Infestation by the blue bottle fly (*Calliphora vicina)* and the clothes moth (*Tineola bisselliella)* inside an Italian art museum

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Abstract
In this paper we describe the experience gained at a major art museum in Bologna (Northern Italy), where we were asked to manage a heavy infestation by the blue bottle fly (*Calliphora vicina*) and webbing clothes moth (*Tineola bisselliella*). Besides being unpleasant for the visitors the droppings represented a potential for contaminating the exhibition rooms and exposed objects. In order to manage the infestation without closing the exhibition, aspirating light traps were placed inside the museum halls to capture the flying insects. A thorough inspection of the building showed the origin of the infestation to be tracked back to the suspended ceiling where dead rat carcasses and old woollen insulations materials were found. The result of these findings induced further action to restore the museum attic and the exhibition rooms.

Keywords: light traps; bluebottle fly; rats; suspended ceiling

1. Introduction: an unexpected problem for the museum reputation and for the artwork integrity

One of the main causes of museum heritage losses is due to insect pests, especially those attacking wood, paper, leather and other organic materials (Pinniger 2004, Chiappini *et al.* 2001). However, issues related to pests that may indirectly affect the museum artworks are not to be neglected. We describe the case study occurred in a major art museum in Bologna (Northern Italy), where a sudden and heavy infestation by the bluebottle fly (*Calliphora vicina*, Diptera, Calliphoridae) and the webbing clothes moth (*Tineola bisselliella*, Lepidoptera, Tineidae) was detected during a period of major flow of visitors (August 2012). The presence of large numbers of these flying insects inside the halls of the museum was annoying and unpleasant for the museum visitors and, at the same time, it posed a threat to the art work on display.

2. A prompt solution

In order to manage the insect infestation without closing the exhibition, a prompt, safe and sustainable solution was required. Control techniques based on insecticides were avoided. The infestation was alternatively managed by using four aspirating light traps (Fig. 1A) that were placed inside the museum halls on special "designed supports". This made the capturing system compatible with the museum context and appeared pleasant also to the visitors (Fig. 1B). This kind of trap is fitted with a circular lamp whose emission spectrum has a peak in the UV range, which is very effective in attracting flies and many other flying insects like moths and beetles. The system was combined with a pheromone lure to attract the webbing clothes moths more efficiently. Four pheromone traps were placed over the indication lights of the emergency exits. With this strategy the problem was solved quickly by capturing all flying insects in the rooms. As a second step, the origin of the infestation by the two types of insects was searched for.

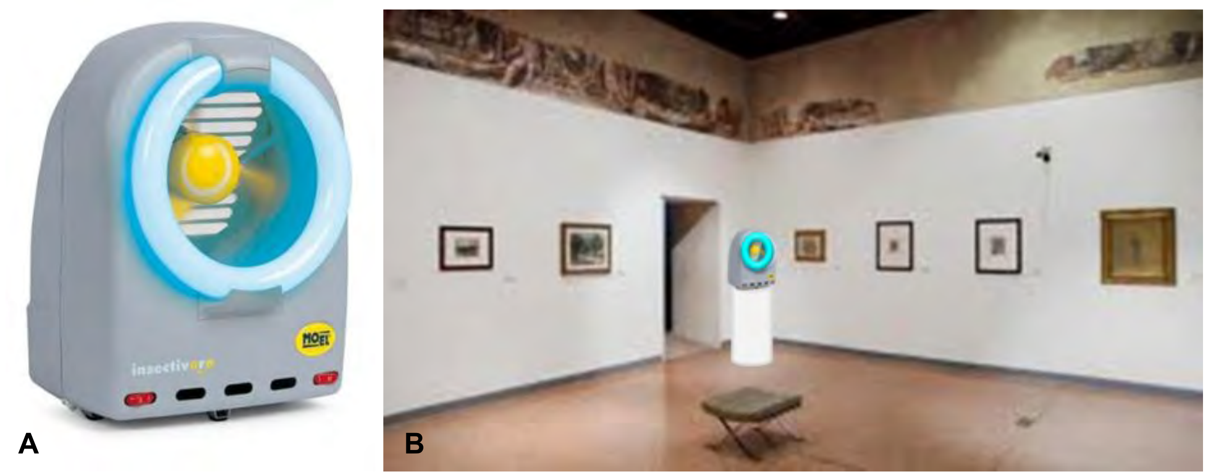

Fig. 1 **A**: Aspirating light trap, **B**: One of the light trap placed in one of the museum halls over a special “design” support.

3. Tracking back the cause of the infestation

The building housing the museum is a thirteenth century castle, with spacious, clean and elegant inner rooms. The exhibition halls had a suspended ceiling (Fig. 2) in which the light and ventilating system are installed. Thanks to a thorough inspection, the origin of the infestation was traced back to structural problems of the building. Above the wooden structure of the ceiling the attic had been neglected during the previous years (Fig. 3). Here an active rodent problem had been managed with poisonous rat baits and dead rat (*Rattus rattus*) carcasses infested by *C. vicina* flies, were discovered.

Fig. 2: Suspended ceiling above the exhibition halls, where the lights and ventilating system are installed.

Fig. 3: Attic in a state of neglect, above the wooden structure of the ceiling.

C. vicina is known as the bluebottle fly because of the metallic blue-grey coloration of its thorax and abdomen (Fig. 4). A female fly can lay up to 300 eggs on fresh carrions or on open wounds. Under favourable conditions the larvae feed for about three to four days and then disperse to find a suitable and dryer place to pupate (Giangaspero 1997). In the case of the museum the pupae had accumulated in the cracks of the ceiling panels of the museum and about ten days after pupation, numerous adult flies began to emerged, invading the underlying museum halls. The presence of these insects in the museum was critical, because flies are unpleasant and annoying in a museum and because of the possible contamination of the paintings with the flies droppings and regurgitations.

Fig. 4: The blue bottle fly (*Calliphora vicina*).

The presence of hundreds of adults *T. bisselliella* moths inside the halls was a reoccurring problem of this museum. The source of the moths was also found in the attics above the ceiling (Fig. 3). *T. bisselliella* was thriving in the footboards woolly material (Fig. 5), used for the insulation coating of the wood panels of the suspended ceiling. These footboards consisted in old woollen fabrics that had never been removed/changed in the last years, representing a perfect environment for the development of the webbing clothes moths. Webbing clothes moths can also feed on fur of dead rodents in might have developed also on the rat carcasses. In both cases, the adult insects entered the underlying museum halls through the wood cracks and the holes for the spotlights.

Fig. 5: A piece of the woollen insulating coating of the wood panels where *Tineola bisselliella* was developing.

Presently the museum artworks have been transferred to another location and the premises are closed. A project for the renovation of this museum has been approved, in order to protect the environment microclimate by restoring the roof and the wooden fixtures.

4. Discussion

Traditionally, the answer to insect infestation in museums was a massive use of insecticides, with the well-known and documented negative consequences both for the works of art and the people attending the museums. Currently, procedures and strategies aimed at prevention and integrated pest management are to be preferred. The best practices available include the implementation of monitoring/maintenance programs associated to the use of physical control methods (e.g. capture and exclusion systems), biotechnical devices (pheromones and growth regulators), treatments with heat, cold and non-toxic gases.

To prevent museum pests we stress the importance of a well planned and executed IPM program and a more effective use of human and economic resources. A good IPM strategy incorporates the results from a continuous microclimate survey and periodical pest monitoring. Here the status of the different environments is evaluated in order to ensure the best conditions to preserve the artworks.

In these cases the IPM coordinator should be a trained person capable of intervening in a targeted manner where the unwanted proliferation occur, prescribing the most appropriate treatment, taking into account the adverse effects. IPM uses a variety of techniques to prevent and solve pest problems using pesticides only as a last resort. It depends on knowledge of a pest's habits, ecology and the environment in which it thrives and survives. IPM is adaptable to any museum. It provides a structure that allows to take responsible decisions about treating pests, based on a variety of monitoring techniques, such as: routine visual inspection of the objects (looking for cast larval skins, holes in textiles, piles of frass, cut hairs around and below artefacts); routine inspection of the building, looking for signs of insect presence and detecting critical points that facilitate the development of pests;

trapping and identifying the pest movements into and throughout the building; documentation of the inspection and trapping data in order to evaluate the problem over time.

This case study illustrates what could happen in a museum in the absence of a proper approach toward pest monitoring and prevention: the consequences of neglecting basic IPM practices could seriously compromise the integrity of the artworks, the appeal of the collection, and therefore the whole museum.

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Integrated Pest Management in Italian cultural heritage institutional structures

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Abstract

The aim of our study was to assess the perception of pest problems and the adoption of integrated pest procedures in Italian conservation institutional structures. This goal was pursued by means of a questionnaire of 31 questions focusing on buildings characteristics, management of the environments, staff organization, pests control, and directors/managers' consciousness of pests problems. This preliminary phase involved 123 different institutions in Emilia Romagna, one of the 20 Italian regions. The results permitted identification of the needs for improvement of pest management, biological risks assessment, and staff training in the region. The project will continue by extending the questionnaire to include heritage organisations in all other Italian regions.

Keywords: environmental management; training; questionnaire; Italy; Emilia Romagna

1. Introduction

In Italy restoration is considered much more important than conservation. For a cultural heritage organisation, a restoration project ensures greater visibility than correct management or a conservation or prevention project. More visibility means more sponsors, above all if it involves great artworks.
Only in recent years the concept of prevention has started to spread in Italy. At a regional level there have been interesting 'preventive' projects, yet not a single one involving IPM. Projects encouraged control of temperature, relative humidity, dust, and light, but they did not include pest problems as part of environmental management. The aim of this study is to understand the current situation in pest management in Emilia Romagna using a survey.

2. Methodology

A questionnaire was sent out to 850 cultural heritage organisations in Emilia Romagna. It consisted of 31 questions grouped into the topics 'Knowledge', 'Perception', 'Management of pest problem', and 'Training'. Clarity and brevity of the questionnaire were considered to encourage as much institutions as possible to participate and therefore to obtain valuable qualitative and qualitative information.

The answer formats chosen were the nominal scale format (=qualitative, yes-no) and interval scale format (= Likert-like, five-point) measuring frequency, satisfaction, and importance. The final section was concerned with gathering information for classification purposes. A first version was tested with a small variety of cultural heritage organisations to find out if it was suitable for any kind of organisation. The final version of the questionnaire took into account all the problems, suggestions and observations made by the testers. The online questionnaire was sent to all managing directors of cultural heritage organisations of Emilia Romagna that were listed in public directories.

3. Results and discussion

The preliminary results show that of the 850 questionnaires that were sent out, 123 were completed (14.5%). The respondents represent museums (44.4%), libraries (38.5%), and archives (12%). The majority of organisations were public and are housed in modern or restored historic buildings. Pests are a problem for circa 80% of the respondents.

To manage pest problems the cultural heritage organisations should have an understanding of their indoor environment and the climate conditions. But the results show that often the exhibition and storage areas are not equipped with temperature and relative humidity control and the conditions are not monitored. In the few cases in which they are recorded, winter temperatures range from 18 to 25°C, while summer temperatures can reach 32°C, both in storage environments and exhibition areas.

Respondents state that during the important procedures for housekeeping they sometimes recognize conservation problems, but rarely pest problems and infestations. This may be because these tasks are often outsourced to external companies or performed by untrained staff. Of the respondents 60% indicated to carry out inspections, which are considered very useful for recognizing both conservation problems and infestations. These inspections are performed mostly by general staff of the museum, sometimes by the keepers, very rarely by the housekeeping staff. In all cases they are carried out by staff that is not trained in dealing with pest problems.

According to the directors pests are a problem, but when asked how often they encountered pests, traces or evidence of their presence (insects, fungi or frass) in their museum, the answer was ‘rarely’, or ‘never’ for both exhibition rooms and storage. It is unclear whether this is because there are indeed no pests or because they are not recognized. Too often their presence is detected when the damage has already been done!

Conservation managers believe that it is very important to know the pests that attack cultural heritage, the methods to control them, and also the health legislation. Yet very few of them have taken courses on pests, either during or after their university training. The same is the case for ‘refresher courses’. In fact they are conscious of their low level of knowledge of methods to detect and control pests in their environments. These considerations are confirmed by the fact that prevention is not applied. Chemical and physical treatments and restoration are carried out more frequently than monitoring, generic prevention or IPM. The trend is to repair rather than to prevent.

When monitoring or prevention measures are adopted the satisfaction is generally high, yet for IPM the satisfaction is low. However, here it must be considered that the majority of respondents do not know what IPM is and, if adopted, it is managed by untrained staff.

The lack of awareness about pests and the lack of funds appear to be the main limitations for implementing an effective pest management strategy. Of the respondents 74% allocate 0% of their budget to prevention.

Another limitation for the application of IPM is the lack of a standard: 86% of the respondents believe that the introduction of an IPM standard could result in implementation of IPM procedures. Those who perceive more pest problems, obviously, believe in the usefulness of a standard. Those who most frequently use chemical treatments do not seem to believe in the usefulness of a standard. It is not a statistically significant difference, but the results show that the respondents that are more inclined towards prevention would like to have a standard.

4. Conclusions and future improvements

It is evident that chemical and physical treatments and restoration are preferred to preventive measures when it comes to managing pest problems. IPM is not known and thus not applied by the majority of the respondents in the Emilia Romagna region of Italy.

The results show that the managers of cultural heritage organisations

- are aware of the importance of pest problems and
- are aware of the importance of knowing pests and their management,

but they are not informed about integrated pest management.

These preliminary results point out the need for education and training in cultural heritage pests and for an IPM standard for all museum staff.

The survey project will continue by extending the questionnaire to conservation institutions in all other Italian regions, in order to establish the situation in the whole of Italy.

A tricky road to IPM at the *Centre des monuments nationaux* (CMN) in France

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Abstract
The implementation of IPM in a complex and extensive institution like the CMN (with about 100 different archaeological sites, caves, castles or historic houses) requires time and can only be achieved in many small steps. This paper presents a programme for training staff and implementing pest control in our cultural heritage buildings in accordance with French law and under persistent financial and human resource constraints. Training of local staff on different aspects of preventive conservation (including IPM) was one of the first steps to raise the level of collection care and housekeeping at the sites. Outsourcing some of the tasks like monitoring to local pest companies was difficult at times, as the level and quality of the pest identification and the documentation methods varied greatly. An additional aspect involves the reconciliation between the protection of local nature and cultural heritage. In a particular example, we focus on the conflict between the protection of bats, a species threatened by extinction in France, and the prevention from damage and staining of objects and collections by the bats.

Keywords: training; decentralisation; protecting nature; bats

1. Introduction

Integrated Pest Management (IPM) has been applied in France for over ten years now, for example in the agro- and food-industry and resulted in a decrease in the quantities of pesticides sold since 2000. The development of general IPM strategies within cultural heritage institutions in France has begun only fairly recently. In 2013, we are still at an early stage of implementing this strategy in France. It is a necessary change, but one that will take some time to complete.

This paper seeks to discuss the sometimes tricky road toward the implementation of IPM at the *Centre des monuments nationaux* (CMN). IPM is presented as a flexible strategy that can be adjusted according to the needs and the size of the institution. However, its implementation in a complex and extensive institution like the CMN requires some time and many small steps. Here we present some crucial steps carried out in recent years and important experiences gained.

2. The Centre and its organization

The *Centre des monuments nationaux* (CMN) was founded in 1914. It is a public institution aiming to preserve, study and inform the public about historical buildings, owned by the French state and spread all over the country. Among these monuments are archaeological sites, caves, castles, sites like the *Arc de triomphe*, and famous houses, adding up to almost 100 sites in total. 2014 saw the 100th anniversary of the Centre, employing about 1.300 people. The collections handled by CMN include buildings, archaeological finds, furniture, paintings, sculptures or books. The head office is in Paris, which makes it sometimes difficult to take care of all monuments in an equal way.

Each monument has an administrator as head of the institution. Local staff have a large number of tasks at the monument. Although their main activities are to welcome visitors and look after safety and security in the rooms, they are also required to clean the rooms. Unfortunately, most of them were not trained in conservation matters before starting their work.

As for the head of the CMN, it is led by a president who is appointed by the Minister of Culture. In the past the head office of CMN in Paris was divided into 5 departments. Among these was a public affairs department. Inside this department was a little group named the collection committee (*la mission des collections*) managed by a curator, with about 10 people, having graduates from the *Ecole du Louvre* or holding a Master of Art and History (*historiens d'art*). The main activity of the collection committee was the inventory of the different collections within the institution. They were also in charge of buying and restoring new objects and collections. At that time, they worked closely with the Ministry of Culture and regional departments of cultural affairs.

At the beginning, the CMN's role was to enable and organize visits of the monuments. The name of the Centre was at that time *'La caisse'*, i.e. a funding body. Later the name changed to Monum. Everything to do with conservation concerns was supervised by another public institution called the *Direction régionale des affaires culturelles* (Regional management of cultural affairs, *DRAC).*

In 2009, the CMN undertook reorganization in order to be not only a funding institution, but also to be an effective actor in the preservation of cultural heritage. Consequently, a collection conservation department and a building conservation department were created and located at the head office in Paris. The collection conservation department is divided into two service units, the inventory service and the conservation-restoration service.

3. Developing working methods

As previously mentioned, the CMN has a complex organization with many departments. In order to ensure good conservation practice, effective communication within the organisation is essential. Therefore, the first step was to draw up inter-departmental working guidelines, especially with the building department, to provide a better equilibrium between collections, the building conservation and training staff working at different monuments.

The five people of the conservation-restoration service are involved in the following tasks: scheduling restoration work, drawing up offers to potential contractors, choosing contractors, following restoration work, training in preventive conservation, managing loans of works of art and fixing the budget. They have also undertaken the task of developing guidelines for conservation. Besides problems related to climate, light and dust, insect eradication after infestations was a particular concern for the conservation department.

3.1 Inter-departmental working guides

An organizational scheme was created with the aim of facilitating the communication between different departments. It determines those main steps which require a common agreement. The meetings allow participants to coordinate and synchronize future processes in order to take care of the collections and optimize the resources.

3.2 Training on-site staff

Training is provided by the conservation-restoration service and by outside conservators and experts.

3.2.1 General training of on-site staff

The programme was drawn up in collaboration with the adult training section of INP (*Institut National du Patrimoine*, *National Institute of Cultural Heritage*). The aim was to provide staff with general knowledge in preventive conservation. Up to now 24 persons coming from 24 different sites have taken part in one of these training courses (Fig. 1). The sites were chosen according to the size and nature of their collections. It was intended that these persons would then be in charge of preventive conservation for their site.

Fig. 1: General training of on-site staff.

Currently two kinds of training are provided: the first is a specific one-day-course that teaches general care of collections, e.g. methods of cleaning. The second three-days course presents the basic principles of preventive conservation. After receiving a theoretical introduction, students form small teams and make a practical visit of the monument in order to reveal the critical points and to discuss actions. These are then carried out by themselves at a later stage. The results are discussed and an intervention protocol is written. The aim of these courses is not only to provide staff with the basics of preventive conservation, but also to make them develop a certain autonomy and sense of community. They help to identifying the skills of each individual and encourage better collaboration in the future.

3.2.2 Practical training of on-site staff

After the general training, on-site visits are important to help staff applying what they have learned. It is important to assess progress and understanding of the subject matter. The practical training included teaching the staff how to measure light or climate, how to handle objects, how to carefully remove dust, and how to assess simple methods for storage conditions (Fig. 2). An example of improving storage conditions was provided by the staff of the castle of Bouges in the centre of France (Fig. 3).

Fig. 2: Practical training of on-site staff.

Fig. 3: Storage areas before and after the preventive plan at the castle of Bouges.

The fact that the sites are scattered throughout France, naturally implies the geographical isolation of some sites and staff. In addition to the national assistance provided by the collection conservation department of the Paris headquarters, the IPM correspondents on site must be able to share their experiences to create a network for the purpose of directly exchanging information. Training days, in addition to their educational purpose, should enable the participants to get to know each other and establish easy exchanges between them.

In parallel with staff training, an illustrated booklet is being compiled in the form of ten practical sheets that provide more detail on monitoring and housekeeping as well as good practice in cases of infestation. The sheets are laid out according to the nature of pests (wood-boring or keratin-eating insects, rodents, flies, pigeons and bats). The booklet contains insect identification keys, general requirements by pests and the actions required to prevent damage and infestation in the short- and medium-term (Gunn 2008). The booklet also contains a self-assessment section (see also Strang 2012, Brokerhof 2013) to understand the causes of the infestation and how to document them.

3.2.3 Training course at the INP

Our work has benefited from the fact that the first year students at the INP (*Institut National du Patrimoine*, National Institute of Cultural Heritage) have a 1-week training course. Some of the work was carried out with the students at the monastery of Saorge in the South of France near the border to Italy (Fig. 4).

Fig. 4: The week-long training course with voluntary students at the monastery of Saorge.

3.2.4 Performing a major project of conservation in monuments

The collection conservation department and the on-site staff are typically not able to ensure the conservation of major collections by themselves. A better approach is to use outside contractors for parts of or all of the necessary work. An example was the conservation project at château de Champs sur Marne near Paris, which was the site of a major preventive conservation and restoration project for both the building and its collection. Altogether there are about 4000 objects at this site. While the major renovation work of the building was being carried out, a temporary shelter was set up outside for working on the collection. The whole collection benefited from the conservation care carried out in the temporary shelter. This included insect eradication by freezing when needed. While the collection conservation department was performing the inventory and the labelling of the objects, outside contractors were marking, cleaning, photographing, displaying and packing them for storage or freezing (Fig. 5).

Fig. 5: Preparation for storage or freezing at the castle of Champs-sur-Marne.

Fig. 6: The castle of Champs sur Marne after treatment and restoration.

4. Pest management

4.1 Wildlife in the national monuments

The *Monuments Nationaux*, which are historical buildings, usually host pests that are fond of castles in the countryside. Indeed, the materials used for the collections are very attractive to pests. The location in rural areas and the lack of good sealing of the building exteriors accentuate the latter phenomenon. These factors induce local infestations processes, for example the presence of necrophagous insects in stuffed specimens. This natural process creates a conflict in the case of cultural heritage, which must be preserved for future generations, and so becomes pathological (Nicosia 2013). Preservation of the collections of the CMN requires the development of modern strategies that should be non-polluting, according to a global and sustainable development.

Entomologists essentially developed IPM; the pest classification is based on biological keys like the anatomy and physiology of the pests. It seemed appropriate to introduce a scale of the impact of pests on collections in order to prioritise responses. Some alterations induced by pests are reversible, while others are destructive and final. We have classified them according to their impact on the collections, distinguishing those that (1) irreversibly destroy the objects, (2) those that only damage the materials to some extent (like wood-boring or keratin-eating insects) and (3) those that stain them (mainly flying creature like flies, pigeons or bats). Rodents that have the particular ability to both gnaw and to soil collections constitute a (4) category. We can then integrate the size of the animal with their propensity to procreate and multiply. Some of the pest have colonised the monuments at the time they were constructed. According to the configuration and state of conservation of the monument, their population is more or less stable. But this balance is fragile, as for instance singular events, such as the heat wave of 2003, have increased the wood-boring population at some sites. Thus both radical treatment to stop the cause of a problem and general treatment of buildings are necessary today.

4.2 The strategy of pest control

Of the one hundred monuments managed by the CMN, approximately forty show a significant infestation and require increased monitoring. Since 2007, the CMN has developed a national plan of IPM (following Pinniger 2009, Strang and Kigawa 2009). It involves the staff working on the site to take care of collections and to continuously monitor infestations. The staff working on site is very versatile; in most cases they keep the cash register, conduct tours and clean-up after closing. However, we wanted to find out, if the staff on site (for example in the castle of Castelnau Bretenoux) could also be made responsible for trapping and monitoring pests. However, it turned out that the operation was too demanding for the staff, as they were already busy with other work. It was difficult to ask them to perform additional tasks on top of their daily occupations without an increase in overall resources.

It was therefore decided to outsource the trapping and monitoring. A second test was carried out on several sites with different companies specialized in pest control. The test lasted two years. The data sent by the pest control companies were analysed in terms of accuracy and format. Some were handwritten, others filled with checkboxes without specific comments; and the documentation for each pest species was not carried out systematically. The terminology and the level of knowledge in entomology varied greatly from one company to another. The analysis of a pest population over time proved laborious because it required a manual data entry on a spread sheet.

The estimated cost of these operations for the 40 sites identified as high priority was beyond the threshold of “simple consultation and request” according to French public procurement law. Facing a stringent budget constraint, we have to adapt our requests accordingly. The requirement level should coincide with our needs and means. The scattered locations throughout French territory considerably increase the travel costs. We must reduce these without multiplying the number of service providers needed. A balance between the quality and the cost of the operations must be found.

To resolve the above problems we wrote two specifications of public offers to tender: A first offer, concerning monitoring and the treatment of areas and sites, divided into six geographical regions; and a second offer, concerning specific curative treatments of collections and promoting the diversity of methods. Service providers conducting on-site monitoring with technical assistance by local staff complete a worksheet in a common format according to a predefined and contractual model. These sheets are then saved and run automatically at the headquarters to verify variations of pest populations. The simplicity of the final result is inversely proportional to the work and energy expended on its development.

5. The protection of nature and cultural heritage: antinomy or synergy

5.1 Bats in our monuments

Colonies of bats are present in the attics of most of our monuments, such as the greater mouse-eared bat (*Myotis myotis*) in the castle of Azay-le-Rideau or the greater horseshoe bat (*Rhinolophus ferrumequinum*) in the castle of Bussy-Rabutin. Their presence does have an impact on the collections

- in fact, they fly into the exhibition and storage areas, stain the objects with their droppings, and can also trigger the alarm. They arrive each year in mid-spring and leave with their pups in mid-August. Thus perennially the *Monuments Nationaux* turn into a bat nursery. In France, all bat species are protected, as well as their breeding sites and resting places (Arrêté ministériel 1981, 2007).

We consider our IPM in a historical building not a dead structure, but a living ecosystem. The bats are considered a natural part of the monument, and, by participating in the regulation of insect populations, they become a living player in IPM. The natural sites and the cultural heritage are not considered antagonistic, but rather interwoven. Each needs to be preserved with no damage to one or the other.

5.2 Some measures for successful co-habitation

For several years the CMN has been developing a close collaboration between a biologist and an environmental protection association with a view to finding a way towards establishing a stable equilibrium of the bat population. In some buildings, a specific area in the attic was created to allow them to reproduce and, at the same time, to prevent the collections from suffering bat damage. This limit is either physical (with rigid partitions or heavy curtains) or strategic with a specific positioning of light sources based on the tendency of bats to avoid light (Lemaire and Arthur 2005). However, the most notable point is that bats have allowed the IPM organization chart to be enriched with biologists, carrying a positive message about biodiversity. A mutual willingness to engage in dialogue led to the abolition of certain terms such as ‘pest’, descriptive of only the harmful nature of bats (Latour 2007).

Combining the preservation of collections with the preservation of protected species, this new mission highlights the positive contribution of the staff present on site, boosts the image of the monument and also develops public awareness about these flying mammals.

Conclusion

Finally, the work accomplished by CMN for pest control brings to light the complex difficulties, which are sometimes as monumental as the buildings themselves. Although the housekeeping of collections and buildings is a matter of common sense, its implementation in such a big institution is difficult. For the moment, most of the on-site staff are still executing their previous assignment provided by the statutes in 1995. Geographic dispersion, lack of new resources and the necessity to conclude public procurement contracts complicate and delay the execution of new tasks aimed at taking care of collections. Recently a project of reorganization of the head office was initiated, following an assessment of CMN’s operation. The aim is to reduce the number of departments to facilitate communication. Thus, the building department and the collections department will be merged into a single department in the future.

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Monitoring of the webbing clothes moth (*Tineola bisselliella*) as a prerequisite for an Integrated Pest Management in the Imperial Furniture Collection, Vienna, Austria

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Abstract
In 2008 a comprehensive IPM concept against the webbing clothes moth was initiated in the Imperial Furniture Collection, Vienna, in cooperation with the University of Natural Resources and Life Sciences, Vienna. The study aimed to provide a detailed overview on the overall situation of moth infestation in the Imperial Furniture Collection, discover sources of infestation and vulnerable areas. For monitoring of the insects, pheromone traps and light traps were installed. In addition, temperature and humidity were recorded by data loggers. Three species of moths were detected by these traps. *Tineola bisselliella* was caught most frequently, followed by *Plodia interpunctella* and *Monopis obviella.* Due to the high density of traps**,** it was possible to identify the sources of moth infestation. In a next step, the moth count was reduced by removing the upholstery and interior padding of severely infested objects or removing infested material such as glue granulate or food products. Due to the latter measures, the counts of *Plodia interpunctella* could be reduced within three years to the same low level like those of *Monopis obviella* (i.e. a few individuals per year). Nevertheless, the count of *Tineola bisselliella* did not decrease significantly in some of the severely infested storage rooms. Therefore, the effectiveness of spraying a pyrethroid was tested in one of these rooms. However, the monitoring after this chemical treatment indicated an insufficient knockdown and long-term effect on the webbing clothes moth population. This led the Imperial Furniture Collection to install a stationary nitrogen chamber, to periodically treat furniture specimens.

Keywords: *Tineola bisselliella; Plodia interpunctella*; monitoring; pyrethroid; nitrogen chamber

1. Introduction

Furniture collections and furniture depots are particularly prone to wood and fabric destroying insects; however, formerly widely used insecticide treatments or conventional fumigations using toxic gases are continuously replaced by less harmful alternative treatments, which are part of an integrated pest management (IPM). In 2006 such an IPM concept was developed for the first time at the Imperial Furniture Collection, Vienna against the common furniture beetle (*Anobium punctatum*) in the course of a Master thesis at the University of Natural Resources and Life Sciences, Vienna. Based on the positive results from this project (Halmschlager and Lohr 2006), the Imperial Furniture Collection, Vienna initiated a similar project in 2008 against the webbing clothes moth (*Tineola bisselliella*). This study aimed to provide a detailed overview about the overall situation of moth infestation in the Imperial Furniture Collection, discover sources of infestation and vulnerable areas, and identify the involved moth species. Furthermore, it aimed to develop a concept to minimize or even avoid chemical treatments with toxic substances due to the development and implementation of an integrated pest management concept including evaluation and documentation of the IPM.

2. Materials and Methods

For monitoring of the webbing clothes moth, pheromone traps and light traps were installed in 14 storage and working rooms in 2008. A total of 48 sticky insect traps (Finicon PPS GmbH, Hochdorf, Germany) with a pheromone for *Tineola bisselliella* were used. In the four main storage rooms eight light traps were additionally installed in 2008 and maintained till the end of 2009. Most of the traps were installed in a hanging position, evenly spread in the storage rooms or placed on the floor or on storage racks. In the first year the traps were inspected weekly, so that the incidence of moths could be detected very quickly, in order to allow an early intervention to rising insect infestations. From March 2008 till May 2009 the traps were inspected weekly during the main flight period and in a biweekly or three-weekly interval during the rest of the year. In the following years traps were monitored monthly. The pheromone traps were exchanged frequently in order to minimise the effect of a fading attractiveness. In addition, room temperature and humidity were recorded by data loggers.

The results of the monitoring were summarized in annual reports, to highlight vulnerable areas and sources of moth infestation. Based on this information recommendations were provided, in order to develop and choose the most appropriate and safest methods to control infestation.

For experimental purposes, in 2008 a pyrethroid (AquaPy from Bayer Environmental Service, Monheim, Germany) was sprayed in the severely infested room no. 12 by a pest control company, using the ultra-low volume technique (200 ml/3.000 m^3). The effectivity of this treatment was also evaluated by our weekly monitoring.

3. Results

Three species of moths were detected by the pheromone traps from 2008 to 2012. *Tineola bisselliella* was caught most frequently, followed by *Plodia interpunctella* (Indian meal moth) and *Monopis obviella* (Fig. 1). *T. bisselliella* occurred in all 14 storage rooms (Fig. 2), whereas infestation of *P. interpunctella* was locally concentrated in one room and occurred only scarcely in a few other rooms. Although the total number of moths was reduced by about 50% from 2008 to 2012, the counts of *T. bisselliella* did not change significantly over time. This was because overall reduction of counts was primarily achieved by reducing the population of *P. interpunctella* due to the removal of infested material such as glue granulate or food products (Fig. 1). Removing the upholstery and interior padding of objects severely infested by *T. bisselliella* during restoration measures did not have a similar effect, because only a few infested objects could be handled with this labour-intensive method. Thus, in some storage rooms severe infestation was still found.

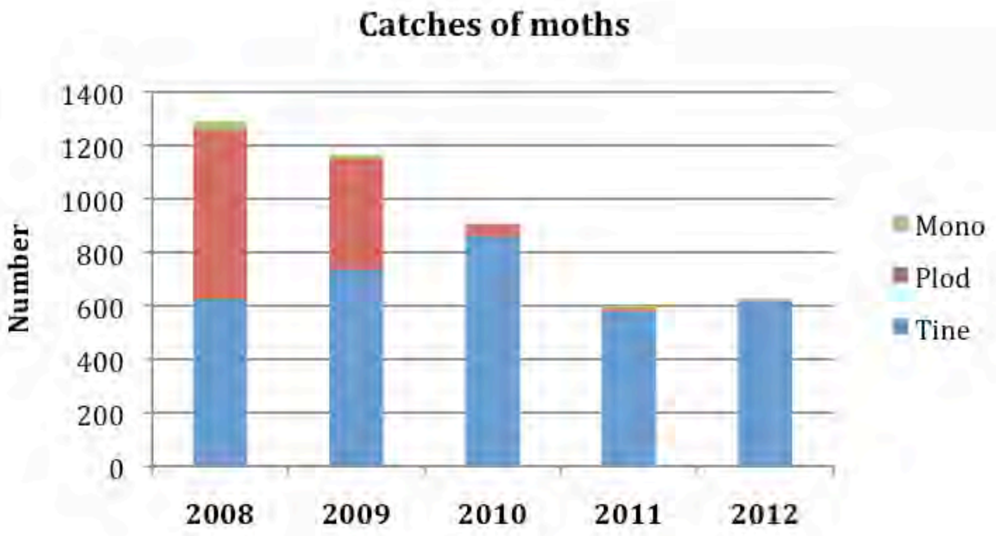

Fig. 1: Catches of *Monopis obviella* (Mono), *Plodia interpunctella* (Plod) and *Tineola bisselliella* (Tine) from 2008 to 2012 (totals for all surveyed rooms).

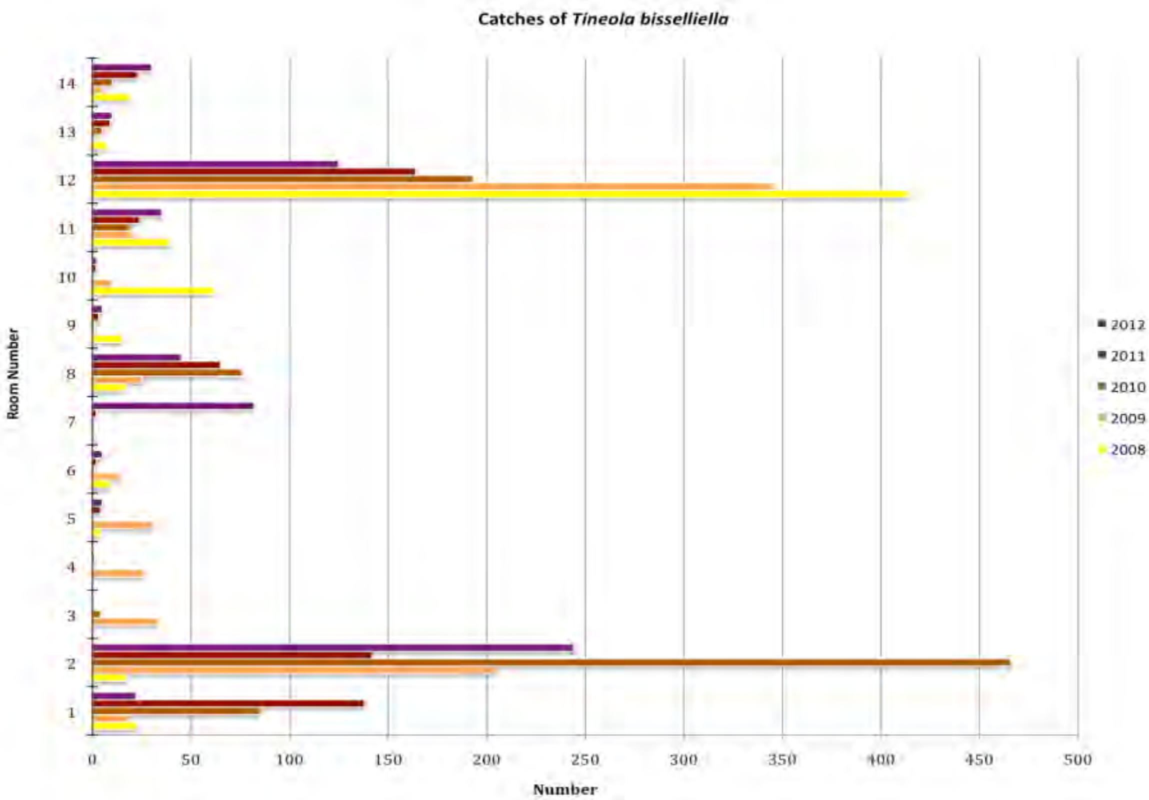

Fig. 2: Results of the monitoring of *Tineola bisselliella* in each room from 2008 to 2012 as a prerequisite for an effective IPM.

Due to the high density of traps and the regular monitoring intervals, it was possible to identify the main sources of moth infestation in each room (see Fig. 3 for room No. 06 as an example), which could then be subjected to further treatment.

Incidence of moths in each room was influenced by the room temperature, whereas relative humidity did not affect the occurrence of *T. bisselliella* (Fig. 4). The early flight of *T. bisselliella* started already in mid-February in some storage rooms, and it did not occur later than in March or April. Catches were obtained till December, but the number of counts decreased after mid-September in most storage rooms. The other two moth species were recorded from mid-May until the end of September (Figs. 4 & 5).

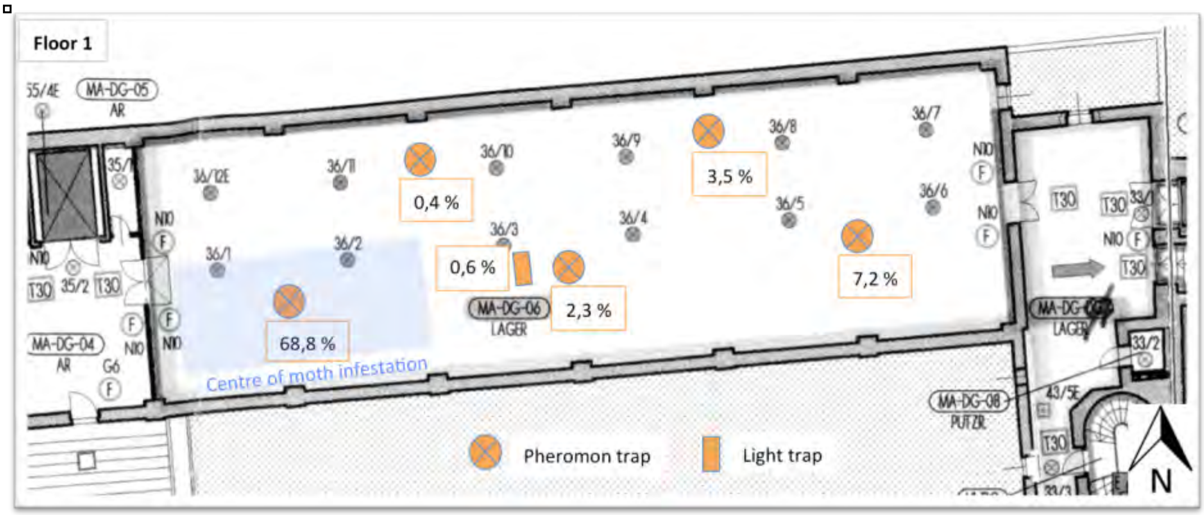

Fig. 3: Positions of several pheromone traps and the percentages of moth catches in the room number 12 from March 2008 to May 2009 on the first floor. The trap with the highest catches indicates the source of moth infestation (blue area).

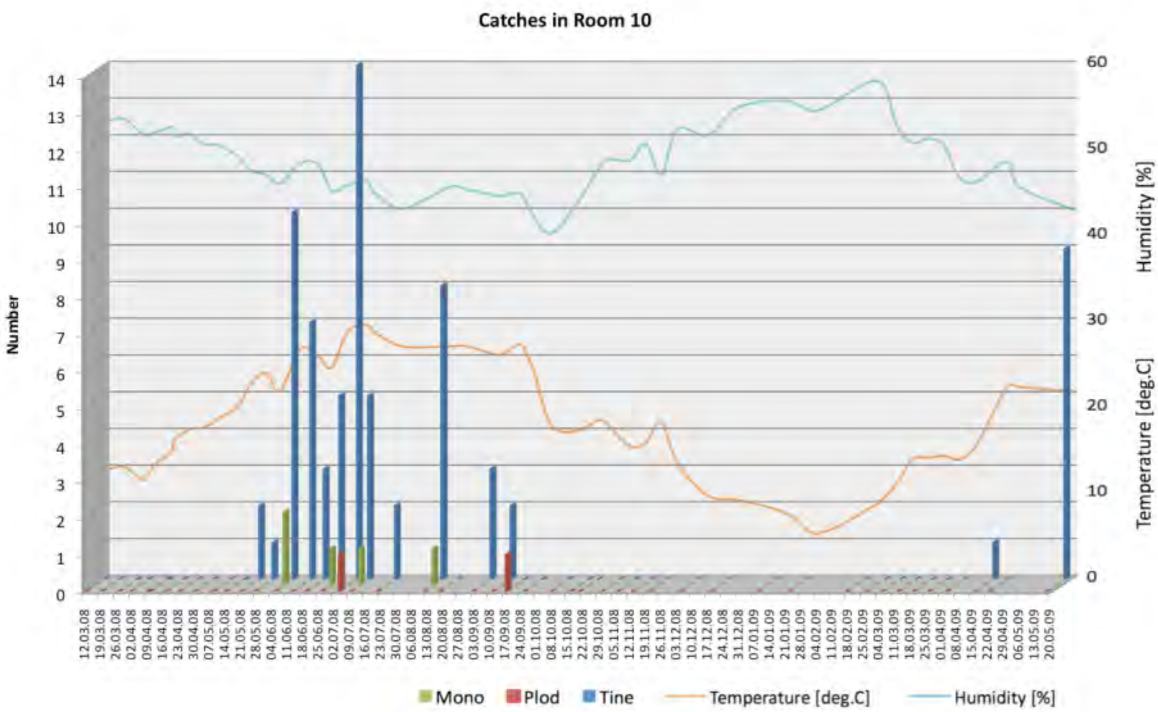

Fig. 4: Abundance of *Monopis obviella* (Mono), *Plodia interpunctella* (Plod) and *Tineola bisselliella* (Tine) from January 2008 to May 2009 in the storage room 10 in relation to room temperature and humidity.

The results of the biweekly monitoring indicated an insufficient knockdown effect of the pyrethroid treatment on the webbing clothes moth, and there was also no long-term effect on its population dynamics (Fig. 5). The light traps only caught a few moths and other insects, indicating that the storage rooms are effectively blocking insects entering the room from the outside (Fig. 3). Finally, recommendations for cleaning, ventilation as well as storage and room management were developed. Transport materials such as packaging and covers were controlled and, if necessary, were cleaned or removed.

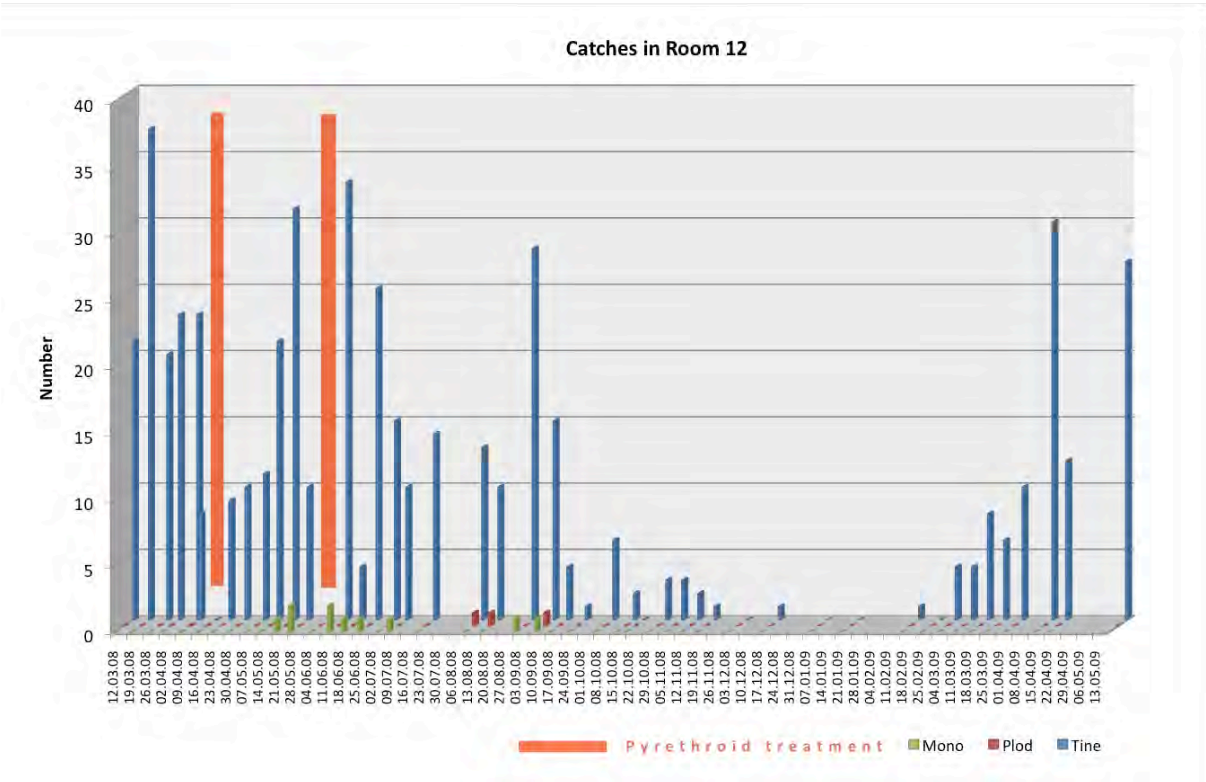

Fig. 5: Abundance of *Monopis obviella* (Mono), *Plodia interpunctella* (Plod) and *Tineola bisselliella* (Tine) before and after the treatment with a pyrethroid in storage room 12.

4. Discussion and Conclusion

The use of pheromone traps has proven to be the most useful monitoring tool but did not result in significant moth reduction over time. However, it allowed to effectively detecting the presence of the webbing clothes moth and other moth species in the Imperial Furniture Collection, as well as the source and severity of infestations. Special attention should be paid to storage rooms with high moth catches and thus high moth populations, and storage rooms that show an increase of catches in the previous years. While the few catches of *M. obviella* most probably were accidental, the high catches of *P. interpunctella* in 2008 and 2009 might have occurred due to contaminations with the pheromone of the Indian meal moth during the production process or because of the attractiveness of the involved organic solvent in the glue of the pheromone trap. However, both explanations have to remain speculative.

While for other insect pests, for example the common furniture beetle (*Anobium punctatum*), control can be achieved by changing the environmental conditions, this measure is ineffective for *T. bisselliella*. This is because of the broad range of temperature and relative humidity allowing the development of this insect species. Likewise, conventional chemical treatment with a pyrethroid using the ultra-low volume technique did not result in the local eradication of *T. bisselliella* and is, therefore, also not an effective control measure for this pest. Presumably, the insecticide did not reach the target insects because of the thick paddings of the furniture, the kind of objects predominately occurring in the storage rooms. Thus, treatment with suitably humidified nitrogen in a stationary chamber (anoxic fumigation) or humidity-controlled warm air treatment was recommended as alternative treatment.

This led the Imperial Furniture Collection to install a stationary nitrogen chamber in spring 2013. Nitrogen as an inert gas reacts with nearly no other chemical substance, and experiments with *T. bisselliella* by Wudtke (2002) revealed that all stages of the clothes moths were killed within four to six weeks of treatment. Child (2007) indicated that at 25°C two weeks exposure is normally sufficient for most insect pests and that longer treatment times are only needed against woodborers or at lower temperatures. Based on these studies, it should be possible to optimize the time of nitrogen treatment, so that a maximum of objects can be treated. In addition, a newly established quarantine area in the Imperial Furniture Collection should guarantee isolation of furniture specimens with an unclear status of infestation from other parts of the collection.

Acknowledgements

We gratefully acknowledge the support of the Imperial Furniture Collection, Vienna, Austria, its gilder team and its scientific advisory board as well as ADir. RR Erich Steinbuch. PD Dipl.-Ing. Dr. T. Kirisits is acknowledged for linguistic corrections.

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Tineola bisselliela at the Natural History Museum, London

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Abstract
Moths, in particular the webbing clothes moth (*Tineola bisselliella*) are becoming an increasing problem in UK and Europe, putting historical collections at risk. The Natural History Museum in London has achieved some success in controlling the population by applying IPM principles but also using new techniques such as pheromone lures for monitoring, pheromone tab dispersals for population control.

Keywords: *Tineola bisselliella*; clothes moths; pheromone traps; risk zones, exosect®

1. Introduction

The Natural History Museum, London (NHM) have had a comprehensive IPM programme and team for some years now, with a dedicated team of about 20 reps from disciplines across the Museum and backing and financial support from higher management. It is evident that these efforts have paid off with the numbers of rodents and beetles reducing within our buildings. We have achieved this by introducing risk zones, where we divided the Museum into zones depending on the vulnerability to pests. Signage and protocols are then in place to ensure behaviour in these areas are in accordance with the zone. We were then able to commission the software company KE Emu to produce a pest module for our collections management system which has been really useful in alerting to emerging infestations and then allowing us to visually present this information and target specific areas.

Our latest and one of our biggest achievements to date is the opening of a new quarantine facility in September 2013. As a museum facility it is not just for the use of particular collections but open to every department. Any specimen/object or material entering the Museum that could pose a pest risk should go through the quarantine facility. It has a large unpacking room to receive specimens and objects, and a treatment room which contains a large freezer, large enough to take a Rhinoceros. It also has a few small upright and chest freezers for smaller items. It has three drying cabinets to dry botanical specimens but also could be used as part of our disaster plan to dry wet objects. We also have a hot/cold chamber which gives us the flexibility to use it for heat treatments or freezing as needed and we also can use this for anoxic treatments. This then goes out to an acclimatisation room or to the exhibitions conservation studio.

However we do have our problems and as with many other institutes in the UK we have seen an alarming increase in the clothes moth (*Tineola bisselliella*) especially in our public galleries. The results from monitoringclearly showed we had a moth problem in the public mammal corridor but we needed to find a way to deal with it. The first response was to freeze the mounted display of infested cats. This was done a few times until the curators in Zoology said look we can’t keep doing this and we are not prepared to let the specimens go back on display until something a little more long term was in place to deal with the moth problem. So for some time the big cats’ case in the mammal hall remained empty. Not a good situation.

One of the IPM reps. from the public engagement team made a huge effort to find the source of the problem. She looked in areas we hadn't looked in before, under floor grates, old exhibition cases and even in the roof voids. What she found was that the old display cases which could not be moved or replaced provided ideal, dark, dirty places for pests to live. She also discovered that we had a few housekeeping issues that needed to be addressed and with some tenacious pestering of Estates she was given access to some very old plans of the Waterhouse building. This showed that many of the galleries were linked through the floor and ceiling vents, heating vents. She arranged a deep and high level clean and for the more inaccessible under floor and ceiling we treated these spaces with a desiccant dust.

While this investigation was on going we decided to look at a moth prevention system called exosect® (www.exosect.com). We were aware of this system as the Royal Opera house in Covent Garden had used it successfully to control moths in their costume stores and it had been discussed at the UK IPM group. So we invited a representative from exosect® to assess and quote the areas we had in mind for the trial. Once we received the quote and discussed our options we decided to do a three-year trial of this system in three of our galleries

2. Material and Methods

Exosect® is a mating confusion system for controlling clothes moths (*Tineola bisselliella*) without using pesticides. It works by deploying an Entostat powder, which is a natural food grade product, combined with a pheromone specific to the female cloth moths.

The powder is placed inside a bespoke dispenser in a tablet form; these are located around the gallery at approximately 5m intervals. The increased presence of pheromone attracts male moths out into the open. The males are attracted to either a monitoring trap where they provide an idea of overall infestation levels or to the Exosex cl tab where they pick up the powder and female pheromone. The male carrying the Entostat powder will form a mobile pheromone dispenser producing a false pheromone trail, which attracts more males into the open. As contact between the males continues the Entostat powder is passed on to more and more male moths. Thinking there are only females in the space this causes confusion and a disruption to the mating cycle, hence the number of moths being produced is reduced.

The decision was made to trail three galleries for a period of at least three years (Tab. 1). The galleries chosen were:

- The mammal gallery as this was a problem we needed to find a new solution for.
- The bird gallery, not a gallery with the same history of moth problems with various infestations and a vulnerable collection and a very busy gallery.
- The Creepy crawlies gallery - This gallery had high numbers of moths. You could see them flying in front of your face as you walked through.

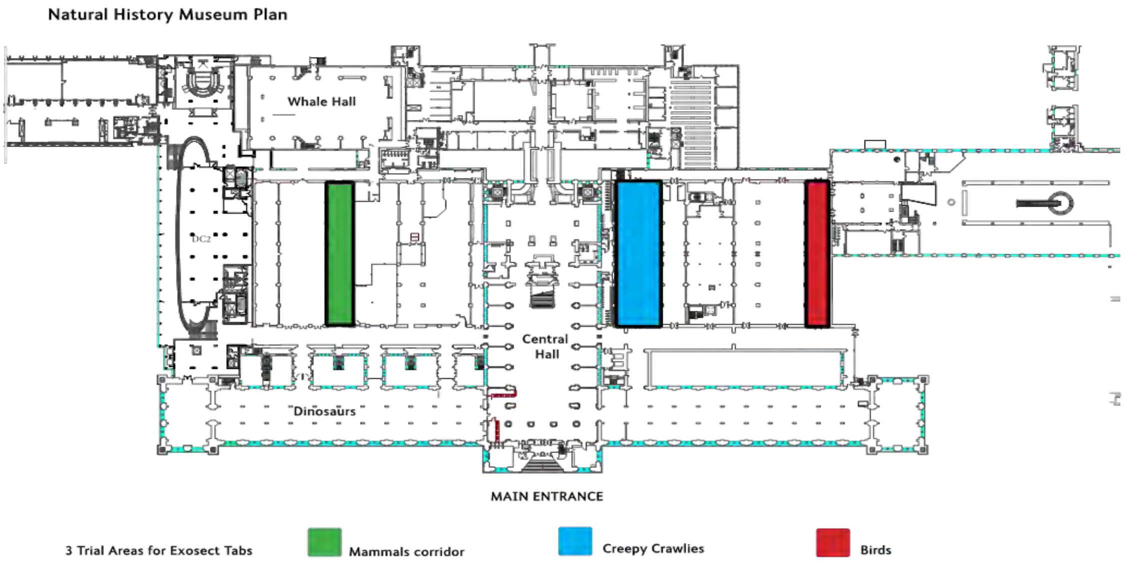


Fig. 1: Proximity of galleries in exosect® trail.

The separation of the galleries chosen was also of interest as they are far enough not to be directly affected by the moths from the other chosen trial galleries but as mentioned before all linked by the vents and ducts.

We are still using AF diamond pheromone traps in these areas because

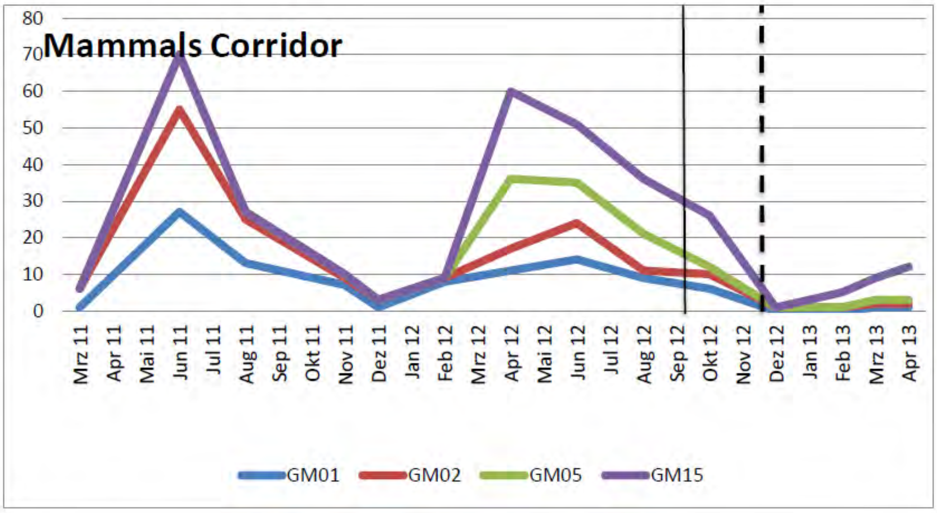
- For consistency, to see if the exosect® is making a difference
- We looked at using Varroa boards in the AF trap cases but this didn't work as they attracted little to no moths to them although there were still loads on the AF diamond pheromone traps.

3. Results

The line on these graphs indicates the start of the trial but also the deep clean and application of the desiccant dust. So the initial indications are good there is a reduction in moth numbers but it is still early days, just the start of the warmer weather and possible decreased due to the cleaning of the areas. So as I think time will tell us if the exosect® control system is really the working as well as we hope.

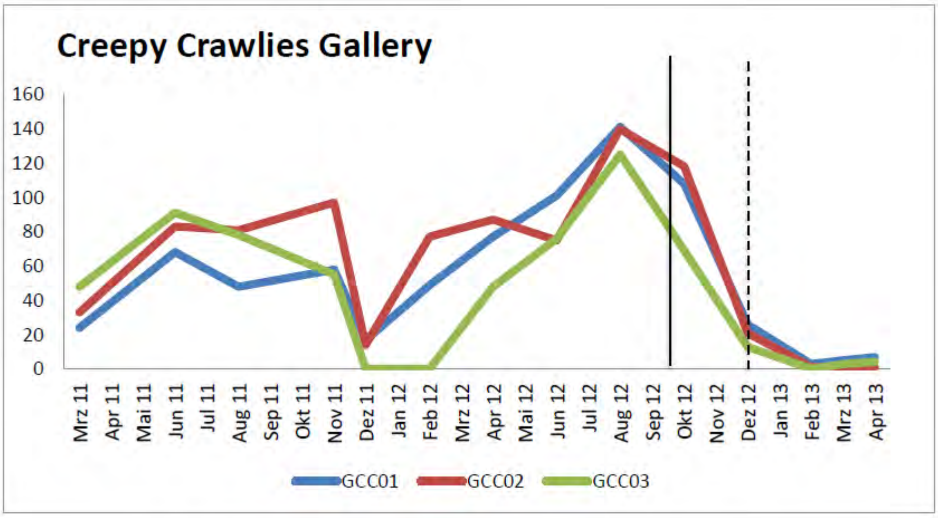
We will continue this trial and hopefully publish the results. However, it is worth mentioning that we will continue to look at other options for control and we are already looking to trail the use of a tiny parasitic wasp *Trichogramma* sp. as a biological control agent.

Different biological agents were reported to control many of our Museum pests. So we are keen to try this. We have an area in the Museum identified as a potential trail site, far enough away from our exosect® trail site not to disrupt results so hopefully we will set this up in the next few months.



Exosect® Tabs placed in Gallery -----

Tops of cases cleaned in gallery - - - - - -



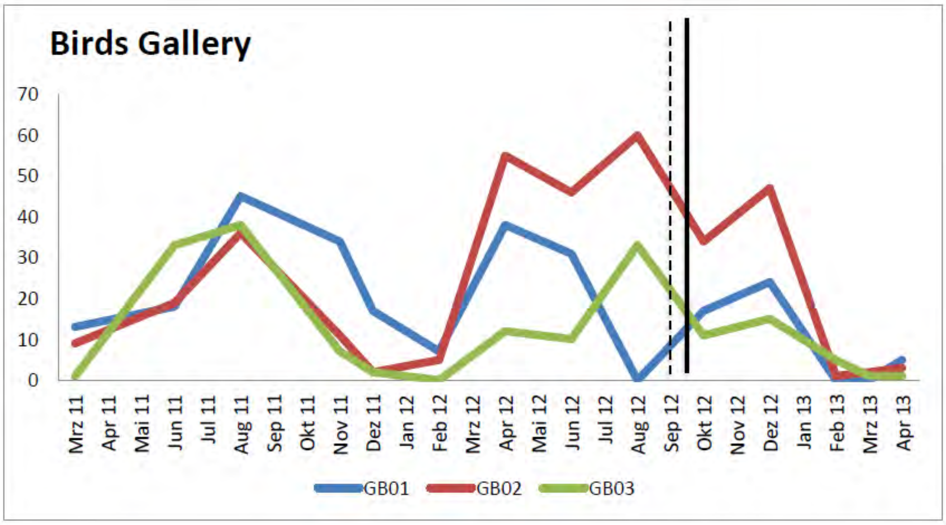


Fig. 2-4: These graphs show the monitoring results for the mammal corridor, the creepy crawlies gallery and the bird.

Conclusion

However, I think it is worth mentioning that whatever system of control we find to work for us in the long time will always work in line with the basic principles of IPM and none can be expected to replace best work practice, monitoring, identification, housekeeping, training, quarantine, environmental control, facilities design & management and high quality collections storage.

Control of the wood boring weevil (*Pentarthrum huttoni*; Coleoptera: Curculionidae) by changing the environmental conditions in the crypt of St. Michael's church, Vienna

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Abstract
Severe damage by the wood boring weevil (*Pentarthrum huttoni*), was recorded from 18th century coffins in the crypt of St. Michael's church in 2005. Because observational research indicates that infestation by this Cossonine weevil is promoted by very damp conditions, measures of dehumidification were initiated in the crypt. These were accompanied by monitoring the environmental conditions and the beetle/larvae activity at two points in the crypt and in a cellar ('Kleiner Michaelerkeller') in the direct vicinity of the crypt, which was not subjected to dehumidification. Temperature and humidity were recorded by data loggers. Timber moisture was determined by gravimetric method. While no significant differences were found for the daily temperature means, humidity differed significantly between the investigated sites. In the cellar, where beetle/larvae activity was still recorded, the annual average humidity was 99%, whereas in the 'priests' crypt' and the 'paupers' souls crypt' humidity was 90% and 85%, respectively. Although humidity at the two points in the crypt is still considerably high, and probably near the range that allows development of *P. huttoni*, no further activity such as presence of fresh bore dust or occurrence of adult beetles or larvae could be detected during our one-year survey. Interestingly, the timber moisture in the crypt ranged between 9 and 11%, although a higher value (20%) would have been expected according to the given temperature (12°C) and ambient air humidity (rH = 88%) during the investigated period. Results indicate that dehumidification is a sufficient method to control development of *P. huttoni* without further application of insecticides and/or toxic gases even though the initial goal of 60-65% ambient air humidity could not be achieved during the study. Through installing new dehumification equipment this goal has now been achieved.
Attempts to prove our finding experimentally in climate chambers failed, although experiments were conducted four times using different types of artificial diets to rear the weevils and induce egg deposition.

Keywords: *Pentarthrum huttoni*; wood boring weevil; environmental conditions; wooden coffins

1. Introduction

Pentarthrum huttoni Wollaston, 1841 (Cossoninae) is a wood boring weevil that was presumably introduced to Europe from Chile (Mc.Caig and Ridout 2012). It is reported from many European countries such as Great Britain (Kemp 1944, Buck 1948, Stables 1973, Allison 2003) and Channel Islands (Barclay 2003), Ireland (Hammad 1955), Belgium (Bruge 1994), the Netherlands (Brakmann 1966), France (Hoffmann 1954), Denmark (Rasmussen, 1976), Switzerland (C. Besuchet, pers. comm.), Germany (Dieckmann 1983), Austria (Halmschlager *et al.* 2007), Poland (Stachowiak and Wanat 2001), Italy (Abbazzi and Osella 1992) and Spain (Folwaczny 1973). It is mainly found in cellars, damp buildings and decaying or dead wood in coastal regions (Folwaczny 1983). Both the larvae and adults cause damage to sapwood as well as to heartwood and both hardwoods and softwoods are liable to infestation.

In April 2005 *P. huttoni* (Fig. 1) was identified to cause severe damage and disintegration of historically significant softwood coffins (predominantly spruce) from the 17th and 18th century in the crypt of St. Michael's church in Vienna (Halmschlager *et al.* 2007). The involvement of other timber pests such as wood boring Anobiidae (e.g. *Anobium punctatum*) or Lyctidae (powder post beetles, *Lyctus* sp.) was ruled out in the same study. Because observational research indicates that *P. huttoni* attacks only damp or wet timber (Allen 1942, Hammad 1955, Folwaczny 1973), it was recommended to implement measures of dehumidification to stop further development of the wood boring weevil in the crypt. This measure would provide a relatively easy and environmentally sound alternative to chemical or anoxia treatment.

Fig. 1: Dorsal view of the wood boring Cossonine weevil *Pentarthrum huttoni* (bar = 1 mm).

The objective of the current study was to monitor the beetle/larvae activity in the crypt due to the changed environmental conditions following dehumidification and to compare it with the situation in a cellar ('Kleiner Michaelerkeller') in the direct vicinity of the crypt, which was not subjected to dehumidification. Furthermore, the study aimed to investigate the temperature and substrate moisture requirements for the development of *P. huttoni* under laboratory conditions in order to confirm anecdotic observations on the substrate requirements of the species reported in the literature.

2. Material and Methods

The beetle/larvae activity was recorded from August 2008 till the end of July 2009 in a bi-weekly interval. Coffins were inspected for the presence of fresh bore dust and the occurrence of larvae or adult beetles. The monitoring was carried out on twelve coffins which had been severely infested by *P. huttoni*, which were still in a good general condition. On each of these coffins a total area of about 0.5 - 1 m^2 was marked with pin board tacks (Fig. 2) and thoroughly cleaned from bore dust with a smooth brush and a vacuum cleaner. Thus, fresh bore dust extrusion on the coffins could easily be detected during the following survey. On two coffins also paper covers (size A4) were mounted in order to detect the chronology of new exit holes. In an adjacent cellar with saturated moisture regime, a severely infested wooden box served as a reference.

Fig. 2: 18^{th} Century coffins in the crypt of St. Michael's church damaged by *Pentarthrum huttoni* with 0.5 – 1 m^2 areas thoroughly cleaned from bore dust and marked with pin board tacks for further inspection of fresh bore dust.

The environmental conditions were measured at two points in the crypt where beetle activity was still detected in July 2008 (before the monitoring of beetle/larvae activity started) and in a cellar ('Kleiner Michaelerkeller' with on-going infestation in the direct vicinity of the crypt, which was not subjected to dehumidification. Temperature (measuring accuracy: ± 0.2 °C) and relative humidity (± 2 % rH) were continuously recorded by data loggers (Minikin-TH-Dataloggers, EMS Brno). Wood moisture was determined by gravimetric method. For that purpose nine planks of children's coffins that had been placed already in 2007 in different parts of the crypt and in the direct vicinity of the data loggers were brought to the laboratory in sealed bags. Planks were then weighted, oven dried at 50°C until constant weight was achieved and weigh again to calculate timber moisture.

Attempts to rear *P. huttoni* under laboratory conditions were carried out in climate chambers (Heraeus Voetsch 'Bioline' HB 0714), at 20 °C and 93 % rH in the dark (modified from Hammad 1955) using three different artificial diets: Diet I (BAM, 2012), which was already successfully used at our institute to rear the common furniture beetle (*Anobium punctatum*) contained 45 g sieved oak wood powder, 52.5 g cellulose powder, 15 g wheat flour and 37.5 g dry yeast mixed with 450 ml water. Diet II consisted of diet I with additional preservative (3 g sorbic acid) and antibiotics (1.5 g Methylparabene and 0.15 g Chlortetracycline) to prevent mould infections that might occur due to the high humidity in the climate chamber. For diet III (modified from Biedermann *et al.* 2009) 7.5 g saccharose, 5 g casein, 5 g starch, 5 dry yeast, 2.5 g wheat germ, 0.65 g Wesson´s salt, 22.5 g agar, 62.5 g wood powder, 0.35 g Streptomycin und 2.5 cl corn oil were mixed with 500 ml distilled water. All media were autoclaved at 121 °C and 1.1 bar for 20 min. Antibiotics were always added after autoclaving using sterile filtration. After a two-hour rest the media was poured into 9 cm Petri dishes, oven dried for 4 days at 60 °C and afterwards stored at 20 °C and 65 % rH.

The records of temperature and relative humidity obtained from the two points in the crypt and the reference point in the cellar were analysed with SPSS 15.0 (© SPSS Inc.) using Kruskal-Wallis-H-, median- and post hoc Mann-Whitney-U-Test for not normal distributed, independent variables. The adjustment of significance of the pairwise tests (Mann-Whitney-U-test) was carried out using the Bonferroni method (Green *et al.* 2000). All results were tested on the $p \leq 0.05$ significance level.

3. Results

3.1 Beetle/larvae activity

Although one living beetle of *P. huttoni* has been detected in the 'priests' crypt' (a more separated part of the crypt, where humidity was expected to be highest) in an initial survey carried out in July 2008, no further beetles were detected in the crypt during the following biweekly surveys carried out over a whole year. Perhaps it was a surviving beetle from the period when saturated conditions were found in the crypt (according to Hammad (1955) adult weevils can live for about sixteen months after emergence). This was also true for fresh bore dust as well as for new exit holes on the paper covers.

In contrast, continued beetle and larvae activity and extrusion of fresh bore dust was observed on wooden boxes in the cellar ('Kleiner Michaelerkeller') in the direct vicinity of the crypt, which was not subjected to dehumidification.

3.2 Temperature

No significant differences were found for the daily temperature means recorded at the three sites (Tab. 1, Fig. 3). Temperature variation was highest in the adjacent cellar (9.9°C) with a minimal temperature of 5.8°C and maximal temperature of 15.8°C. In the 'priests' crypt' and the 'paupers' souls crypt' temperature variation was distinctly lower (5.7°C and 6.6°C respectively).

Table 1: Descriptive statistics of temperature (mean, standard deviation, median, minima, maxima and thus the range of temperature) in the 'priests' crypt', 'paupers' souls crypt' and the adjacent cellar ('Kleiner Michaelerkeller').

	Mean [°C]	Std. dev.	Median [°C]	Minima [°C]	Maxima [°C]	Range [°C]
Paupers' souls crypt	11.1	1.79	11.6	7.8	14.4	6.6
Priests' crypt	11.3	1.49	11.6	8.7	14.4	5.7
Adjacent cellar	11.1	3.10	11.6	5.8	15.8	9.9

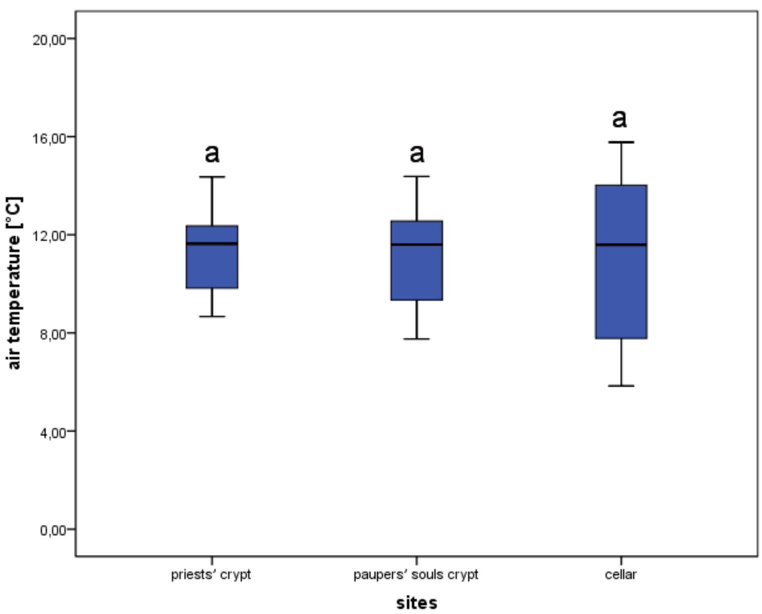

Fig. 3: Boxplot of air temperature (daily means) from 08/2008 till 08/2009 at two points in the crypt ('priests' crypt', 'paupers' souls crypt') and the reference point in an adjacent cellar ('Kleiner Michaelerkeller'); different letters indicate significant differences between the respective sites (Kruskal-Wallis-H-Test, $p \leq 0.05$).

3.3 Relative humidity

The relative humidity differed significantly between the investigated sites. In the cellar, where beetle/larvae activity was still recorded, the annual average humidity was 99% (median: 100%), whereas in the 'priests' crypt' and the 'paupers' souls crypt' humidity was 90% (median: 91%) and 85% (median: 86%), respectively (Tab. 2, Figs. 4, 5). The lowest daily mean was recorded in the 'paupers' souls crypt' (RH = 71%), which was also characterised by the highest variation of relative humidity (27%). In the 'priests' crypt' and the adjacent cellar the limits of variation were distinctly lower (11% and 8%).

Table 2: Descriptive statistics of relative humidity (mean, standard deviation, median, minima, maxima and thus the range of RH) in the 'priests' crypt', 'paupers' souls crypt' and the adjacent cellar ('Kleiner Michaelerkeller').

	Mean [%]	Std. dev.	Median [%]	Minima [%]	Maxima [%]	Range [%]
Paupers' souls crypt	85.0	7.78	86.4	70.8	97.5	26.6
Priests' crypt	90.4	2.89	91.1	83.4	94.3	11.0
Adjacent cellar	98.6	1.99	100.0	92.0	100.0	8.0

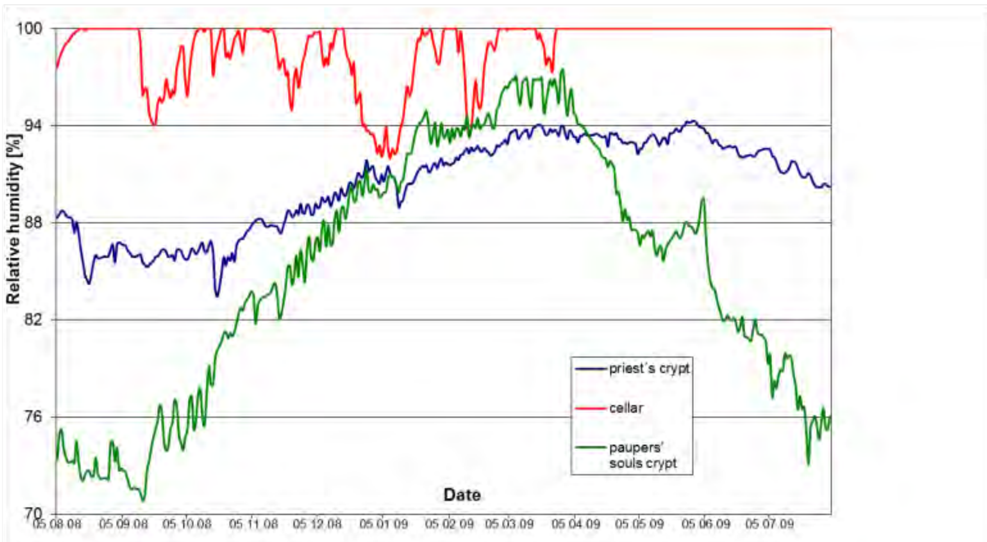

Fig. 4: Relative humidity over the year at two points in the crypt ('priests' crypt', 'paupers' souls crypt') and the reference point in an adjacent cellar ('Kleiner Michaelerkeller') that was not subjected to dehumidification.

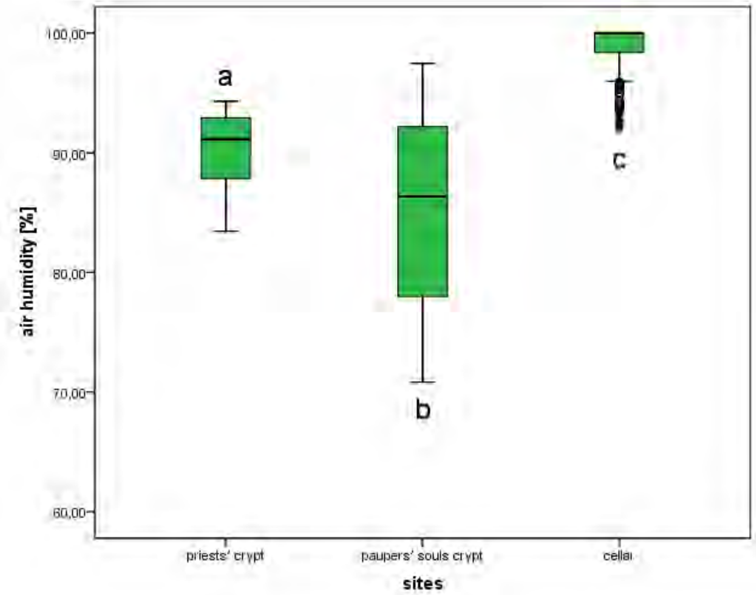

Fig. 5: Boxplot of the relative humidity (daily means) from 08/2008 till 08/2009 at two points in the crypt ('priests' crypt', 'paupers' souls crypt') and the reference point in an adjacent cellar ('Kleiner Michaelerkeller'); different letters indicate significant differences between the respective sites (Kruskal-Wallis-H-Test with post hoc Mann-Whitney-U-Test, $p \leq 0.05$).

3.3 Wood moisture

The average wood moisture calculated from 9 samples that were placed in the crypt was 10%. In the 'paupers' souls crypt' wood moisture was 9.5%, whereas in the 'priests' crypt' wood moisture reached the maximum of 11.1%. Unfortunately no reference sample had been placed in the adjacent cellar with on-going infestation in 1987.

3.4 Rearing experiments in the laboratory

Due to the fact, that no further activity of *P. huttoni* could be detected in the crypt during our one-year survey the only source to collect beetles/larvae were the two infested, small wooden boxes in the adjacent cellar ('Kleiner Michaelerkeller'), which of course limited the number of individuals to be used in the rearing experiments.

The first rearing experiment was started in August 2008 with nine beetles (2 ♀ and 7♂) on artificial diet I. The medium was inspected weekly, however, after three months all weevils had died and no egg deposition had taken place. The same result was obtained in the second rearing experiment which started in November 2008, with 7 weevils (2 ♀ and 5 ♂) and using artificial diet II. In a third experiment in January 2009 five larvae were excised from parts of the wooden boxes and inserted into small holes that had been punched into a disk of artificial diet III. However, after 6 month again only dead larvae could be found and no further development took place. In the last experiment the remaining infested parts of the wooden boxes were brought to the laboratory. From that wood, larvae and pupae (7 larvae and 4 pupae) were dissected and inserted into suitable holes of diet II as described above. In addition, also three adult weevils (1 ♀ and 2 ♂) were obtained, which were offered a disk of diet II and also a small wood sample of the wooden box for egg deposition. Again, no egg deposition took place and no larvae survived within the next two months. Pupae continued development into beetles, but the emerged weevils did not survive on the artificial diet.

Fig. 6: Individuals of *Pentarthrum huttoni* on artificial diet No. I, prepared to rear the weevil under controlled conditions in climate chambers.

4. Discussion

4.1 Development of P. huttoni according to temperature, relative humidity and wood moisture

As no significant differences were obtained for the daily temperature means between the three sites, temperature has to be considered to be not the limiting factor for the development of *P. huttoni* in the present study. In the cellar, where beetle/larvae activity was still recorded, the temperature ranged from 5.8 to 15.8 °C and Hammad (1955) successfully bred the weevil in the laboratory at a temperature of 25°C. So development of *P. huttoni* will occur within a broad range of temperature that usually is found in buildings without heating. Generally, insect pests that attack cultural property prefer temperatures between 15°C and 35°C (Child 2007), but many adult beetles are still active at temperatures down to 0°C. The lack of any beetle/larvae activity in the crypt cannot be explained by limiting low temperatures, because in the adjacent cellar *P. huttoni* was active at the same temperatures.

However, as it is true for all invertebrates, higher temperatures will increase beetle/larvae activity and shorten insects' life cycle, which was found to take to four and a half months on artificial diet (Hammad 1955). Temperatures above 40°C are known to kill most insect species within a few hours and for pest control a norm of 52°C for two hours has become a standard (Child 2007). However, regard has to be paid to the drying out effect of high temperatures (e.g. shrinkage of wood, damage to organic material). Thus, changing temperature to a range that would stop further activity of *P. huttoni* or even kill all stages will not be an appropriate and technically feasible method. This problem could be overcome when humidity will also be increased during the heating process as it is technically realized with the Thermo Lignum controlled humidity treatment.

In contrast to temperature, relative humidity differed significantly between the three sites. In the cellar, where beetle/larvae activity was still recorded, the relative humidity was always near saturation. This result is in accordance with observations reported in literature that *P. huttoni* attacks only moist timber in ill-ventilated situations (Allen 1942, Kemp 1944, Stables 1972, Folwaczny 1973, Hickin 1975, Rasmussen 1976, Allison 2003). The same situation was found in the crypt before onset of dehumidification measures. Due to dehumidification, humidity was reduced from saturated conditions to 85% - 90% rH, which is still considerably high but below the range that allows development of *P. huttoni* as we could prove in our study. So we hypothesize that the threshold value for successful development of *P. huttoni* is at about 95% rH. This assumption is also supported by the results of our rearing experiments that failed at 93% rH, whereas Hammad (1955) successfully bred the weevil at a rH of 95-100%.

In the meantime new dehumidification equipment has been installed in the crypt that enables reaching a relative humidity of 60 – 65% at 14 °C (i.e. the initial goal), which is far beyond the suitable range for the development of *P. huttoni*.

Interestingly, the timber moisture in the crypt ranged between 9 and 11%, although a higher moisture content (20%) would have been expected as equilibrium with the given temperature (12°C) and ambient air humidity (rH = 88%) during the investigated period. This could be due to a reduced water absorption capacity of the coffins´ planks that may result from historical ornamental paintings on the coffins´ surface or other historical surface treatments.

4.2 Rearing experiments under laboratory conditions

Although observational research indicated that *P. huttoni* is often found on wood with fungal decay (Hammad 1955, Hickin 1975) there is no evidence in the literature that the weevil can only develop on wood infected with fungi. Furthermore, Hammad (1955) was able to successfully breed *P. huttoni* on artificial diet made from wholemeal flour amended with 10 – 15 % yeast.

The fact that we failed to rear *P. huttoni* successfully might therefore be due to the point that rearing experiments were carried out in climate chambers that were set to 93% relative humidity, which was the maximum value that could be technically achieved in the chambers. Although this value is close to the range (95 – 100%) that was used by Hammad (1955) who successfully bred the weevil in the laboratory, it obviously was too low to allow development of *P. huttoni*. However, these results fit well with our observations from the 'priests' crypt', where humidity was between 83% and 94% and no further activity of beetles or larvae could be detected.

Conclusions

The results from our one-year monitoring of beetle/larvae activity in combination with the records of temperature and relative humidity in the crypt of St. Michaels church, Vienna indicate that no further development of *P. huttoni* took place when humidity was reduced from saturated conditions to 85% - 90% relative humidity. Thus, dehumidification is an easy and environmental-friendly method to control development of *P. huttoni* without further application of insecticides and/or toxic gases. This point is also supported by our experimental studies in climate chambers, where rearing *P. huttoni* on three different types of artificial diets failed at a relative humidity of 93%.

Acknowledgements

We thank Padre Dr. P. van Meijl, parish of St. Michael, for his interest and the possibility to conduct the investigations in the crypt of St. Michael's church. Dr. A. Rainer and Brigadier i.R. Dipl.-Ing. F. Faltus are acknowledged for their help and coordination work on-site. We are also grateful to Dr. H. Schönmann, Natural History Museum Vienna, for making material available, to L. Behne, DEI, Müncheberg, who kindly confirmed our identification and provided valuable comments on literature on this species, and to Dipl.-Ing. Emma Blackwell for linguistic corrections to the manuscript. The Vienna Chamber of Commerce and Industry, Austria and the Society 'Freunde der Michaelerkirche' are acknowledged for their financial support of this study.

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IPM at the Technisches Museum Wien

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Abstract
As a part of preventive conservation, IPM is an important factor in averting damage to collections. The Technisches Museum Wien (TMW) has sought solutions tailored to the conditions at the institution. Focused measures for integrated pest management have been installed in stages and successively extended and optimised. This paper affords an overview of action taken by the TMW and the benefits of IPM. In 2004 initial steps were taken with the introduction of expert consultancy and pest monitoring as well as activities to improve hygiene at all three museum facilities. Since then, constantly increased and more regulated cleaning measures have been performed. An important step in active pest control was the purchase of mobile nitrogen fumigation equipment in 2007. Awareness training for museum staff and modifications in the environmental conditions of the buildings commenced in 2009. Due to an increase in demand, particularly in connection with the accessioning project of the historic musical instrument collection at the depositories, in 2012 the museum purchased an additional nitrogen gas generator with a much greater capacity and a mobile barrier film tent.

Keywords: Technisches Museum Wien; Nitrogen fumigation; Anoxia treatment

1. If it itches, scratch!

The battle against irritating pests has a long and refined history. The TMW has amongst its collections some fine examples of the weaponry employed over the centuries to wage this war. Great ingenuity was invested in developing the most efficient tool for the job. Some of these devices were devoted to the search, some to the cure and some to the palliative care. Pests, as dangerous carriers of infection, have been hunted down with fine tooth combs for centuries. Flea traps, little amulet-like cages filled with sticky bait prepared from blood, honey and fragrances, were worn close to the body to entice the blood-thirsty beasts. However, as not every flea willingly jumps into a trap, a backscratcher can also be really handy (Fig.1). During the second half of the 19th century the concept of hygiene, or rather industrial hygiene, became a new leading science within the context of increasing industrialisation and urbanisation. The hygiene movement is illustrated by various parts of the collections at the TMW (Lackner 2009, Noggler-Gürtler 2009). On this introductory note, let us now switch from the early days of IPM to its current implementation at TMW.

Fig. 1: Backscratcher, bone and wood, before 1837, TMW inv.no. 7815/7
(TMW, Peter Sedlaczek).

2. The Museum and its collections

The TMW was founded in 1908 and was opened to the public at the end of the First World War. The museum currently employs the equivalent of 156 full-time employees and visitor numbers amount to approximate 316.000 per annum (statistics taken from 2013). It documents the history of industry and technical innovation and is divided into the following broad yet distinct fields:

- Technical and scientific principles
- Information and communication
- Energy and mining
- Production technology
- Transport
- Everyday life and the environment

The institution remains the only broad-based museum of technology in Austria to this day. The permanent exhibition is arranged in six collection areas and incorporates a total of 12.000 exhibits. The store rooms house approximately 95% of the collection holdings. The objects vary enormously in size, from a thimble to a hydro-electric turbine. Many of the large exhibits cannot be housed in display cases and so there is no viable alternative to open presentation, with all of the related risks. Due to a large diversity in the nature of the objects and their materials, it is impossible to categorise most of the collection strictly according to material groups. The majority is made of a combination of materials, which means that infestation can occur in every collection area and affect almost all objects. In 2003 the museum started an accessioning programme in both depositories. This includes systematically unpacking the objects, accessioning, digitising and cleaning them as well as improving their storage. The project has now reached its half-way stage.

3. The buildings

The museum building and the storage facilities are historic structures with extensive windows and large open-plan spaces, which are mainly unclimatised and uninsulated. The Museum building, built in the early 20th century, is one of the first reinforced concrete structures in Austria and is listed as a historic monument. For decades, only absolutely essential repair work was carried out on the building envelope. In 1992 the Museum was closed for extensive adaptation and renovation, and reopened in 1999 with a total of 22.345 m^2 of exhibition space. Although the original architecture was open plan, the renovation converted it into a 'wide-open' plan building. As the interior is not divided into self-contained spaces, overall climate control is impossible (Fig. 2). Ventilation via windows and doors permits large amounts of dust, dirt, pollutants and insects to enter.

Fig. 2: Modern open-plan architecture in the museum building from the early 20th century. © TMW, Peter Sedlaczek.

The two main storage facilities of the Museum are located in the suburbs of Vienna with a total area of 19.000 m^2. Both buildings are old factories and were not adapted immediately for their present use. Adaptation has been an on-going affair. The Breitensee depository is the largest facility and has an area of around 12.000 m^2 distributed between two buildings and is used for medium-sized and small objects. The older of the two is a listed 4-storey reinforced concrete structure erected in 1916 by Zeiss Werke, and was later a production workshop of Philipps. The second building dates from the 1950s and has 5 floors. The buildings were taken over by the Austrian Federal Army in the 1980s and the Technisches Museum Wien has been a tenant since the 1990s. The second storage facility at Floridsdorf was built as a boiler manufactory in the early 20th century and was owned by the Josef Pauka-Werke. It then became the Simmering-Graz-Pauka-AG. It was taken over by the Technisches Museum Wien in 2002 and has a total area of around 7.000 m^2. It is a large, single-storey, open-plan facility reserved primarily for medium large to very large objects which are stored on large shelving systems or directly on the floor. This facility also has cranes to aid object manipulation.

In both depots, storage is provided in a number of forms depending on the requirements of the object. Many objects are packed into standard sized boxes attached to wooden pallets and reinforced for stacking, while other more bulky or irregularly shaped objects are secured to carpentered pallets, with or without support frames, and covered with cotton dust sheets (Fig. 3). Storage is also provided with plan chests, shelving, cabinets, mobile picture racking and shelving systems.

Fig. 3: Mobile storage devices in the Breitensee depository. © TMW, Walter Schmidl.

4. Expert consultancy and pest monitoring

The first consultation and monitoring regarding pests at all three locations took place in 2004. Since then the external consultant Dr. Pascal Querner is identifying pests and advising the Museum on appropriate action. The pests found to date include: the webbing clothes moth (*Tineola bisselliella*), by far the most common pest in the museum; the varied beetle i.e. the two-spotted carpet beetle (*Attagenus pellio*), the fur beetle (*Attagenus unicolor*), the biscuit beetle (*Stegobium paniceum*), the larder or bacon beetle (*Dermestes lardarius*); and diverse wood pests, e.g. the house longhorn beetle (*Hylotrupes bajulus*), the powder post beetle (*Lyctus* sp.), the capuchin beetle (*Bostrichus capucinus*). Occasionally birds, martens, and mice have also been discovered.

Textile objects or components are the most prone to infestation, for instance the upholstery and carpeting of cars and carriages, where, besides moths (*Tineola bisselliella*), it is not unusual to find the varied carpet beetle (*Anthrenus verbasci*), larder beetle (*Dermestes lardarius*) or fur beetle (*Attagenus unicolor*). Over the years, it has been observed that it is usually the same objects that are affected by moths (*Tineola bisselliella*), which may be related to the use of certain types of pesticides in the past. Some of these chemicals are obviously still active in a number of objects as these do not suffer infestation. The objects with the heaviest infestation are those which either have closed or sealed parts or which had been packed away for a long time without being disturbed, e.g. locked car interiors or car boots. Interestingly, infestation by moths (*Tineola bisselliella*) can also occur on objects solely made of metal as this can take place on the layers of soiling. In the depositories, most of the larger objects did not possess any dust protection and were neither optimally nor sufficiently packed prior to the general accessioning programme. Woodworm (*Anobium* sp.) infestation occurs mainly in the storage facilities and is generally discovered during the accessioning procedure or when an object is inspected for possible display. Factors favouring the risk of pest infestation can also be display elements or exhibition installations, e.g. wheat fields in the past exhibition 'Matters of Taste' (2008-2009) or railway sleepers under locomotives in the permanent exhibition areas.

Only adhesive and pheromone traps are employed for insect monitoring at the TMW. Five tours of inspection are undertaken each year by our external consultant, Pascal Querner, within the framework of our monitoring programme. Plans of trap locations were drafted in 2011 and regularly updated, so that any need for intervention can be recognised faster. These plans have also proved to be very helpful in the planning and execution of environmental modifications in the depository buildings. In

2012/13 the trap locations were colour marked with spray paint in the depositories to increase staff awareness of their presence as they were often displaced accidentally (Fig. 4). In the museum building, trap locations will be made more visible using a more elegant solution.

Fig. 4: Insect traps with location markings in the depository. © TMW, Friedrich Weixelbaumer.

5. Active Pest Control

An early active pest control measure in the museum was the introduction of facilities for freezing at -20°C at all locations in 2004 for the treatment of infested objects less susceptible to variations in ambient climate. Traps for small animals have been in continual use in the museum and storage facilities (e.g. the use of mouse traps and live catch traps for martens). Some isolated fumigations had been carried out by external companies in the past. In 2004 anoxia nitrogen treatment was carried out *in situ* on three large railway carriages in the museum by the Singer Company: the Hannibal passenger coach, the summer railway carriage and the Imperial sleeping car of the Empress Elisabeth. A problem then was to produce an airtight bubble around such large and heavy objects because they had to be lifted to slide the plastic film between wheels and rail.

Since 2007, the museum has possessed its own equipment to start its own programme of anoxia nitrogen treatment. In the depositories the use of pads drizzled with essential oils as repellents was introduced in 2008 and continues to this day. Various essential oils were used, mainly lavender, cedar wood, lemon and eucalyptus. The oils are refreshed once a month. This requires regular monitoring, which is also beneficial to the collection care programme. In 2009, experimental trials using parasitoid wasps (*Trichograma evanescens*) against moth infestation of interior textiles in some of the vehicles in the permanent exhibition area did not lead to any noticeable success. In 2012, an increase in demand for treatments led to the purchase an additional and larger nitrogen generator and a fumigation tent.

6. Anoxia equipment

The museums first equipment was the Veloxy® (very low oxygen System, RGI bioSteryl Tech Srl Genova) anoxia nitrogen generator and an oil-lubricated rotary compressor (manufactured by Hydrovane, with a motor output of 1.1 Kilowatts and a 25 litre compressed air tank) from the Italian company R.G.I Genova, purchased in 2007. Nitrogen purity can be regulated with the flow control of this apparatus, whereby minimizing the flow increases purity. In practice this facility never produced less than 0.3% residual oxygen. A residual oxygen meter was also purchased along with a plastic film that was heat sealed with impulse welding tongs that already had been acquired before for other purposes. But the use of these tongs and film proved to be too troublesome and so in 2008 the museum purchased heat-sealing tongs (HPL WSZ, 300TB, Long Life for Art) and Veloxy plastic film (Veloxy gas-impermeable coated plastic film, LDPE/EVOH/PA). These heat-sealing tongs have the advantage of producing a 12mm deep horizontally grooved seam, which is often sufficient, rather than the 3mm deep simple seam of the impulse welding tongs of which two or three are generally necessary. However, these tongs can only be used on special films coated on one side with, for instance, aluminium or iron to prevent the films from melting and sticking to the tongs. As a result, such films can only be welded on one side. In contrast, impulse welding tongs are suited for use on all weldable films. In this case, it is the duration of welding and not the temperature that is regulated. With the new tongs and film, sealing smaller to medium size objects was much quicker, but it was more convenient, faster and less expensive to have the sealing of large objects in bubbles done by an external company. A new residual oxygen meter (Hand-held device GMH 3691 GOG-L, Long Life for Art) was purchased in 2009 that required considerably less of the treated air to take measurements.

Between 2007 and 2010, a large number of small objects were fumigated with a volume of usually only one to two, but never exceeding 5 m^3. Larger objects, such as coaches and cars, average a volume of between 15 and 20 m^3, requiring much larger welded film bubbles or tents, and this posed new problems that had to be solved. A major issue was the draining of the compressor during operation. Automating this procedure with a timer switch and magnetic valve was augmented by employing the 'Gardena irrigation computer' and, although it was designed to do just the opposite, it actually drains quite magnificently.

In 2012, a new plastic sheet was introduced, Styria Form BAR laminated film, which had been tested during the Kunsthistorisches Museum Wien film project between 2002 and 2004 (Griesser *et al.* 2010). With this material, barrier impulse welding tongs are used instead of heat-sealing tongs. The film is less expensive and also easier to use than the Veloxy film. 'Beak-shaped' impulse welding tongs were acquired. These could be opened much wider than the old ones, making work faster. This equipment enabled the museum to seal and fumigate large objects like carriages or cars independently (Fig. 5), In order to make optimal use of the generated nitrogen, two to three tents were connected to each other and the reduced oxygen air of the first bubble was forced into the second by the in-flowing nitrogen.

Fig. 5: Nitrogen fumigation with the Veloxy system and the Styria Form BAR laminated film. © TMW, Martina Wetzenkircher.

As a result of more intensive inspection, a need for more fumigation was recognised and in 2012 the museum purchased a larger nitrogen generator (with a carbon molecular sieve and the capacity of 1.6 m^3 nitrogen/h, compressor is oil-free and silenced 2.2 KW; 0.195 m^3 air per minute at 10 bar air pressure; Singer) and a mobile fumigation tent (Fig. 6). This equipment permitted much shorter operating periods than the Veloxy equipment, and also lower residual oxygen content was reached. A value below 0.1% can be attained in the tent in three days. Modular assembly of the equipment allows for the rapid replacement of components should the need arise. At a nitrogen purity of 99.9%, the equipment produces 1.6 cubic meters per hour and at a purity of 99.999% even 0.4 cubic meters. This is in contrast to the 0.5 cubic meters at purity of 99.7% with the old equipment. Such levels of purity are advantageous compared to fumigation with 0.3% residual oxygen, where 12 changes of treated air are required as opposed to the present 7 changes. The tent is 5 m long, 2.5 m wide and 2.5 m high and is made of transparent PVC coated material which hangs from an external aluminium frame. It stands on tarpaulin to protect the tent floor. Inside the floor is also covered with tarpaulin with the addition of 19 mm thick pressboard to make transporting objects on jack lifts possible. Sealing discs and magnetic tapes are used for the opening. Three other pieces of equipment for climate control can be regulated via a control panel: an electric heater, humidifier and dehumidifier.

Fig. 6: Nitrogen fumigation with the larger nitrogen generator and a mobile fumigation tent. © TMW, Peter Sedlaczek.

7. Measures to improve general hygiene

Due to the enormous number of objects and the on-going accessioning project at the depositories, which has only just covered approximately half of the collection as a whole, a total and regular monitoring of all collection objects is not feasible. 2004 also saw the reorganisation of collection care in the exhibition areas as well as in the depositories where an annual spring clean is carried out by an external company which includes all accessible areas. Since 2009, constant and more regulated cleaning measures have been performed in the depositories. When necessary, hygiene activities are increased and this has been a cumulative procedure. The museum employs additional trained staff for a systematic inspection of the storage units in the depositories and displays in the exhibition areas, they concentrate on areas where pests have previously been located and intensify the search there. Experience has shown that infested objects should be immediately isolated using welded plastic film and removed until they can be treated. An unnoticed infestation can cause untold damage within one season. It is also standard practice to clean objects that have been fumigated or frozen in order to remove insect remains.

The care of objects on display is carried out on a continuous and regular basis by a team of trained, staff under the supervision of the conservation department. The exhibits are divided into three categories according to their cleaning requirements and are inspected on a twice-weekly basis to ensure quality control. The exhibition areas, including podiums, partition walls and display cases, are cleaned and maintained by an external cleaning company and the museum‘s technical staff. Due to the size, nature and location of the building and the collections, the problems posed are both large and varied. Visitor numbers and interaction with the collections also present large and varied challenges for the collections’ care team.

8. Awareness training and modifying the environment

As doors and windows were often simply left wide open, it was deemed necessary to induct the museum staff into exactly why they should follow regulations. 2009 saw the implementation of new window ventilation restrictions in the main museum building with staff training, stickers being placed on the windows that were to be used and the hours of ventilation. In 2010, the external consultant was invited to give presentations to the personnel. This has proven to be highly successful.
Starting in 2010, intensified efforts at modifying the environment in the depositories have included diverse measures: sealing windows, doors and floors, followed by the partly extensive renovation of windows in both storage facilities and the installation of mosquito nets in the windows of one depot. Extensive renovation of heating and building shell sealing measures was carried out in 2011. The modifications of the building structure and staff awareness have led to a notable improvement in control and an exclusion of insects.

9. Success

Lastly, the constant improvements and intensification of measures in the battle against the pests (Table 1) have resulted in impressive results, if not total victory. In table 2 the dramatic decline of the presence of moths since 2009 can be clearly seen to be the success story of IPM at the TMW.

Table 1: Chronology of IPM measures at the Technisches Museum Wien 2004-2013.

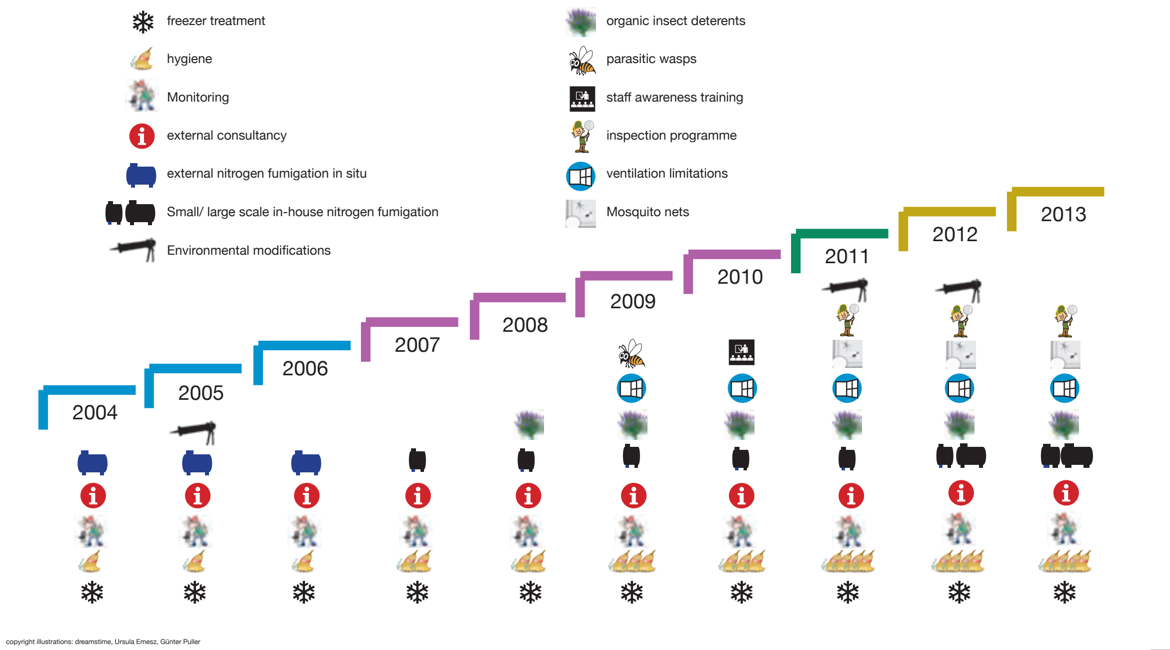

Table 2: Decline of the presence of moths in all three locations since 2009.

	2009	2010	2011	2012
Museum building	604	425	381	364
Depository Breitensee	1761	494	209	147
Depository Floridsdorf	1050	1446	556	365

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Thirteen years of IPM at the Imperial Carriage Museum, Vienna - from the beginnings to now

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Abstract
The Imperial Carriage Museum 'Kaiserliche Wagenburg Wien' is situated in the middle of the park of Schönbrunn. It stores and exhibits objects like horse carriages, harnesses and textiles, which consist of different organic materials, such as, wood, wool, feathers or leather. In addition to pests like the furniture beetle (*Anobium punctatum*), the drugstore beetle (*Stegobium paniceum*) or the powder post beetle (*Lyctus linearis*), the webbing clothes moth (*Tineola bisselliella*) is the most abundant pest. In the past a variety of materials like the horse carriage cushions and textiles were heavily infested by the moths, but today, after 13 years of IPM, the number of moths were significantly reduced and most of the moths caught emerge rather from the building than from infested objects. Due to the old building, weak points allow pests to enter and survive unnoticed in shafts or under the parquet floor. Further reasons for new infestations are frequent object movements between infested and non-infested exhibition and storage rooms. The implementation of IPM included the introduction of different kind of traps, training of the staff, thorough cleaning, elimination of possible food sources in the building and improvement of climate conditions. Objects that are obviously infested by insects are treated in the nitrogen chamber of the museum and in especially constructed large tents in the storage sites. This paper gives an overview of the problems with pests, the solutions to be found and the measures resulting from the IPM of the last 13 years.

Keywords: horse carriage; horse harness; textile pests; Nitrogen treatment; microwave treatment; heat blanket; monitoring; parasitoids

1. Introduction

The Wagenburg is located in the park of the Schönbrunn Palace. The collection includes about 180 historic vehicles, sleighs and sedan chairs. There are currently about 60 carriages and sleighs displayed in the 1.300 m^2 exhibition space, the remaining objects are stored in two depots also located in the historic buildings (total surface of about 6.000 m^2). These also house large parts of the historic horse harnesses collection.

The annual number of visitors is at about 70.000, so dirt carried in by visitors is high and dirt traps, air locks and cloak rooms are not available because they are difficult or impossible to implement, due to structural reasons. The leaky building as a whole, especially the roof and old shafts, make it impossible to clearly separate between exterior and interior. Due to the diverse building fabric and the location of the building parts, a variety of climate problems occur, such as high relative humidity especially during the transitional period (spring and autumn), cold-wall problem and light incidence from the outside. The suspended ceiling for the light installation is an additional uncontrollable space that gives potential to pest infestation.

The badly insulated building (historic doors and windows, un-tight roof and a number of shafts) results in reoccurring pest infestations. For many years the major pest in the collection has been the webbing clothes moth (*Tineola bisselliella)*, since many objects are made of wool, silk, feathers and the padding of the carriages and sleigh upholstery are filled with horse hair. Other pests are biscuit beetles

(*Stegobium paniceum)* infesting the starch paste of the horse harnesses and horse figurines. Carpet beetles (*Anthrenus verbasci* and *Anthrenus scrophulariae*) are also repeatedly found in the collection where they probably mainly feed on dead insects (Querner 2009, Querner and Morelli 2009).

Fig. 1: Overview of the exhibition space of the Wagenburg in Schönbrunn Park in Vienna, Austria.

1.1 IPM at the Wagenburg

Up until the 1990s it was common to apply pesticides both prophylactically and as a treatment in case of infestation. Such pesticides were often applied directly onto the objects, neither checking the origin of the infestation nor including the environment. As pests have become resistant to these poisonous chemicals over the years and because these products proved to be harmful to humans and the environment, previous pesticides were replaced by new ones. In the collection substances like DDT, Lindane, methyl bromide and prussic acid (Hydrogen cyanide) were used. These pesticides remain toxic up until today and lead to a long term degradation of all kinds of materials and cause corrosion of metal. Furthermore they may pose a health hazard for the people handling those objects. For these reasons, the restorers of the collection were looking for alternatives.
More and more naturally based repellents were used, such as sweet clover or lavender sachets, patchouli, clove oil or commercial repellents for the wardrobe. Since it was known that also these substances can trigger negative reactions to historic objects and that they also can be toxic, and due to the fact that the general health awareness of restorers was rising, other options had to be found. After completing an IPM course by Bob Child and David Pinniger at the University of Applied Arts Vienna in 2001, the transition to IPM was initiated (Pinniger 2004, 2008).

2. Material and Methods

Since 2000, regular IPM monitoring with traps has been carried out in all rooms of the Wagenburg collection. At present, pheromone traps for webbing clothes moths, biscuit beetles and carpet beetles are used (Child and Pinniger 1993, Cox *et al.* 1996, Child 2011). Pheromone traps for moths were also set up in the suspended ceiling of the exhibition hall and all accessible shafts of the attic storages once a year. Additional sticky traps were located near doors and other passages. A total of 174 pheromone traps and 37 sticky traps were placed in the different exhibition and storage rooms and are checked five times a year between April and October.

The amount of moths caught in the traps is entered in tables in which the reference number of each object is listed. Then the data is compared with the location plan of the objects, making it easy to locate possible sources of infestation. The traps are checked and evaluated once a month in the warm season between May and October, during the active cycle of an adult moth's life. From November to March we have temperatures between 3°C and 10°C, so we assume that only one population of moths is developed per year.

3. Results

3.1 Webbing clothes moth (*Tineola bisselliella*)

Webbing clothes moths are the most abundant pest in the collection of the Wagenburg, but the number has been reduced considerably, especially in the exhibitions spaces (Table 1). In some of the storage rooms numbers have risen over the last years. A large proportion of the moths trapped in the last monitoring year of 2013 were found in the suspended ceiling and other shafts and spaces where no historic objects or materials are stored. We assume that the moth larvae are feeding on dead animal remains or other organic materials not related to the collection.

Table 1: Webbing clothes moths trapped over the years 2001-2013 in the exhibitions hall, the suspended ceiling of the hall, the attic of the building (storage I and II), different shafts of the attic and two separate horse carriage storages in two separate buildings.

Year	Moths trapped Exhibition hall	Moths trapped in the suspended ceiling	Moths trapped in storage I Dachb. 1	Moths trapped in storage II Dachb. 2	Moths trapped in shafts	Moths trapped in storage III Engl.Reitst.	Moths trapped in storage IV Kutschenh.
2001	580	Not included in the monitoring	9	Not included in the monitoring	Not included in the monitoring	23	24
2002	249	Not included	6	Not included	Not included	14	9
2003	220	Not included	0	Not included	Not included	21	0
2004	197	Not included	4	0	Not included	2	0
2005	175	Not included	2	0	Not included	1	2
2006	139	Not included	3	0	Not included	5	2
2007	95	Not included	4	0	125	1	5
2008	125	235	6	0	47	24	20
2009	99	228	10	0	54	6	11
2010	158	37	7	0	74	47	7
2011	60	45	3	0	53	39	15
2012	70	28	2	0	67	64	11
2013	46	28	1	1	124 (65 moths were counted in one shaft!)	38	13

However, the amount of moths found in the exhibition space has been consistently low, some dust samples from the floor (space between the wooden planks of the parquet floor, Fig. 2) were analysed and remains of webbing clothes moths and other pests like carpet beetles were found (Fig. 3, see also Chaviara 2011).

Fig. 2: Dust sample from underneath the parquet floor.

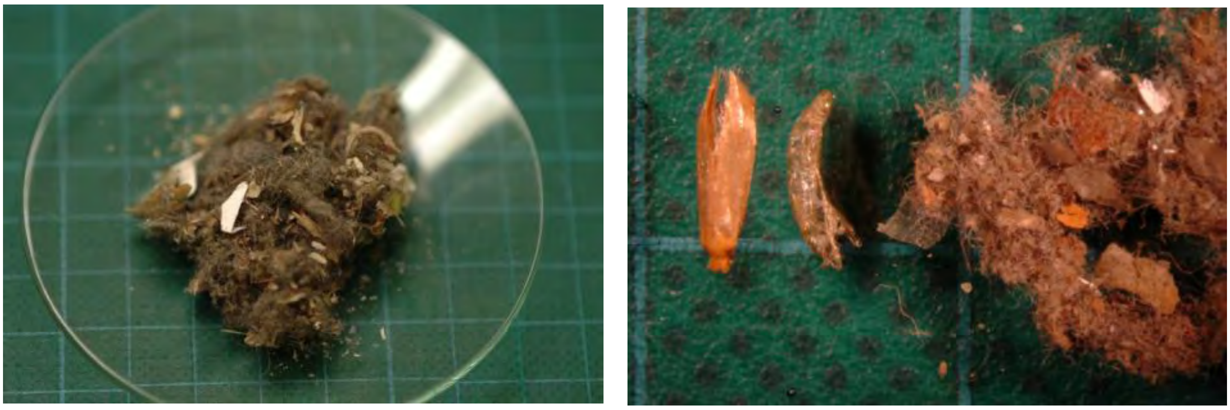

Fig. 3 a,b: Dust sample with insect remains.

3.2 Carpet beetle (Anthrenus verbasci and *Anthrenus scrophulariae)*

Carpet beetles repeatedly occur and have become a problem over the last years. We assume that the beetles are feeding mainly on dust (see Fig. 2 and 3) and dead insects, but fortunately no objects are currently infested with these species. In the past there have been active infestations by these beetles in the collection, mainly on feathers.

3.3 Biscuit beetle (*Stegobium paniceum)*

Active biscuit beetle infestations were discovered on objects with starchy bonds, for example in parts of horse harnesses or horse figurines in one of the attic storage rooms. A few individuals are found every year and their spread is immediately limited by the exposure of parasitoid wasps (*Lariophagus distinguendus)*. In case of an infestation objects subsequently undergo a fumigation treatment in the in-house nitrogen chamber and the surrounding area is thoroughly cleaned.

3.4 Furniture beetle (*Anobium punctatum)*

Over the last years very few individuals of the furniture beetles were found, but nevertheless one carriage was treated with nitrogen due to a suspected infestation. Many vehicles show exit holes typical for this pest, but they are presumably caused by former infestations. Currently there is no infestation of furniture beetle in the collection.

3.5 Powder post beetle (Lyctus linearis)

In 2009 an active infestation of the wooden parquet floor was discovered in the oak floor of the exhibition hall (Fig. 4). After an initial sample treatment, the visible infested areas as well as surrounding areas were treated with microwaves by the company MTB (Fig 6). Just one year later in September 2010 we found new exit holes in the parquet floor. There are various explanations: Firstly, the treatment took place in August during the time of flight of the *Lyctus* and adult beetles were able to escape in the cavities under the floor boards. Secondly, the treatment was carried out from the edge towards the centre of the room. It would have been better to work from the centre towards the edges of the room to drive the pests into a corner. Thirdly, the power supply needed for the microwaves was insufficient, so instead of 10 only 6 generators could be used simultaneously.

Fig. 4: Active infestation of the wooden parquet floor by the powder post beetle (*Lyctus linearis*).

3.6 Treatment methods

Since the late 1980s objects of the collection have been treated exclusively with the in-house nitrogen chamber of the Kunsthistorisches Museum Wien. However, large objects, such as carriages were often too big for the museum's chamber or the number of objects to be treated exceeded the capacity of the chamber. Therefore these objects had to be treated individually in self-constructed tents made of tubes and plastic film in one of our carriage stores (Fig. 5).

Fig. 5: Nitrogen treatment in self-made tents and using nitrogen from bottles.

In addition to the microwave treatment applied 2009 and 2010, we recently experimented with the treatment using electric blankets on a large-scale, done by the company Thermo Lignum (Fig. 7). This was conducted in March 2012 at a room temperature of below 10 °C. This method involves heating the floor directly by the blanket. Unfortunately, occasionally individual excursion holes reoccur in the sapwood areas of the floor, which are then partially treated with electric blankets. The only justification for this persistent infestation seems to be that the thermal treatment does not reach possible affected hardwood wedges which might be hidden underneath the softwood construction. In the long run, we will have to replace the floor in the exhibition hall, as it continues to attract pests.

Fig. 6: Microwave treatment of the parquet floor.

Fig. 7: Heat blanket treatment of the parquet floor.

For a biological control of the biscuit beetles parasitoid wasps (*Lariophagus distinguendus*) (Fig. 8) were released to the affected areas. This was done to diminish the infestation before a treatment of the objects with Nitrogen was possible or as an additional method for killing the larvae of the beetles in the storage room.

Fig. 8: Parasitoid wasps (*Lariophagus distinguendus)* released in areas with an active infestation of biscuit beetles.

4. Discussion

Implementing pest monitoring is a relatively simple task. Much more time and labour consuming are (1) finding possible leaks in the building, (2) the organisation of the subsequent maintenance and building repair as well as (3) the implementation of a regular housekeeping. In addition, we are trying to limit insect development reducing relative humidity in order to improve the general climate conditions by controlled air exchange. Furthermore, educational work, i.e. IPM training within the museum is necessary to further spread the information and increase the readiness of all employees to work towards the same goal (Querner and Morelli 2010a,b, Querner *et al.* 2013). In recent years, the infestation of clothes moths in the exhibition hall has steadily decreased, probably due to the consistent implementation of the IPM over the years and the systematic nitrogen fumigation of infested carriages.

Even though we may suffer repeated minor setbacks (like the example from the powder post beetle infestation), after having 13 year of experience we can predict that pest infestation will decline gradually. Due to regular IPM, infestation can be detected faster, can be localized and subsequently treated. A big problem we face is that treated objects are put back into the exhibition room or storage spaces and therefore can be re-infested by untreated objects in the surrounding areas.

Currently our solution to this problem is to isolate objects that are "clean" from the ones that are infested by encasing them in plastic foil and adhering the foil to the floor. Pheromone traps are used as an indicator and the encasing either protects against infested objects or acts as quarantine. This quick, efficient and inexpensive method ensures objects are not a hazard for other objects while waiting for treatment. With all the evidence, we are convinced that IPM is the only nontoxic and long term way to handle pest problems.

Acknowledgements

I thank my colleague Dani Sailer for the translation and correction of this text.

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Relocation of the collections from the Kunsthistorisches Museum Wien to a newly built storage site – consequences for the IPM

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Abstract
The Kunsthistorisches Museum Wien is one of the largest fine arts collections worldwide, comprising the Kunsthistorisches Museum itself, the Austrian Theater Museum and the Museum of Ethnology (Weltmuseum Wien), all placed in Vienna, and Ambras Castle Innsbruck, Tyrol. The Museum was the first with an Integrated Pest Management (IPM) concept and a nitrogen chamber (since 1998) in Vienna. In September 2009 the museum decided to build a new central art depository. Due to financial reasons not all of the one million objects relocated could be treated against an insect attack as a preventive measure. Therefore, in preparation for the relocation, all relevant storage sites were monitored as part of a large IPM program. With the results of the monitoring, infested objects were found and specific pest problems within the collections could be identified. Concrete examples were a biscuit beetle (*Stegobium paniceum*) infestation on paintings of the Picture Gallery lined with starch paste. On the textile décor of vehicles belonging to the Museum of Carriages and on costumes or mixed media objects of the Austrian Theatre Museum webbing clothes moths (*Tineola bisselliella*) were found. Before the collection's removal in 2011, all infested objects were treated with nitrogen to prevent an introduction of pests into the new central art depository. To expand the capacity of the museums' nitrogen chambers at the old and new storage sites, three large nitrogen tents had to be built. Considerable costs and logistics were saved by not treating all fitments and objects such as many of the wood pallets and large parts of the textile collection. The risks associated with this were discussed and taken in these cases. In the new central art depository a new monitoring program was installed in 2012 and showed the success of the IPM program. New preventive measures such as, regular release of parasitoid wasps in the new storage, installation of UV traps, fly-screens and annual general cleaning were also introduced.

Keywords: IPM concept; relocation; central art depository; insect pests; biscuit beetle infestation; paintings

1. Introduction

The protection of the objects from pests was, and still is, a major challenge for museums and collections and an important part of preventive conservation. Some pests cause considerable damage to objects such as, the webbing clothes moth (*Tineola bisselliella*), the biscuit beetle *Stegobium paniceum*, the furniture beetle (*Anobium punctatum*) and various fur beetles (*Attagenus* sp., or *Anthrenus* sp.).

In the past insecticides such as cyanide, DDT and lindane were used regularly against the pests. Nowadays the concept of Integrated Pest Management (IPM) is applied in museums. Avoidance of an insect infestation is the most important part of IPM (Querner and Simon 2011, Querner *et al.* 2013). This is achieved by sealing the building, climate regulation, regular cleaning, the introduction of quarantine and regular monitoring of collections by using traps. A single person should be responsible for the IPM concept and coordinate the activities and set priorities. If an infestation occurs, non-toxic treatment methods such as freezing, controlled heating or anoxia should to be applied to kill pests in all stages of development.
The Kunsthistorisches Museum with the Weltmuseum Wien (formerly Museum of Ethnology, MVK) and Austrian Theatre Museum (ÖTM) were one of the first museums in Vienna and Austria to introduce an IPM concept and in 1996 performed tests with nitrogen treatments in the Picture Gallery. In 1998 an 80 m^3 nitrogen treatment chamber was built and used until 2011 to treat infested objects in a five-week cycle from the in-house collections, and also those from other museums, institutions and private collections in Austria. In addition monitoring with sticky blunder and pheromone traps was introduced in most collections, for example in the Picture Gallery since 1993 and in the World Museum and the Museum of Carriages since 2003.

2. The new central art depository

2.1 Initial situation

In September 2009 the museum's management decided that it was time to inventory and centralize the > one million objects dispersed over nine different locations in and around Vienna. The main drive of this decision was to achieve savings and better stock control of the eight collections: Coin Collection, Collection of Greek and Roman Antiquities, Collection of Sculpture and Decorative Arts (including the Tapestries Collection), Museum of Carriages and Department of Court Uniforms, Egyptian and Near Eastern Collection, Historic Musical Instrument Collection, Picture Gallery, Collections from the Austrian Theatre Museum and three archives. Most of the rented storage space used until then was in need of extensive renovation or updating. The Kunsthistorisches Museum wanted to create a comprehensive state-of-the-art location suitable for all objects in its collections.

The new depot should meet the storage needs over the next 30 years. The project goals were notably a single location with high standards (climatic condition, fire safety, security, hygiene, IPM, logistics, storage techniques), to get rid of rental obligations and to optimize the costs. In the difficult economical context, the management not only considered the initial investment, but also the subsequent running costs. The existing budget for the project had been 14 million Euros including the purchase of land and relocation costs, which is considerably low for a project of this amplitude (Fleck *et al.* 2012, Kimmel *et al.* 2012).

The project was initiated in 2009 and came to an end in 2013. Two project teams were created, one for the conception and construction of the building, consisting of five members, and the second one for all relocation aspects consisting of six to 15 members according to requirements. The responsibility for the specific area of pest control was contracted to an external consultant (Pascal Querner).

2.2 Building

After an extensive period of planning and all necessary preparatory administrative steps, the construction of the building started on October 2010. Despite the difficult weather conditions, the building construction was finished after only eight months. On 6th of July 2011 the former Austrian Minister of Education, Arts and Culture, Claudia Schmied, together with the management and staff of the museum inaugurated the new central art depository in Himberg close to Vienna.

The building measures 14.000 square meters in total (Fig. 1). It contains all required space for transport, easy access and a special room for nitrogen treatment of pest-infested objects (Fig. 2). The building has been designed to minimize risk of fire. To keep costs low, prefabricated building components were used meeting all the needs, functionality was crucial in this construction. Instead of a fully climatised building, it was decided to use geothermal energy, offering the advantage of being more cost effective and less prone to malfunction. Therefore, 32 deep probes (each with a length of 100 m) were inserted until the strata of groundwater keeping stable climatic conditions of 20°C and 50 % relative humidity appropriate for most objects. The few items requiring specific storage climatic conditions, such as metal coins and bronze statues, are stored in separate boxes providing lower humidity of 40 %. The fully automatic computer system monitors temperature and humidity. It immediately reports any malfunction in the building via email and sms.

Fig. 1: Central art depository of the Kunsthistorisches Museum, exterior view. © Stefan Fleck, KHM.

Fig. 2: Central art depository of the Kunsthistorisches Museum, view of the interior of the nitrogen

chamber. © Christina Schaaf-Fundneider.

2.3 Relocation

The collection comprises objects as diverse as delicate textiles, bronzes and even carriages. For the relocation, details of logistics and scheduling had to be planned. The most important part consisted of establishing a comprehensive inventory and determining the artefacts' conditions. Depending on the state and type of possible infestation, specific treatments were necessary before moving the items. One of the tasks also was to develop standardized packing solutions for 95 % of the objects moved as well as special solutions for outsize or particularly fragile artefacts (Fig. 3). When necessary, the artefacts also had to be cleaned, mould removed or set aside from the noninfested objects.

Fig. 3: Packing of a delicate crocodile mummy belonging to the Egyptian and Near Eastern Collection by the staff of a local art forwarding company for the relocation from the old to the newly built storage site. © Irene Engelhardt, KHM.

By the end of November 2011, the first transfer phase was successfully completed. All rented storage units were cleaned out ahead of time after 345 truck movements without any problems or incidents. While phase I was rather straightforward, phase II was more difficult. The local storage areas that had to be cleaned out were basically basements and attics or other remote rooms spread over different storage facilities. There was no or only a little room to pack and bring the objects from their previous storage to the truck.

In total, approximately one million objects from the late Middle Ages to Modern and Contemporary Art were transferred (Fig. 4a,b). The relocation cost one million Euros. By making an investment of 1.7 million Euros in shelves, cupboards, compactors, hoisting walls and special construction, it was possible to ensure the best housing for the objects in the collections. A bar code system will be used to enable quick identification and the tracking of locations (Kimmel *et al.* 2012, Schaaf-Fundneider and Kimmel 2012).

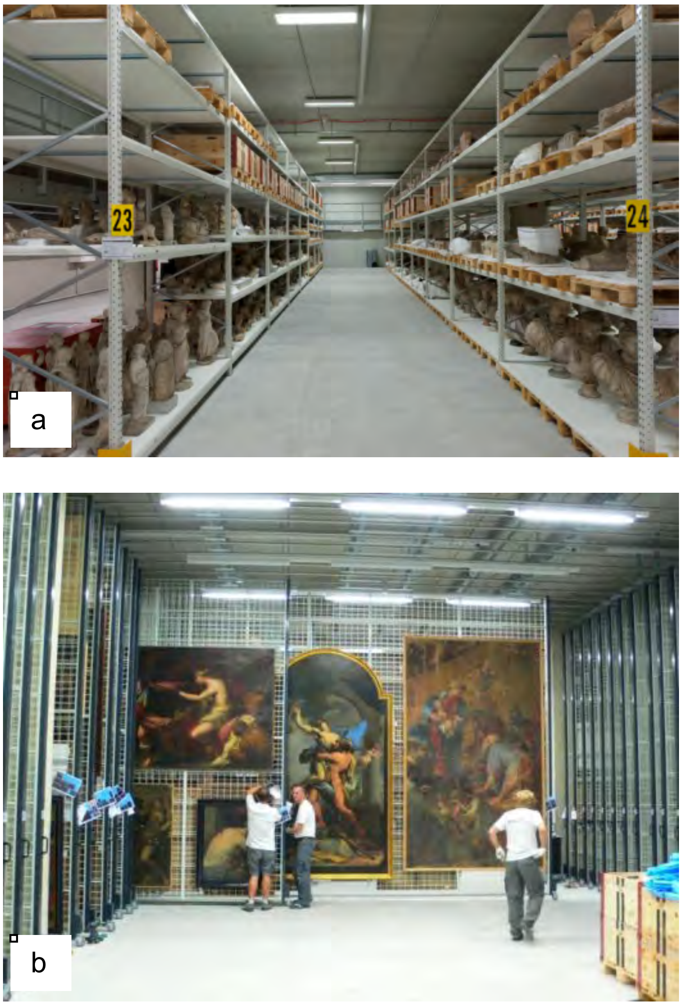

Fig. 4 a,b: Central art depository of the Kunsthistorisches Museum, depot area of the Collection of Greek and Roman Antiquities (a) and the Picture Gallery (b) after the objects had been stored. © Tom Ritter (a) and Tanja Kimmel (b), KHM.

3. Planning the new art depository and the preparation of the relocation in consideration of IPM

When planning the new central art depository, the most effective pest prevention from outside was chosen and the following requirements of the floor plan put into practice (see also Querner *et al.* 2013):

1. Best possible separation of delivery and storage areas (at least 3 door passages);
2. A separated area for the delivery of infested objects to the nitrogen chamber;
3. Quarantine rooms for objects infested with insects and microorganisms (mould) in close proximity to the nitrogen chamber;
4. Larger treatment chamber (100 m^3) to meet the increased needs of the museum;
5. Keeping the walls in the storage area as free as possible from shelves and objects, so that monitoring with traps and regular cleaning can be performed.

The relocation of Collections and archives to a newly built art depository is a unique chance for museums to start a pest-free storage. The time before the move should be used in order to identify and treat infested objects. Since not all objects from all collections could be treated against pests, because of time, money and logistical reasons, the IPM results were an important tool to select priorities and choosing treatment actions. The results of these investigations and the subsequent measures taken are presented below.

4. Material and Methods

In total 251 sticky blunder traps (type CATCHMASTER), 151 pheromone traps for webbing clothes moths (type FINICON) and 31 pheromone traps for biscuit beetles were placed in March 2010 and checked ten times until October 2011 in all former storage depositories to locate infested objects/collections before the relocation. All pests on the traps were identified to species level and the other arthropods to group level.

Sticky blunder and pheromone traps for webbing clothes moths and for biscuit beetles were ordered from Pestimo Services. The test insects for controlling the nitrogen treatments and the parasitoid wasps were ordered from the BAM, Federal Institute for Materials Research and BiP, Biological Consulting Ltd. in Berlin.

5. Results of the monitoring and treatments

5.1 Infestations found

In the Museum of Carriages and the Austrian Theatre Museum an active infestation of webbing clothes moth (*Tineola bisselliella)* had been detected in previous monitoring actions and could be confirmed in the new and standardised monitoring of 2010 and 2011. In addition, an active infestation of biscuit beetles (*Stegobium paniceum*) of starch-glue containing horse's harness collection and horse Fig.s was found (Fig. 5). Also carpet beetles *Anthrenus verbasci* and *Anthrenus scrophulariae* were found repeatedly in the collection. In the collection of the Picture Gallery an infestation of biscuit beetles (*Stegobium paniceum*) was discovered in the first year (Fig. 6). This infestation of paintings was already known from the past and is a recurring problem. Other collections of the former main storage such as the Department of Court Uniforms, the Egyptian and Near Eastern Collection, the Tapestries of the Kunstkammer Wien or the Collection of Historic Musical Instruments were found to be pest free.

Fig. 5: Infestation of biscuit beetles (*Stegobium paniceum*) on horse Fig.s of the Museum of Carriages made from maché and starch-glue. © Pascal Querner.

Fig. 6: Infestation of biscuit beetles (*Stegobium paniceum*) on starch-glue lined painting of the Picture Gallery. © Eva Götz, KHM.

5.2 Choosing objects and collections to be treated

To prevent a spread of pests in the new central art depository and at the same time saving costs for nitrogen treatments of objects infested, the monitoring results from 2010 and 2011 were regularly discussed with the Relocation team and measures to manage the infestation prepared. In collections with an active infestation (e.g. infestation of biscuit beetles in the storage of the Picture Gallery) 100 % of the premises' objects were treated with nitrogen. In this case, no risk was taken and in addition to the paintings, the stock of decorative frames was completely treated, although the wooden frames are not in danger of being infested by biscuit beetles.

The Collection of Greek and Roman Antiquities stores a multiplicity of its objects on wooden pallets. For a possible infestation by wood-boring beetles (Querner 2007) the 1400 units were visually inspected in September 2010 (Fig. 7). With the help of a flashlight, they were searched for exit holes, frass and dead beetles on, beside and under the wooden pallets. On shelves located at eye level and on the ground, no signs of old or current infestation was found. Wood-boring insects had not been found in this storage area over the last years nor on the traps used. We therefore assumed a low chance of an unnoticed active infestation and reused most of the pallets without treatment. Only old or unstable units were replaced and all new wooden pallets purchased were heat-treated before being used in the new art depository.

Fig. 7: Wooden pallets of the Collection of Greek and Roman Antiquities, visually inspected for wood-boring beetles before their relocation in the newly built storage site. © Pascal Querner.

5.3 Nitrogen treatment of infested objects

In the old store the museums' existing nitrogen chamber was used for treatments of infested objects until the decommission of the rented storage site. For two collections (Picture Gallery and Museum of Carriages) the number of objects to be treated was so high that three large additional tents had to be set up at two sites by an external company (Assanierungsgesellschaft Michael Singer GmbH & Co. KG). One big 1.000 m^3 tent was installed at the old storage site in Inzersdorf and used twice for the treatment of all paintings and decorative frames. Two smaller tents with a total volume of about 100 m^3 were set up in one of the Carriage Museums' storages located on the premises of Schönbrunn Palace for the treatment of vehicles and some furnishing (Fig. 8). The first cycle in the big tent worked well. The second cycle of the large tent and the treatment in the two smaller tents had to be repeated: Due to technical problems, the residual oxygen content had risen in the tents and we were not sure of a 100 % effectiveness of the treatment. For additional control of the nitrogen treatments, test insects (webbing clothes moths, all stages; drugstore beetle, all stages and longhorn beetle, larvae) were placed in the sealed tent and checked after the treatment: Inside the tent all animals were dead and all the reference specimens placed outside survived.

In order to avoid contamination just before the opening of the tent, the insecticide Cyfluthrin was sprayed along all corners of the room. In addition fogging with Pyrethrum-piperonyl butoxide was performed to kill all potential surviving biscuit beetles outside the tent. To prevent a new infestation, the treated objects were transported directly from the chamber or tents to the new central art depository or temporarily stored in a pest-free environment.

Fig. 8: Museum of Carriages, nitrogen treatment of infested objects in one of the collection's storages. © Pascal Querner.

5.4 Temporary action against the biscuit beetle until the nitrogen treatment

To prevent further damage to the objects until the nitrogen treatments was performed (1.5 years after the detection of the infestation) parasitoid wasps (*Lariophagus distinguendus*)were released at regular intervals in July, August and September 2010 in the vicinity of the infested objects (Querner and Biebl 2011, Querner *et al.* 2013, Schöller and Prozell 2014). The female wasps lay her eggs on the larvae of the biscuit beetle and kill them, which was a useful measure to reduce the population.

6. Monitoring and current operation in the new central art depository

In March 2012, a monitoring programme was started in the new art depository in Himberg, close to Vienna. The traps were located in the floor plan and general information on the IPM programme are stored for the museums' management. Information panels on the traps and potential pests were attached to doors and insect screens were installed on all windows that have to be opened. In addition, three UV traps (Flytrap 80 with 2 x 40 watt tubes) were placed at the two main delivery areas and the general area where show cases and other expedients are stored. Every year a large cleaning campaign is performed in all areas of the storage to prevent the accumulation of dust.

7. Discussion and conclusion

With the large IPM program presented we successfully prevented the spread of pests to the new art depository in the course of transfer of the museums' collections. After two years of monitoring in the new storage facility we can give a résumé: Insects, including some pests have occurred in the new storage site and have to be dealt with, but we are confident that they were not transported with the objects. Large numbers of webbing clothes moths were trapped in the first year of monitoring, originating from non-museum objects, such as catalogues, furnishings and show cases stored in a separate storage area. Bugs (Heteroptera**,** *Rhaphigaster nebulosa*) and ground beetles (Coleoptera*, Harpalus rufipes*) are regularly found entering the building from outside (the storage is located in an intensively used agricultural area). In 2013, two years after the relocation of the objects to the newly built storage site, a new active infestation of paintings by biscuit beetles was discovered. As no beetles were discovered in the previous year, we are sure the nitrogen treatment of the paintings was successful. It could be possible that the infestation occurred at the new location or some beetles were transported with packing materials.

Deciding not to treat all objects was a difficult decision as some organic objects, such as historic textiles, can easily be infested by moths or beetles. But our results show that we have efficiently saved time and money by treating only the parts of the collection where it was needed. We propose that other museums already in the stage of planning a new art depository or relocation of their collection should consider spending time and money on a good monitoring system before deciding what objects or collections need to be treated (Querner and Simon 2011, Querner *et al.* 2013).

Acknowledgements

We are particularly thankful to all people involved in this project. If you are interested in more details of the project we refer you to an extra volume of the in-house publication called "Technologische Studien, Sonderband Depot" with different articles and numerous pictures. Querner *et al.* 2013.
We thank the Kunsthistorisches Museum Wien for the support and funding of the IPM program in the various collections and its staff for their technical suggestions and good cooperation.

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