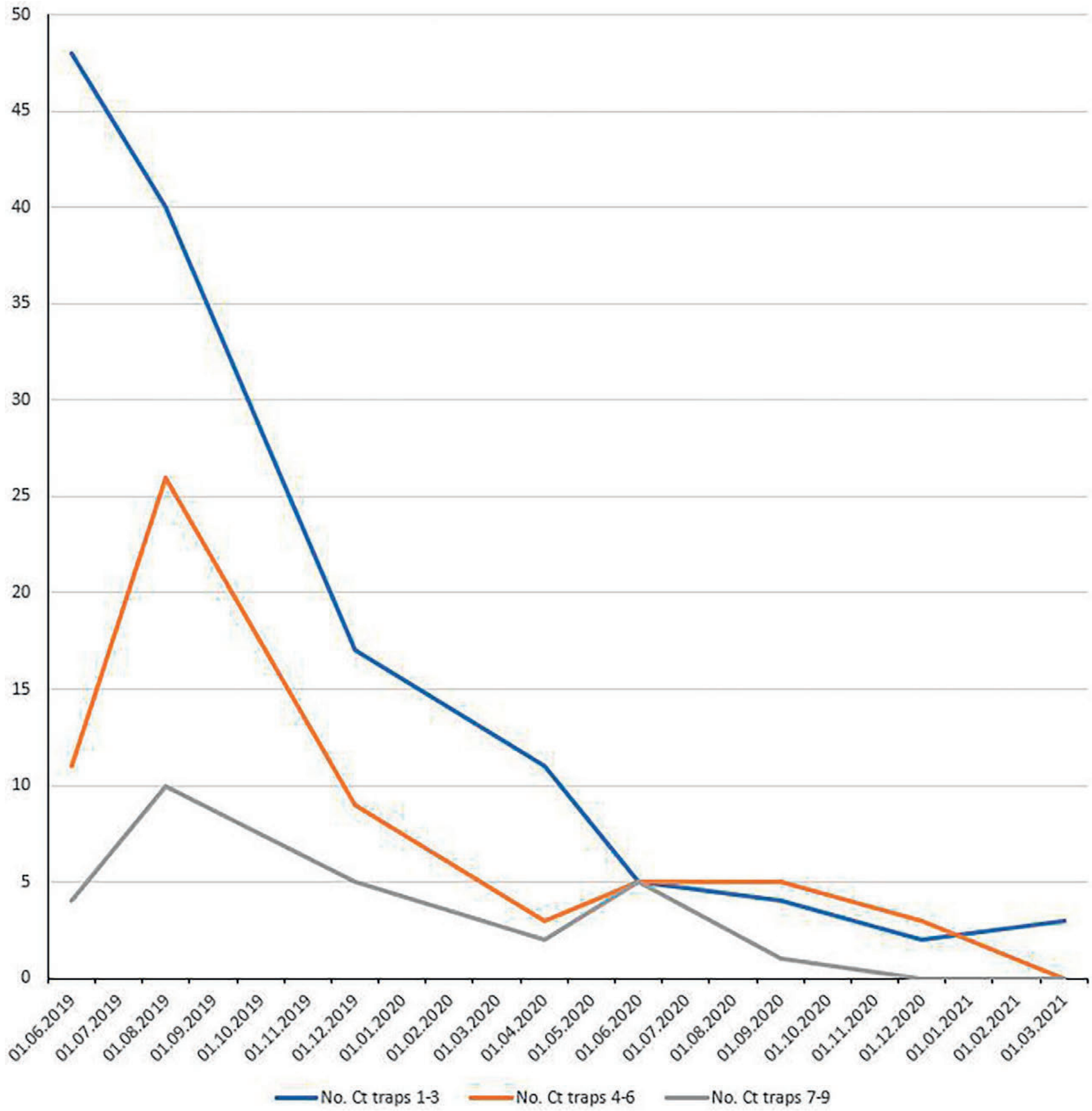


**Figure 4** Number of *Ctenolepisma longicaudatum* recorded in three sticky traps each in the field trial on dispersal in three archive rooms on the floor (none on shelves, not shown).

silverfish in the archive rooms for objects on shelves and pallets. Future studies could determine the exact roughness of the metal needed for the silverfish to climb on the vertical surfaces. However, the fact that no silverfish activity was recorded on pallets, even though they are capable of climbing on pallets, indicates a behavioural component (foraging) as well.

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# Conservation of cultural heritage: biological control of the common furniture beetle (*Anobium punctatum*) with the parasitoid wasp species *Spathius exarator*

Judith Auer, Christine Opitz and Alexander Kassel

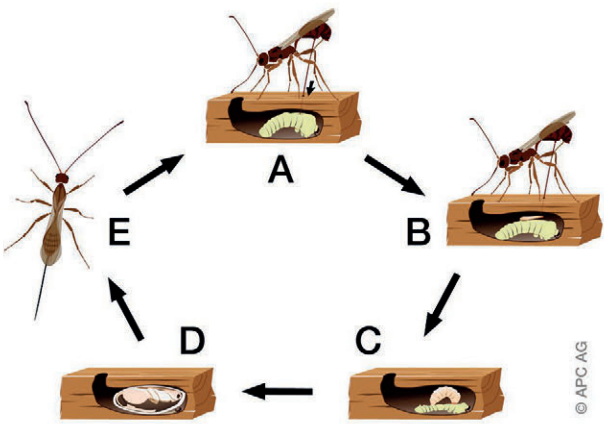


**Figure 1** The life cycle of *S. exarator*: the braconid wasp localises its host within the wood, paralyses it (A), followed by oviposition onto the *A. punctatum* larva (B). The wasp larva feeds from the beetle larva (C). The anobiid larva dies and *S. exarator* larva pupates (D) and hatches about 28–30 days after oviposition (E).

## Introduction

The common furniture beetle *Anobium punctatum* De Geer, 1774 (Coleoptera, Anobiidae) is considered the most abundant and destructive wood pest in churches and museums (Child and Pinninger 2014). The infestation can be efficiently controlled by releasing a mass of the parasitoid wasp species *Spathius exarator* (Linnaeus 1758) (Hymenoptera: Braconidae) which are the most frequent antagonists (Lyngnes 1956; Auer *et al.* 2020). The braconid wasp parasitises its host species by piercing its ovipositor through the wood surface followed by oviposition onto the beetle larvae. After development, it emerges as an adult through a self-gnawed hole (Fig. 1) (Auer and Kassel 2017). This tiny 0.5 mm wood hole can easily be distinguished from the 2 mm wide exit hole of *A. punctatum*, which enables us to monitor the parasitation success.

## Material and methods

Between 2012 and 2021, the beneficial wasps were released in more than 200 different *A. punctatum*-infested churches, castles and museums. At least 12 treatments over a period of three years were performed, followed by single releases. Between 400 and 2000 wasps were applied per treatment. A parallel monitoring programme was established. On defined infestation plots, wasp and beetle exit holes were counted before the start of treatment and at the end of each year. Parasitation rates were calculated as the proportion of parasitised *A. punctatum*:

$$\frac{\textit{no.S.exarator exit holes}}{\textit{(no.S.exarator exit holes)+(no. A. punctatum exit holes)}}$$

## Results

Parasitism rates in *A. punctatum*-infested buildings significantly increased after treatment for one year

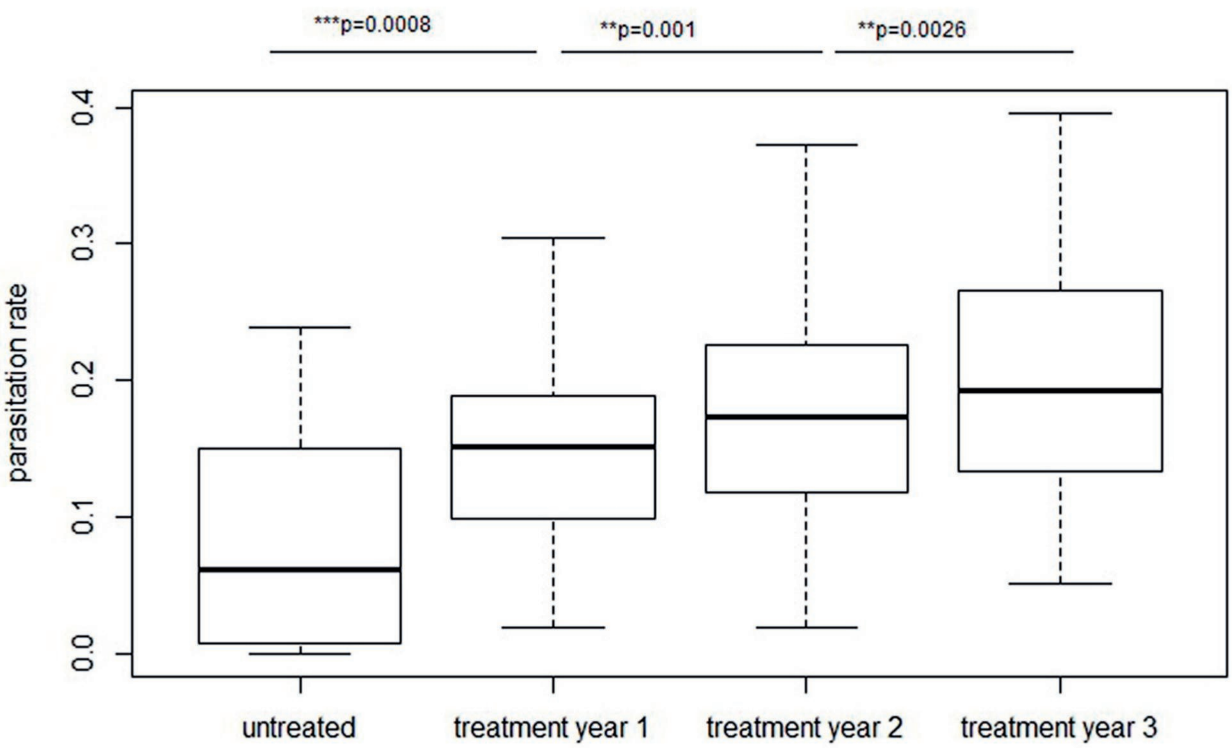


**Figure 2** Parasitism rates of *A. punctatum*-infested buildings (*n*=42; before the first treatment (untreated), after one (number of treatments: 4.74±1.40; mean±SD; *n*=42), after two (number of treatments: 4.19±1.58; mean±SD; *n*=42) and after three years of treatment (number of treatments: 3.05±1.70; mean±SD; *n*=42). Asterisks indicate significant differences among the parasitism rates (*p≤0.05; **p≤0.01; ***p≤0.001; Wilcoxon rank-sum test). Data were collected between 2012 and 2020.

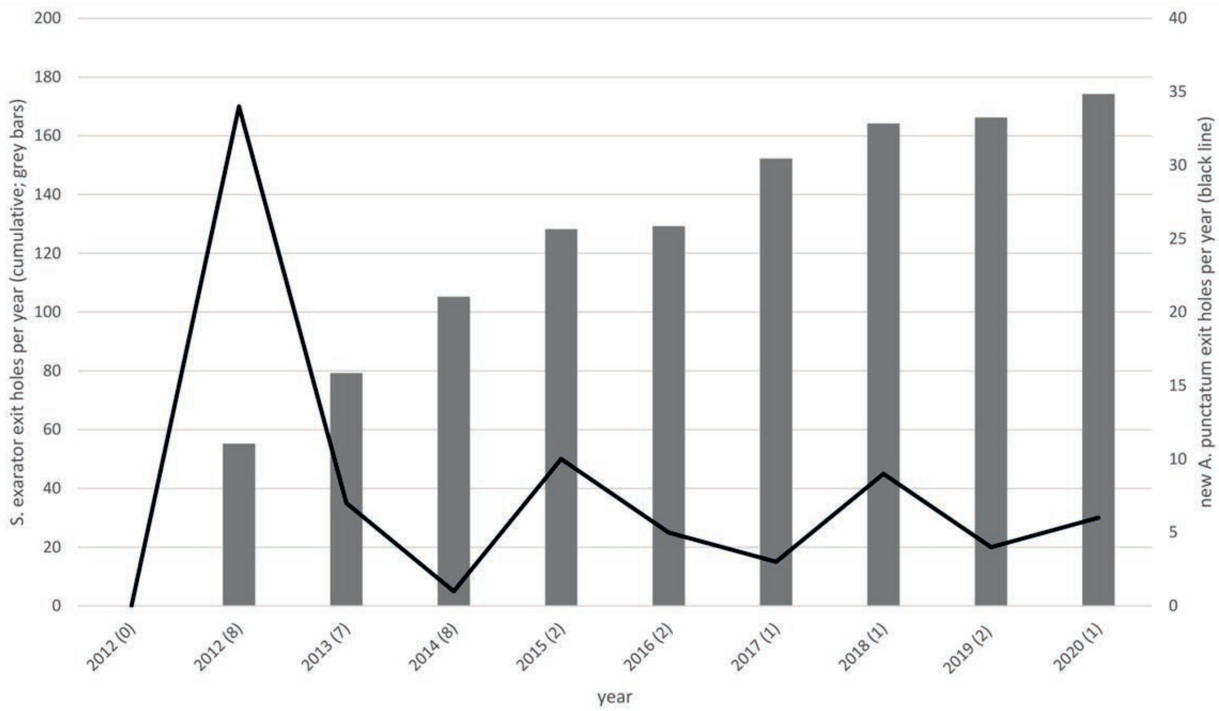


**Figure 3** Cumulative number of *Spathius exarator* exit holes per year (grey bars) and number of new *Anobium punctatum* eclosion holes per year (black line) in an infested part of the pews of church 'Pa.' after each year of treatment. The number in brackets indicates the number of annual treatments.

with *S. exarator* (Wilcoxon rank-sum test, $p=0.0008$; $n=42$), and continued to increase in the second and third years of treatment (Fig. 2). As an example for population dynamics over a treatment period of nine years, Figure 3 shows the number of hatched beetles and wasps per year. After nine years of treatments, a cumulative amount of 174 *S. exarator* exit holes was counted, representing 174 killed *A. punctatum* larvae. According to the increase in parasitation, the beetle population was reduced by up to 97% after the third year of treatment and until now has remained at that low level.

## Conclusions

Nearly a decade of experience in more than 200 historic buildings has shown that *A. punctatum* can be successfully controlled by regular releases of its antagonist, *S. exarator*.

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# Making room for traditional ecological knowledge in conservation: learning by example

Elizabeth Salmon

## Introduction

Fields outside conservation have turned to traditional ecological knowledge of indigenous communities to identify affordable, sustainable and safe pest management solutions. Referring to the resulting literature can help us estimate vast advantages and potential challenges of adopting indigenous solutions in museum pest management.

## Considerations for TEK in conservation

Traditional ecological knowledge (TEK) is linked to specific localities and often dependent on indigenous communities for development and perpetuation. This knowledge is refined across generations, containing valuable solutions to address challenges including pest management. Several academic fields in the natural and health sciences have successfully turned to TEK for pest management solutions yet its potential has been insufficiently considered by conservators. By looking to other disciplines – including agriculture – that have successfully integrated TEK solutions into their work, we can consider how to utilize traditional solutions for sustainable and resource-efficient museum pest management.

Economic and health concerns are among the top motivations for TEK-related research. The agricultural industry has documented and evaluated traditional pest management practices as an affordable option due to their local availability. Commercial pesticides are increasingly considered globally inaccessible for meeting agricultural needs due to their high cost (Lambert *et al*. 1985). Indigenous, plant-based pesticides emerged as economically viable alternatives because they generate greater profit margins than commercial pesticides (Tijani and Omodiagbe 2006) and decompose more quickly, making them less persistent in the environment and safer to use (Khater 2012).

**Figure 1** Neem (*Azadirachta indica*) leaves are a culturally significant insect repellent indigenous to the Indian subcontinent (© Elizabeth Salmon 2021).

It is important to consider both the content and context of traditional knowledge to ensure successful use, particularly when new applications are considered (Gopalam and Reddy 2006). For example, neem (*Azadirachta indica* Jussieu, 1830) leaves, a pest control method utilized for centuries on the

**Figure 2** Dried neem leaves are stored with collections to protect against insects (© Yasir Anwar 2021).

Indian subcontinent, are prepared by drying them in shaded areas, as sunlight is understood to hinder their insect-deterring properties; these are the intangible aspects of traditional pest management that must be understood by practitioners to ensure correct use (Figs 1 and 2).

Engaging with indigenous knowledge systems to learn about local, time-tested methods of controlling insects, as researchers in other disciplines have begun to do, has potential to provide conservators with increasingly sustainable, non-toxic, and culturally conscious methods of pest management to supplement existing museum IPM practices.

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# The history of integrated pest management (IPM) at the Natural History Museum, London

Suzanne Ryder and David Pinniger

The Natural History Museum (NHM) in London was one of the first museums to formally set up a comprehensive integrated pest management (IPM) programme in 2002, but it had already been developing and using pest management strategies for many years before this.

## It all started with the Quagga!

In 1976, insect pest damage was seen on the iconic taxidermy specimen of this extinct zebra on display at Tring Museum in Hertfordshire (Fig. 1). A programme was set up to treat the infestation initially by fumigation then to deploy dichlorvos (2,2-dichlorovinyl dimethyl phosphate (DDVP)) strips to prevent further damage to the collections. This strategy worked well for many years both at Tring and in London, but this led to complacency. While we were able to rely on preventive chemical solutions, such as paradichlorobenzene, naphthalene and dichlorvos, it became clear to some NHM staff that a radically different approach to the problem was needed to avoid the use of toxic pesticides. Phil Ackery, a curator of Entomology, was key in instigating the move away from pesticides to an integrated pest programme. He began regular monitoring and recording pests in the Entomology collections (Fig. 2).

**Figure 1** The Quagga on display at Tring.

In 1992, he presented the first pest strategy for the NHM. The next department to use insect pest traps was Botany following an outbreak of biscuit beetle (*Stegobium paniceum* (Linnaeus 1758)) in the Herbaria. The Guernsey carpet beetle (*Anthrenus sarnicus* Mroczkowski, 1963) was first recorded in the Entomology building but soon spread to replace the varied carpet beetle (*Anthrenus verbasci* (Linnaeus, 1767)) as the main pest in the museum. These departments, together with the Zoology, then adopted freezing as the main treatment option to replace pesticide use. An IPM culture was promoted through example and training.

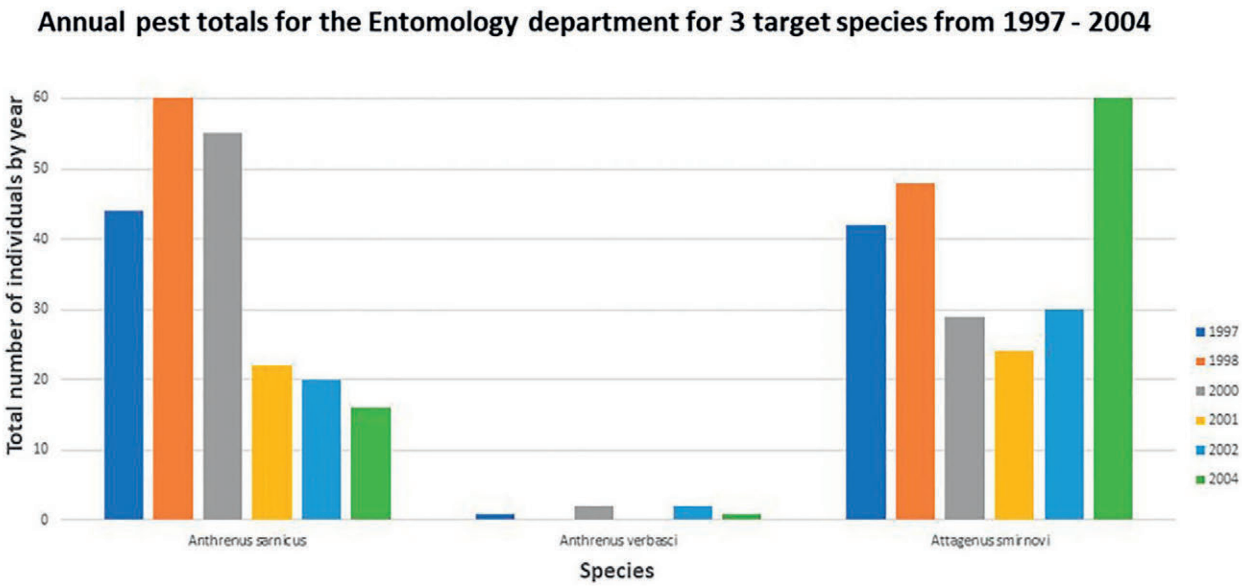


**Figure 2** Trapping results for the Entomology Department.

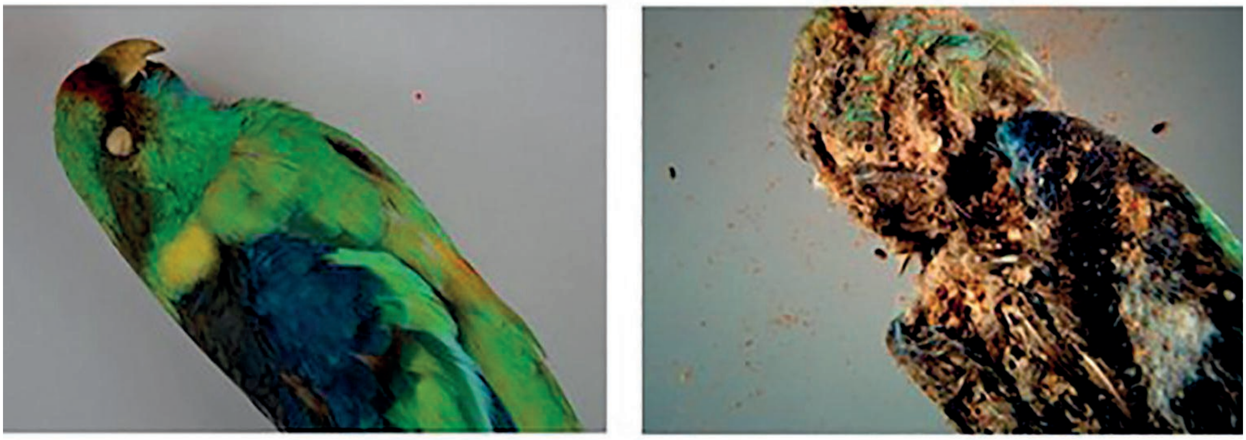

**Figure 3** Barnard's Parrot *Barnardius barnardi* (Shaw, 1805) used to emphasis pest risk (© The Natural History Museum, London).

For the next 10 years, with the pest strategy in place, it proved difficult for the small number of individuals responsible for pest management to contend with the enormous task of protecting the vast collections at the NHM. An external consultant, David Pinniger, was invited into the museum to persuade senior management of the need to take IPM seriously. He showed the Board a specimen of a parrot destroyed by pests to demonstrate the very real risk insect pests pose to natural history collections without dichlorvos, which was soon due to be banned in the UK (Fig. 3).

As a direct result, pests were recognised as the biggest corporate risk to the collections. With the support of the Board, an IPM champion at senior management level was appointed to promote the adoption of IPM and a group from across the museum was selected to coordinate pest management on all sites. A comprehensive approach was implemented which included monitoring, recording, training, housekeeping, identifying and communicating standard best practice, facilities design and maintenance. This holistic approach produced positive results. The IPM group then formulated and introduced the risk zones system across all sites (Fig. 4) and designed and built a central quarantine facility (Fig. 5). These ambitious initiatives have been highly successful in managing pests, reducing risk to collections at the NHM and embedding the continued need for vigilance by all staff.

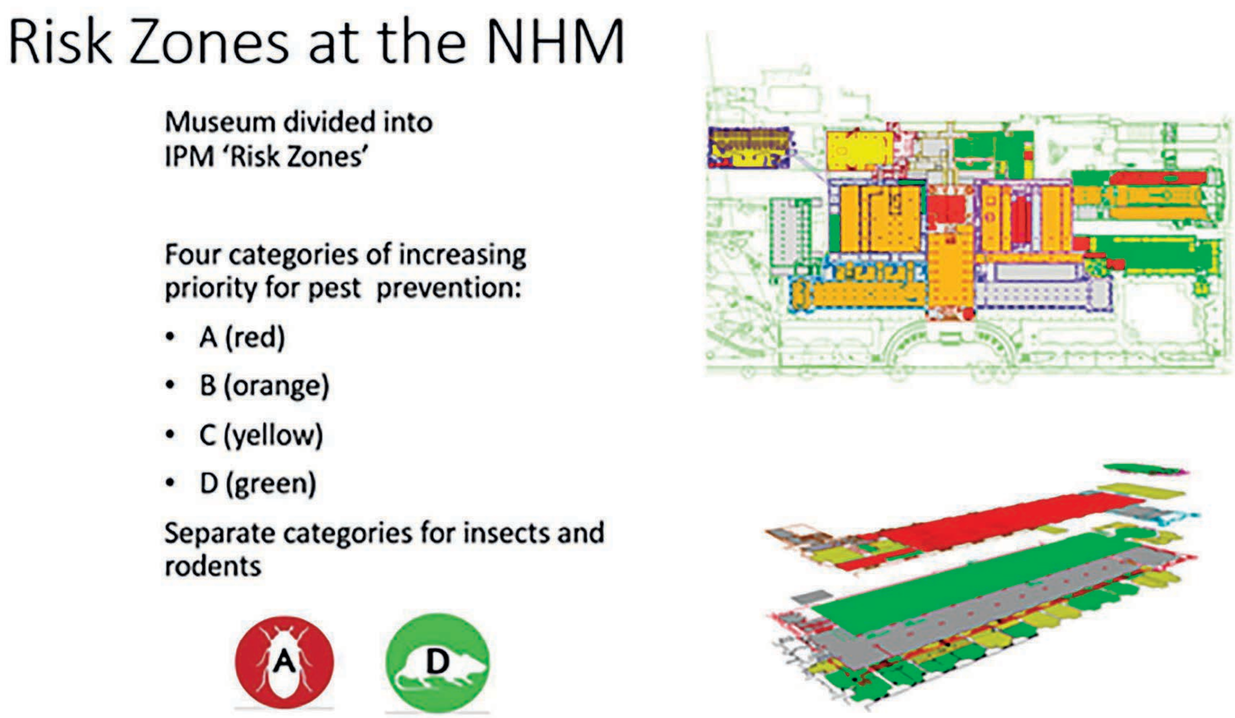


**Figure 4** Risk zones were implemented to manage pests (© The Natural History Museum, London).

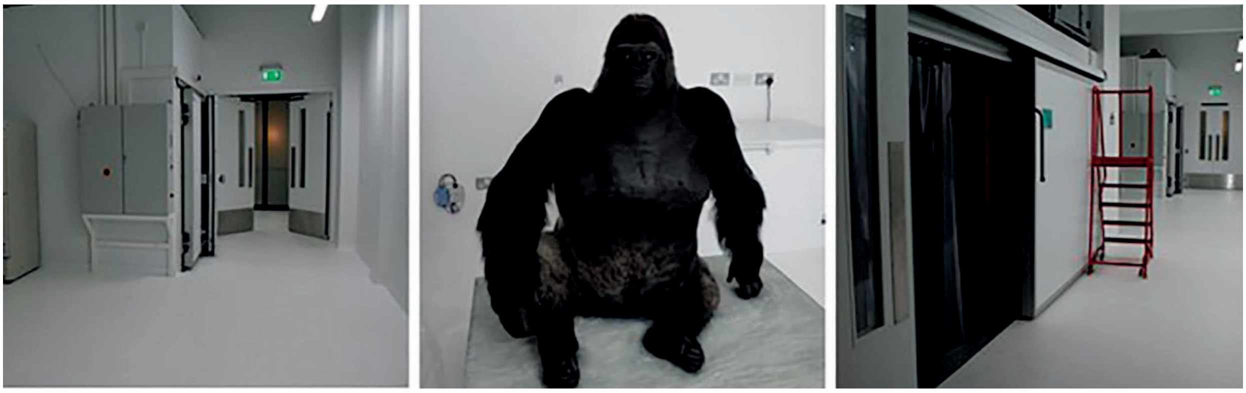

**Figure 5** The central quarantine facility opened in 2012 (© The Natural History Museum, London).

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# The *Spiraea* who came in from the cold: treating an entire collection, kitchen sink and all

Clare Booth-Downs and Yvette Harvey

**Figure 1** The old herbarium in the laboratory: the plastic sheet above the row of cabinets on the left was providing protection against water ingress (photo: Yvette Harvey © The Royal Horticultural Society).

## Introduction

The Royal Horticultural Society (RHS) Herbarium has suffered from outbreaks of *Stegobium paniceum* (Linnaeus, 1758) for many years. Here we share how we seized the opportunity of a new purpose-built herbarium to plan carefully for a pest-free future (Fig. 1).

## A collection move in the time of Covid: adapting, mitigating and managing against the odds

Those familiar with the Royal Horticultural Society (RHS) Garden Wisley will often think of the iconic Arts and Crafts style laboratory, built in the early 20th century. The RHS Herbarium was located here, behind single paned, leaky wooden-framed windows. This, combined with inefficient central heating, limited environmental controls and human behaviours, led to a battle against the repeated infestations of *Stegobium* (Fig. 2).

Herbarium staff passed through the collections to reach their work areas. During winter the team required additional heaters, while in summer the temperatures rose to 30 °C+. As Pinniger (1994: 52; 2015: 141) points out, temperatures above 20 °C encourage insects to breed. With the herbarium's temperatures often reaching above 25 °C, the development cycle was quicker and thus much harder to control. These outbreaks meant the impact on the specimens was catastrophic (Fig. 3).

To mitigate for these circumstances, large Ziploc bags were used to store the specimens within the cabinets, both to limit the ingress of the beetles and to protect the specimens during any preventive treatments. The main method of pest management was a constant cycle of freezing the collection of 90,000 specimens using Strang's (1992) guide of a –30 °C freeze for a minimum of 72 hours.

The completion of the new National Centre for Horticultural Science and Learning at Wisley, which included a purpose-built herbarium in late 2020, provided the opportunity to move from pest practice to best practice. The entire collection would need to be beetle-free prior to the move, so an original plan involved appointing a specialist removals company to transfer the carefully packed herbarium


**Figure 2** *Stegobium* damage to a specimen (*Lobelia* × *speciosa* 'Cherry Ripe') (photo: Mandeep Matharu © The Royal Horticultural Society).


**Figure 3** Herbarium specimen folders were contained within Ziploc bags to hinder movement of *Stegobium* throughout the collection (photo: Lydia Walles © The Royal Horticultural Society).


**Figure 4** Bishop's Move vehicles transferring specimens from the freezer lorry unit (seen in white) (photo: Yvette Harvey © The Royal Horticultural Society).

**Figure 5** Incorporating herbarium specimen storage boxes in the new herbarium during the winter 2021 countrywide lockdown (photo: Yvette Harvey © The Royal Horticultural Society).

collection to West London for heat treatment. While this was under way, items unsuitable for this treatment, including some Entomology and Library collections, would be frozen in a freezer van over a two-week period. This plan was thwarted however by the sudden onset of the post-Christmas COVID-19 lockdown (Fig. 4).

Faced with this maelstrom of keeping both the collection and staff safe, a new plan was needed as we could not delay the collections move. The removals company, Bishop's Move, located a 10 m long freezer truck, fortuitously capable of reaching the magic −30 °C, which was set up at Wisley. Splitting the collections into two parts meant we could allow for a minimum 2–3 week freeze for each load. This was far longer than the suggested 72 hours but provided a safety net in case of any issues with the freezer or temperature gauge inaccuracies. The freezers were gradually brought up to ambient temperature a few degrees at a time over a period of 4 days. While this was happening, the new herbarium's environmental controls were lowered to 40% to avoid moisture build up in the newly thawed specimen boxes (Fig. 5).

Despite the challenges of moving during a global pandemic, we are delighted that the RHS collections are safely housed in their new repository and to date no beetle activity has been noted.

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# Insect pests underground: managing pests in the secret wartime tunnels under Dover Castle

Wendy Richardson

## Introduction

English Heritage displays and stores collections in the secret wartime tunnels beneath Dover Castle where the environment is ideal for wood-boring insects to thrive. Improving the environmental conditions to eradicate these insect pests would be impractical so a collaborative management programme has been introduced to control them. The secret wartime tunnels at Dover Castle consist of four miles of tunnels which are split into three main levels: Casemate, Annexe and Dumpy. Annexe and Casemate are currently presented as dressed spaces from the Second World War with collections on open display (Fig. 1), while Dumpy is chiefly used for collection storage.

## Environment in the secret wartime tunnels

The tunnels were dug into permeable chalk and therefore museum environmental guidelines of 40–60% RH (ICOM-CC/IIC 2014) are difficult to achieve. Monitoring has shown an average RH of between 70 and 80% in most areas (Fig. 2). This environment, along with poor quality materials used in construction, provide ideal conditions for wood borers such as *Anobium punctatum* De Geer, 1774, *Euophryum confine* (Broun, 1881) and *Pentarthrum huttoni* Wollaston, 1854 (Pinniger and Lauder 2018).

## Monitoring and prevention

The main tenets of the management of pests within the tunnels are vigilance and observation (Fig. 3). This is facilitated by an integrated pest management (IPM) programme (Lauder and Pinniger 2021), highly trained collections staff, a well-established and rigorous housekeeping schedule, and the strong relationships between departments. This enables problems to be highlighted as soon as possible and ensures swift and measured responses, whether implementing further monitoring or proceeding to treatment or quarantine.

## Treatment and response

Local dehumidification has been introduced in some areas to discourage pests and lower the risk of damage to the collections but it does mean that insect pests can be more prevalent in the uncontrolled areas of the complex; their spread has been controlled by regularly fogging areas in which their presence has been identified with Constrain (Historyonics 2014). In other cases, the swift removal of infested material for freezing, quarantine or disposal (Fig. 4) has proved invaluable in managing the risk of damage spreading throughout the system of tunnels.

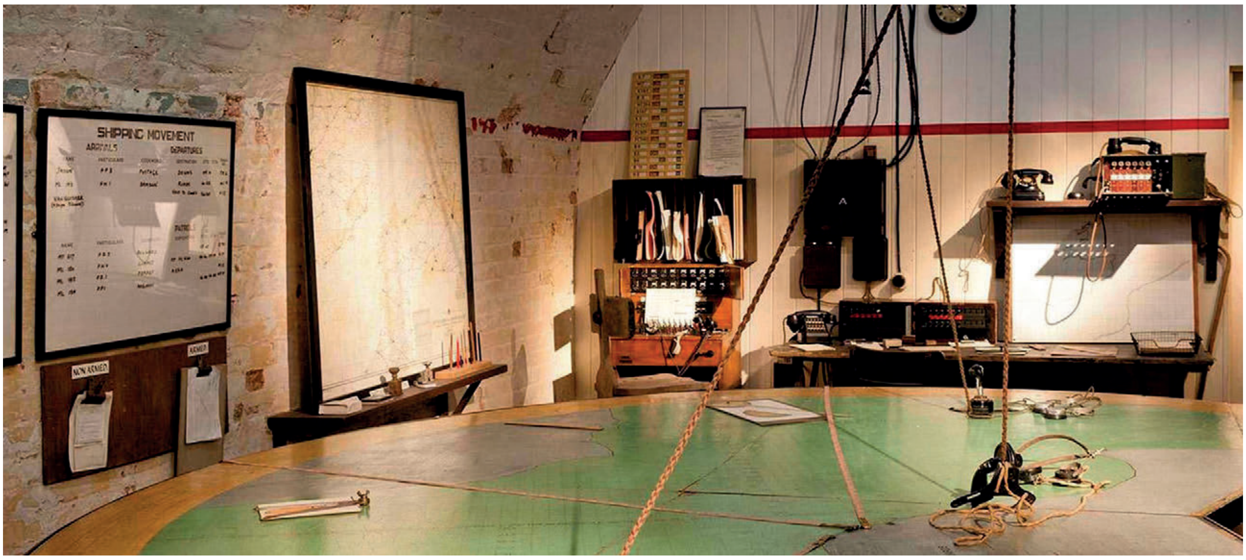


**Figure 1** The collections on open display in the secret wartime tunnels below Dover Castle (© English Heritage 2021).

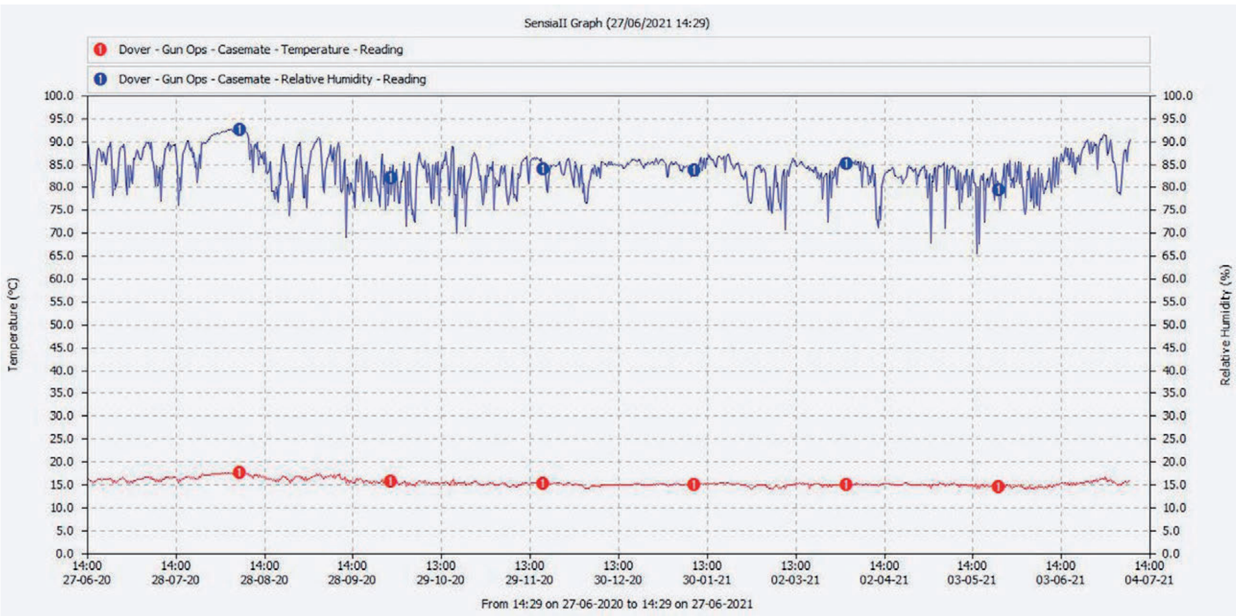


**Figure 2** Data from the Gun Operations Room which is illustrative of the environmental conditions within the tunnels' complex over the past 10 years (© English Heritage 2021).

## Conclusions

The extent and complexity of the tunnels required the development of a strategy to manage the risks of pest damage. The conservation team at Dover Castle collaborates with the collection's pest control manager, the estates staff, and curatorial and operations teams to ensure that this strategy is implemented. Developing channels of communication between these departments has been key to success. The collaborative approach, rigorous IPM and housekeeping programmes, combined with environmental monitoring and regular checks, have helped us to successfully manage and reduce the number of insect pests in the tunnels (Table 1).


**Figure 3** Volunteers attending an integrated pest management training session before working in the tunnels (© English Heritage 2021).

**Figure 4** Removal of non-historic, wood borer-infested lining panels from the tunnels (© English Heritage 2021).

**Table 1** Table showing that the overall presence of wood-boring insect pests within the tunnels from 2012 until 2020 has been slowly decreasing (Lauder 2021).

| Location | Species | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Annexe | furniture beetle | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 |
| Annexe | wood weevil | 25 | 21 | 36 | 30 | 42 | 20 | 11 | 6 | 4 |
| Casemate | furniture beetle | 5 | 3 | 0 | 1 | 0 | 0 | 2 | 0 | 0 |
| Dumpy | wood weevil | 7 | 13 | 22 | 20 | 18 | 15 | 31 | 16 | 2 |

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# Management of priorities, goals, and training in the execution of a pest mitigation project at the Peabody Museum of Archaeology and Ethnology

Cassy Cutulle

## Introduction

This poster presentation focuses on how priorities, deliverables, and team training were managed to mitigate a webbing clothes moth infestation at the Peabody Museum of Archaeology and Ethnology (Peabody Museum) at Harvard University using project proposal and training documents.

## Establishing project priorities and goals

In 2016, an infestation of webbing clothes moths (*Tineola bisselliella* (Hummel, 1823)) was detected in the largest storeroom for ethnographic objects within the Peabody Museum, which posed a high-risk threat to the objects housed within. A mitigation project was developed to address the recovery of the objects. To define the overall project boundaries, goals, and a timeline for deliverables, a project proposal document was drawn up by the present author at the start of the project. This document communicated to senior staff and administrators the activities to be undertaken, the funding, staffing and time necessary, and the projected yearly quotas. This provided an overall understanding of the expected progress over time.

## Successful team training

A comprehensive training manual was also created, which contained administrative on-boarding information for new team members and detailed instructions for object examinations to identify condition concerns and assign condition grades. The training manual delineated the specific information needed in the assessment, including identifications of pests – webbing clothes moths or otherwise – suggestions for exterior or interior support systems that stabilized objects for long-term storage, and whether the damage observed necessitated more intensive treatment (Figs 1–4).

Material-specific reference sheets provided within the training manual detailed the physical and chemical properties of proteinaceous objects constructed of materials such as wool, furs, hides, feathers, quill, and hair, while diagrams showed construction technologies for objects encountered. This aided in the gentle removal of moth frass, eggs, larval casings, feeding tubes, and adult moths using tweezers, low-suction vacuums, and magnified lenses. The manual was updated throughout the project as new strategies or methods developed, and ultimately provided team members with a reference when they become more independent. Other details such as important cultural sensitivities to be observed and health and safety concerns were also communicated in the manual.

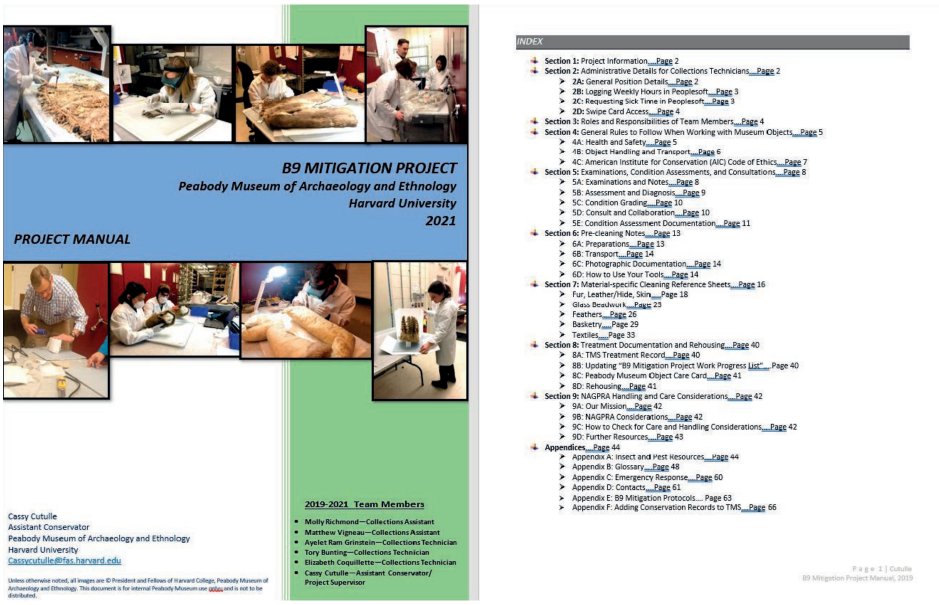
**Figure 1** Assistant Conservator, Cassy Cutulle discussing the removal of pest debris from miniature mukluks with Collections Technician Lindsay Koso (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

**Figure 2** Collections Technician Ayelet Ram Grinstein inserting acid-free interleaving tissue paper to reroll a textile after examining and cleaning it (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

## Conclusions

As the project enters its fourth year, in total approximately 4,000 objects have been contained, disinfested at –21 °C to –40 °C, cleaned, and stabilized, which demonstrates the tangible success of this methodology. Time should be devoted to proposal and manual writing at the start of a pest mitigation project in order to provide a smooth and efficient workflow, especially where large quantities of objects are

**Figure 3** Collections Technicians Khanh Nguyen and Lindsay Koso conducting condition assessments on objects at the start of their training (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).



B9 MITIGATION PROJECT
Peabody Museum of Archaeology and Ethnology
Harvard University
2021

PROJECT MANUAL

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2019-2021 Team Members

- Molly Richmond—Collections Assistant
- Matthew Vigneau—Collections Assistant
- Ayelet Ram Grinstein—Collections Technician
- Tory Bunting—Collections Technician
- Elizabeth Coquillette—Collections Technician
- Cassy Cutulle—Assistant Conservator/ Project Supervisor

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**Figure 4** Image of the front page and index of the Mitigation Project training manual (© President and Fellows of Harvard College, Peabody Museum of Archaeology and Ethnology).

affected. Using such documents, a strong foundation can be created from which to start the project. While this may take time, its benefits are numerous, making it worthwhile in the long term.

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# Advocating for IPM during a pandemic when a local authority has bigger concerns

Gwenllian Thomas

## Introduction

This poster provides an overview of the measures taken by the City of Edinburgh Council's Museums & Galleries to ensure continued insect pest monitoring of museum venues during restrictions posed by COVID-19, and the actions and outcomes deriving from these. At the start of the national COVID-19 lockdown in March 2020, the City of Edinburgh Council directed all but necessary staff to work from home. Essential functions such as schools, care homes and COVID-19 resilience centres were prioritised. All requests for access and resources were decided by a central panel. Weekly checks of museum sites were permitted, conducted mostly by non-collections staff. Remote access to relative humidity and temperature data was in place, but integrated pest management (IPM) activities had to be carried out in person.

| What are the hazards? | What/where is at risk? | What are you already doing? | What further action is necessary? | Risk rating | Action by whom? | Action by when? | Done |
|---|---|---|---|---|---|---|---|
| Pest infestation | All venues – quarterly checks and regular cleaning are not taking place | Weekly venue checks by staff – staff should spot check blunder traps and report to CCO | CCO to provide guidance to C&VE staff for checking blunder traps | Medium | CCO | 5/4/2020 | √ |
| | Queensferry Museum – chimneys drop significant debris | Underoccupancy means less opportunity for pests to be attracted into the buildings | Display cases in vulnerable areas in MOC to be visually inspected by staff (Gallery 3, 4, 5) – CCO to provide guidance to staff checking venues | | CCO | 5/4/2020 | √ |
| | Lauriston Castle – chimneys drop significant debris | All waste is removed from buildings | | | | | |
| | Rodent infestation is a recurring problem in several venues including Lauriston Castle (ground floor rooms) | In the event of rodent infestation, pest control will still attend | | | | | |
| | MOC has repeated insect pest infestation issues due to wool lining of cases; high level of organics at higher risk include costume, dolls and teddy bears | | | | | | |

**Table 1** Extract from an organisational risk assessment for the management of museum venues during COVID-19 lockdown, highlighting pest infestation (© The City of Edinburgh Council Museums & Galleries).

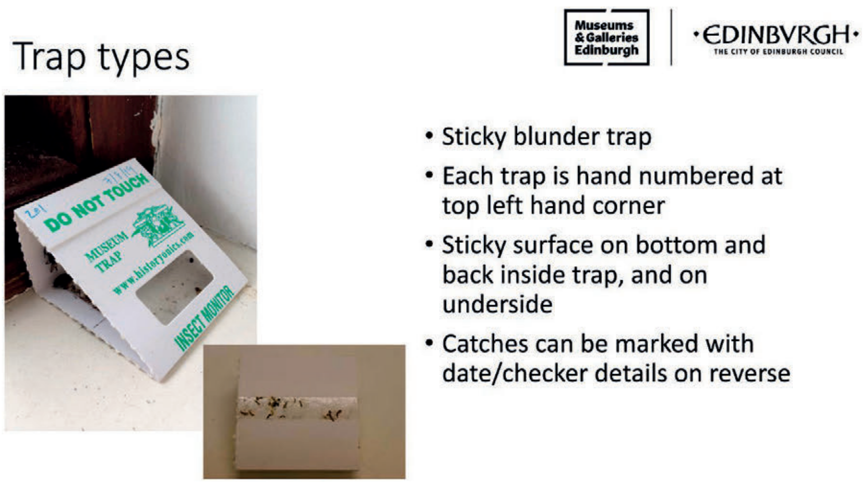


**Figure 1** Slide from an organisational pest awareness training session introducing blunder traps (© The City of Edinburgh Council Museums & Galleries/Gwenllian Thomas).

## Making a case

As the sole conservator for Museums & Galleries Edinburgh, I championed the value of continued IPM within the wider museum service so its importance would be recognised by all. As checklists were compiled for site security and building checks, limited pest monitoring was embedded into these by framing the risks of pest activity in the context of building maintenance and catastrophic damage to collections (Table 1). Trap lists were rationalised for each site so that staff were only required to inspect key traps. Introductory training was delivered to visitor services colleagues with no previous knowledge of IPM who were to act as my eyes on the ground. The online training session highlighted pests common to our museum sites and set out the actions to be taken if populations were identified (Fig. 1).

**Figure 2** Image of evidence of *Anthrenus verbasci* activity in a bisque doll case (© The City of Edinburgh Council Museums & Galleries/Laura McVie).

## The outbreak

The interest and diligence of colleagues paid off when *Anthrenus verbasci* (Linnaeus, 1767) activity was identified by an events duty manager in the bisque dolls case at the Museum of Childhood in August 2020 (Fig. 2). This collection comprises a huge variety of objects and materials, and the two affected galleries contain at-risk objects including soft toys and costumed dolls (Fig. 3). A case was presented to senior management for a small team of staff to carry out object checks, cleaning and treatment, stressing the essential nature of the work and the potential for loss if no action was taken.

## The response

Before any work could commence, individual vulnerability and transport restrictions were considered. A risk assessment and standard operating procedure were compiled to ensure that COVID-19 safe practices as well as sector standards of collections

**Figure 3** Image of a felted soldier doll damaged by *Anthrenus verbasci* (© The City of Edinburgh Council Museums & Galleries/Gwenllian Thomas).

**Figure 4** Image of a curator vacuuming a display case (© The City of Edinburgh Council Museums & Galleries/Gwenllian Thomas).

care were implemented. Obtaining equipment and resources, spread across multiple sites that were closed or inaccessible, required significant planning. By the end of August, a rota of three staff began methodically checking and cleaning the contents of the cases, containing over 1,100 objects, one day per week (Fig. 4). Affected objects were treated with Constrain (Historyonics) water-based insecticide or frozen. Social distancing was easily achieved while working in the gallery but setting up workstations required precise communication.

Progress was reported upwards to higher management throughout this period, and the potential impact of further restrictions assessed so senior managers could continue to support the work and lobby for it to be maintained as the council's work from home edict was extended. Having seen that their checks had yielded a direct impact, enthusiasm for supporting collections care work was boosted within the visitor services team. By November 2020, the two galleries had been completed.

## The outcomes

- Improved communication and working relationships between collections and visitor services staff.
- A wider understanding of all aspects of monitoring across the service.
- Greater service-wide interest in collections care.
- Online training has been rolled out in other aspects of collections care.

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