Proceedings of the Ninth International Conference on Urban Pests
Matthew P. Davies, Carolin Pfeiffer, and William H Robinson (editors) 2017
Printed by Pureprint Group, Crowson House, Uckfield, East Sussex TN22 1PH UK

BIOLOGICAL CONTROL WITH LARVAL PARASITOID *LARIOPHAGUS DISTINGUENDUS* IN MUSEUMS AND HISTORIC BUILDINGS

PASCAL QUERNER
University of Natural Resources and Applied Life Sciences, Department of Integrated Biology and Biodiversity Research, Institute of Zoology, Gregor-Mendel-Straße 33, A-1180 Vienna - Austria
Universitity of Applied Arts Vienna, Institute of Archäometrie, Expositur Salzgries, A-1010 Vienna, Austria

Abstract In this paper the biological control of biscuit beetle (*Stegobium paniceum*) and spider beetle (*Gibbium psylloides)* found in different museums, historic buildings and a monastery library in Austria is described. Six case studies are presented where the insect pest monitoring with sticky blunder traps showed the activity of biscuit beetles and spider beetles. It was not clear if objects were actively infested or the pests were coming from the building. Success of the release of wasps varies and no clear trend was found. In two cases the monitoring in the years after the release clearly showed the success of this control method. In the other cases the number of the beetles remained about the same. In those cases the beetles were probably not living in infested objects but were coming from the building. In the infested library other measures needed to be taken as the trapped number of beetles increased significantly. Biological pest control with mass release of parasitoid wasps might have a future in preventive conservation of museum objects, but success depends very much on the local circumstances and the type of the infested objects.

Key words Museum pests; Integrated Pest Management; IPM; treatment; costs.

INTRODUCTION

Integrated Pest Management (IPM) is an important part of preventive conservation in museums and aims to stop both damage to valuable museum objects and the spread of pests between collections. In IPM, different measures like sealing the building, regulating the climate, quarantine for all incoming objects, good cleaning and housekeeping, training museum staff and monitoring all help to prevent an infestation (see for example Brokerhof, 2007; Flieder and Capderou; 1999, Florian, 1997; Pinniger, 2015; Querner, 2015; www.museumpests.net). Most museums try to reduce the application of pesticides in their collections and use freezing, controlled heating, nitrogen or CO_2 fumigation or anoxic treatment to kill all stages of pests in wood, textile, natural history, ethnographic, modern art objects, historic libraries, archives or historic buildings (see Querner and Kjerulff, 2013 for an overview of treatment methods used in museums).

For some years, parasitoid wasps have been applied in biological pest control to reduce infestations in food storage and processing facilities (Schöller et al., 1997; 2006). Various parasitoid species are now commercially available and can be applied against different kinds of moths and beetles (Schöller and Flinn, 2000). Good results have been obtained from different experiments using various selected foods, breeding and releasing parasitoids against different stored product pests (Schöller et al., 1997; 2006).

The same pests as in the food industry like the drugstore beetle (*Stegobium paniceum*), the tobacco beetle (*Lasioderma serricorne*) and the webbing clothes moth (*Tineola bisselliella*) are also important pests in museum, therefore parasitiods could also be used to control them (see Schöller, 2010; Schöller and Prozell, 2011; 2016). Over the last years biological control of insects was tested in several museum collections (Querner and Biebl, 2011; Anheuser and Garcia Gomez, 2013; Anheuser, 2016; Querner et al., 2013; Biebl, 2013; Auer and Kassel, 2014; Querner et al., 2015) but most of these applications were carried out alongside other treatments such as freezing or nitrogen fumigation (Biebl and Reichmuth, 2013; Querner et al., 2015). Until now it is not clear whether a biological control using parasitoid wasps can be 100% successful in a museum environment. Compared with stored product protection, food storage and processing facilities, where biological control is used mainly to reduce infestations under a commercial threshold, in a museum context the infestation needs to be eradicated completely, as the objects are stored for long periods and cannot be replaced.

In this paper we report on the release of the larval parasitoid *Lariophagus distinguendus* against an active biscuit beetle infestation in a museum. See Table 1 for an overview of the most important pests and their natural predators (or predators accepting them as host), that are of relevance for biological control of museum pests.

Table 1. Different insect pest species found in museums or historic buildings (see Pinniger, 2015; Querner, 2015) and their biological control agents). Species marked with " * " are commercially available (Table modified from Biebl personal communication, Zimmermann, 2005; Al Kirshi, 1998).

Moth Species	**Egg and Larval Parasitoid**	**Reference**
Tineola bisselliella	*Trichogramma* spp. * *Apanteles carpatus* *	Zimmermann, 2005 Plarre et al., 1999
Tinea pellionella	*Baryscapus tineivorus* (Eulophidae)	Zimmermann, 2005
Beetles Species	**Predator or Larval Parasitoid**	
Stegobium paniceum *Lasioderma serricorne* *Niptus hololeucus* *Gibbium psylloides*	*Lariophagus distinguendus* * *Anisopteromalus calandrae* * *Cephalonomia gallicula*	Kaschef, 1961 Kaschef, 1955 Biebl and Reichmuth, 2013 Schöller, 2010
Trogoderma angustum *Anthrenus verbasci*	*Laelius pedatus* *	Al Kirishi, 1998
Attagenus unicolor *Attagenus smirnovi* *Anthrenocerus australis*	*Xylocoris flavipes * (bug)*	Al Kirishi, 1998
Anobium punctatum	*Spathius exarator* * *Cephalonomia gallicula*	Auer and Kassel, 2014

Larval parasitoid *Lariophagus distinguendus* (Hymenoptera, Pteromalidae).

A naturally occurring parasitoid of the biscuit beetle *S. paniceum* is the pteromalid parasitoid *Lariophagus distinguendus*. The larval parsitoid wasp has a cosmopolitan distribution and is reported to attack about 15 different beetle species from several families (Noyes, 2014), but not all equally successfully (Goodrich, 1921; König et al., 2015). Several of these pests are regularly active in museum collections or historic buildings and naturally become parasitized by *L. distinguendus*. Examples are: The larvae of the drugstore beetle *S. paniceum*, of the tobacco beetle *L. serricorne,* both occurring in museums and historic libraries and the hump beetle *Gibbium psylloides* and the golden spider beetle *Niptus hololeucus,* both frequently occurring in historic buildings.

The wasps find their hosts mainly by olfactory stimuli (Benelli et al., 2013; Steidle, 2000; Steidle and Ruther, 2000). *L. distinguendus* occurs naturally in central Europe and can also be found in high infested museum locations. The wasps lay up to 60 eggs on the larvae and pupae of the beetles, which are found within the infested materials. Parasitoid wasps should be released either monthly, or 2-4 times per year to treat an infestation.

MATERIAL AND METHODS

Monitoring insect activity in the storage or museums

In all locations monitoring with sticky blunder traps (type Catchmaster) was performed to collect regularly active insect pests and non-pest arthropods. Traps were replaced twice per year and checked six times per year between March and October. Traps were left in place also for the winter months but not checked regularly. The results and details from the monitoring data are not presented here. Table 2 presents the abundance of the pests *S. paniceum* and *G. psylloides* in the last years.

Parasitoid release after beetles were found

If an activity of pests like *S. paniceum* and *G. psylloides* was found, the release of the parasitoid wasps *L. distinguendus* was discussed with the conservator and the number of wasps and release dates decided on a case by case situation (see Table 2). There were released in the rooms where the beetles were found, usually close to the objects on the floor.

Table 2. Location (exhibition space in a museum = M, museum storage = S, historic library = L), pest species found and treated, years where the monitoring was performed, parasitorid release dates, number of parsitoid wasps *L. distinguendus* released each date.

Location and Pest Species	Year	Numb. of Pests	Parasitoid Release Dates	Number of Parasitoids Released	Success or Failure
Hofburg Wien (M) *G. p.*	2012 2013 2014 2015 2016	46 47 44 44 55	2., 3., 4., 5. 2014 2., 3., 4., 5. 2015	4 x 150 ind. 4 x 150 ind.	No effect on the biscuit beetles! -> can not reach the beetles underneath the floor boards
Monastery library (L) *S. p.*	2014 2015 2016	207 273 681	11., 12. 2014 4., 5., 7., 10., 10. 2015 3., 4., 5., 6. 2016	2 x 900 ind. 5 x 900 ind. 4 x 900 ind.	No effect on the biscuit beetles -> high infestation of books -> other treatment needed
Academy picture gallery (M) *S. p.*	2013 2014 2015 2016	5 8 4 8	4., 5. 2014 2., 3., 4., 5. 2015	2 x 120 ind. 4 x 180 ind.	No effect on the biscuit beetles ! -> they come from the building
KHM picture gallery (M) *S. p.*	2012 2013 2014 2015 2016	18 2 8 8 9	4., 5. 2012 4., 5., 6. 2013 3., 4., 5. 2014 2., 3., 4., 5. 2015	2 x 100 ind. 3 x 300 ind. 3 x 300 ind. 4 x 300 ind.	No effect on the biscuit beetles ! -> they come from the building
KHM old storage (S) *S. p.*	2010 2011	51 5	4., 5., 6. 2010	3 x 360 ind.	reduction of beetles, but all objects (paintings lined with starch paste linings) were treated with Anoxia before transport to new storage
KHM new storage (S) *S. p.*	2013 2014 2015 2016	51 ind. 0 0 0	monthly 7. 2013 until 9. 2014	6 x 1800 ind. 9 x 1800 ind.	no more biscuit beetles were found-> 100% success!

RESULTS AND DISCUSSION

In the two storages where old master paintings were infested by *S. paniceum* (see also Fohrer et al., 2006; Liu, 2013), the release of the wasp had a clear effect on the beetles resulting in much lower number of beetles found on the traps, or none at all. This result shows that biological control of museum pest is possible and can even result in 100% success.

No effect on the contrary was found in the infested library where the historic books already had quite a high infestation. The infestation was discovered in 2013 only by chance and the monitoring and release of parasitoids started soon after. We monitored the effect of the wasp released for two years, but after the beetle population increased significantly in 2016, the release of wasps was stopped and a alternative treatment method had to be found. Similar results were found by Anheuser and Garcia Gomez (2013) for biological control of the webbing clothes moths in an infested store. Also here the release of the wasps could not reduce the moth population. Anheuser (2016) describe pesticide residues in the objects as a potential reason for the failure of this method. This might also be the case in the historic library in Austria, where dead *L. distinguendus* were found close to the release tubes. Parasitoid wasps are known to be very sensitive towards historic pesticides (Mathias Schöller, oral communication) which might be a limitation of this method as many museum collections, especially natural history and ethnography, are still heavily contaminated. A second reason for the failure in the case study of the historic library is the already advanced and high infestation. Not a few beetles were found every year but hundreds (Table 2 presents only the number of beetles found on traps and by the windows, this probably reflects only a portion of the beetles hatching each year). As shown in other examples, parasitiod wasps are only effective when the infestation is still low (Schöller, 2010; Schöller and Prozell, 2011). Therefore a good monitoring and IPM program needs to be in place to monitor pest activity and be able to react when the population is still low.

No effect was also found in three locations where only a low number of *S. paniceum* and *G. psylloides* were found each year. Few beetles of both species were collected on the traps in each location, mostly in the same room year after year. Objects were checked for an infestation and none was found in all three locations. We therefore assume that the beetles were not coming from infested objects (this would have resulted in a clear increase of trapped beetles over the years), but from within the building. *S. paniceum* is known to be a generalist feeding on all kind of food. In museum and historic buildings it prefers food like starchy and dry plant material (see pest fact sheet on www.museumpests.net, www.whatseatingyourcollection.uk and www1.montpellier.inra.fr), but they can feed also on dust, debris, dead animals, bird nests or dead insects. In the historic location *G. psylloides* is probably coming from below the floorboards where it (and other spider beetles) is known to feed on plant material like straw that was historically used for insulation. The location is a palace in the centre of Vienna with a historic floor. When the beetles are coming from within the building, the parasitoid wasps don't seem to find their host larvae, which might be difficult to access underneath the wood parquet floor or in other areas like shafts, a hanging sealing or other dead spaces. If the source of the infestation is assumed to be here, other measurement like cleaning, sealing of gaps or acceptance of a low but stable pest level have to be considered.

We show that the release of parasitoid wasps as part of an Integrated Pest Management concept could have a future in museum environments. The method is cheaper than other methods like nitrogen fumigation, depending on the number of objects or room size. It is also easy to use by non-trained staff and some of the main museum pests can be controlled. The fact that objects do not require transportation to a nitrogen chamber or other facility is a big advantage, since the handling of museum objects bears risks and is also costly.

***Advantages of the biological control in museums*: 1.** No chemicals are applied which could harm objects, staff or the environment; 2. Easy to use; 3. Cheaper than other treatment methods; 4. Objects do not need to be moved to another location for treatment..

***Disadvantages*: 1.** Natural enemies are only commercially available for specific pests; 2. They have to be regularly applied over a long period; 3. They are only effective in the early stages of an infestation; 4. Wasps need to be able to access all pest larvae in the objects; 5. The dead wasps need to be cleaned / removed after the treatment.

ACKNOWLEDGEMENTS

We thank the all Museums in Vienna and the monastery in Klosterneuburg for supporting and funding an IPM program and also for their open approach to testing and funding the use of parasitoid wasps in the collection. We also thank Mathias Schöller, Stefan Biebl and Bill Landsberger for discussion on the use of parasitoid wasps in museums.

REFERENCES CITED

Anheuser, K. and I. Garcia Gomez. 2013. *Trichogramma evanescens* contre *Tineola bisselliella*: expérience de lutte biologique contre la mite des vêtements dans une réserve d'objets ethnographiques. Studies in Conservation 58: 269-273.

Anheuser, K. 2016. Parasitoids against insect pests - a future for IPM? 233-239. *In*: Querner, P., D. Pinniger, and A. Hammer. (eds.) Proceedings of the International Conference on IPM in museums, archives and historic houses. held in Vienna, Austria, 5.-7. June 2013. Online http://museumpests.net/conferences/international-conference-in-vienna-austria-2013/ Accessed 17.1.2017

Auer, J. and A. Kassel. 2014. Braconid Wasps: A biological control method. *In*: Proceedings of the 8th International Conference on Urban Pests: 335-340.

Benelli, G., N. Pacini, B. Conti, and A. Canale. 2013. Following a scented beetle: Larval feaces as a key olfactory cue in host location of *Stegobium paniceum* (Coleoptera: Anobiidae) by *Lariophagus distinguendus* (Hymenoptera: Pteromalidae). Chemoecology 23(2): 129-136.

Biebl, S. 2013. Nützlinge gegen Kleidermotten. Praktische Erfahrungen im Deutschen Museum München, Restauro 1: 39-41. In German

Biebl, S. and C. Reichmuth. 2013. Stickstoff-Behandlung gegen Materialschädlinge. Journal für Kulturpflanzen 65(3): 99-109. In German

Brokerhof, A.W., B. van Zanen, K. van de Watering, and H. Porck. 2007. Buggy Biz: Integrated Pest Management in Collections. In: Netherlands Institute for Cultural Heritage (ICN), Amsterdam.

Dummer, J. and S. Prozell. 2013. Zwergwespen auf Schlittenfahrt. Materialschutz mit Nützlingen. Restauro 1: 46-49. In German

Flieder, F. and C. Capderou. 1999. Sauvegarde des collections du patrimoine - La lutte contre les détériorations biologiques. CNRS éditions.

Florian, M.L. 1997. Heritage Eaters: Insects and Fungi in Heritage Collections, Earthscan Publications Ltd.

Fohrer, F., K. Basle, and F. Daniel. 2006. Problématique de l'infestation des colles de rentoilage des peintures de chevalet par le *Stegobium paniceum* (L.). In: Support tracé n° 6: 78-85.

Goodrich, E.S. 1921. Note on the Hymenoptera parasite in beetle infested grains. Report of the Grain Pest (War) Committee of the Royal Society of London 9. Cambridge Scholars Publishing.

Kaschef, A.H. 1955. Étude biologique du *Stegobium paniceum* L. (Col. Anobiidae) et de son parasite *Lariophagus distinguendus* Först. (Hym. Pteromalidae). Annales de la Societé Entomologique de France 124: 1-88.

Kaschef, A.H. 1961. *Gibbium psylloides* Czemp. (Col., Ptinidae) new host of *Lariophagus distinguendus* Först. (Hym., Pteromalidae). Zeitschrift für Parasitenkunde 21: 65-70.

Al-Kirshi, A.G.S. 1998. Untersuchungen zur biologischen Bekämpfung von *Trogoderma granarium* Everts, *Trogoderma angustum* (Solier) und *Anthrenus verbasci* L. (Coleoptera, Dermestidae) mit dem Larvalparasitoiden *Laelius pedatus* (Say) (Hymenoptera, Bethylidae). PhD Landwirtschaftlich-Gärtnerische Fakultät der Humboldt-Universität zu Berlin, Berlin.

König, K., E. Krimmer, S. Brose, C. Gantert, I. Buschlüter, C. König, S. Klopfstein, I. Wendt, H. Baur, L. Krogmann, and J.L.M. Steidle. 2015. Does early learning drive ecological divergence during speciation processes in parasitoid wasps? Proceedings of the Royal Society B: Biological Sciences 282: 1799.

Liu, L.Y. 2013. First Case of *Stegobium paniceum* (L., 1758) (Coleoptera: Anobiidae) Infesting *Paintings* in a Taiwanese Museum. The Coleopterists Bulletin 67(1): 52-53. http://www1.montpellier.inra.fr/CBGP/insectes-du-patrimoine/?q=en Accessed 17.1.2017www.museumpests.net Accessed 17.1.2017

Noyes, J.S. 2014. Universal chalcidoidea database. See http:www.nhm.ac.uk/chalcidoids. Accessed 17.1.2017

Pinniger, D.B. 2015. Integrated pest management in cultural heritage. Archetype Publications, London.

Plarre, R., K. Lieber, W. Burkholder, and J. Phillips. 1999. Host and host instar preference of *Apanteles carpatus* (Say) (Hymenoptera: Braconidae) a possible parasitoid for biological control of clothes moths (Lepidoptera: Tineidae). Journal of Stored Products Research 35: 197-213.

Querner, P. and A.K. Kjerulff. 2013. Non-Chemical Methods to Control Pests in Museums: An Overview. *In*: **Rogerio-Candelera, M.A. Lazzari, M., and Cano, E.** (eds.) Science and Technology for the Conservation of Cultural Heritage. Taylor & Francis: 273-276.

Querner, P. and S. Biebl. 2011. Using parasitoid wasps in Integrated Pest Management in museums against biscuit beetle (*Stegobium paniceum*) and webbing clothes moths (*Tineola bisselliella*). Journal of Entomological and Acarological Research 43(2): 169-175.

Querner, P., E. Götz, T. Kimmel, and M. Morelli. 2013. Einsatz von Lagererzwespen im Rahmen eines Integrierten Schädlingsmanagements (IPM) im Museum. Restauro 1: 42–45.

Querner, P. 2015. Insect pests and Integrated Pest Management in museums, libraries and historic buildings. Insects 6(2), special issue on Integrated Pest Management: 595-607.

Querner, P., T. Kimmel, S. Fleck, E. Götz, M. Morelli, and K. Sterflinger. 2015. Integrated Pest Management (IPM) as part of the move to the new storage in Himberg. Technologische Studien 9/10, Kunsthistorisches Museum Wien: 63-80.

Schöller, M. 2010. Biological control of stored-product insects in commodities, food processing facilities and museums. 10th International Working Conference on Stored Product Protection Julius-Kühn-Archiv 425: 596-606.

Schöller, M. and P.W. Flinn. 2000. Parasitoids and predators. *In*: Subramanyam, B. and Hagstrum, D.W. (eds.) Alternatives to Pesticides in Stored Product IPM. Kluwer Academic Publishers, Boston, USA: 229-271.

Schöller, M., S. Prozell, A.G. Al-Kirshi, and C. Reichmuth. 1997. Towards biological control as a major component of integrated pest management in stored product protection. Journal of Stored Products Research 33: 81-97.

Schöller, M., P.W. Flinn, M.J. Grieshop, and E. Zdarkova. 2006. Biological control of stored product pests. *In*: **Heaps, J.W.** (ed.) Insect Management for Food storage and Processing. American Association of Cereal Chemists International, St. Paul, Minnesota, USA: 67-87.

Schöller, M. and S. Prozell. 2011. Biological control of cultural heritage pest Coleoptera and Lepidoptera with the help of parasitoid Hymenoptera. Journal of Entomological and Acarological Research 43(2): 157–168.

Schöller, M. and S. Prozell. 2016. Biological control of cultural heritage pests – a review. 157-232. *In*: Querner, P., Pinniger, D., and Hammer, A. (eds.) Proceedings of the International Conference on IPM in museums, archives and historic houses. held in Vienna, Austria, 5.-7. June 2013. Online http://museumpests.net/conferences/international-conference-in-vienna-austria-2013/ Accessed 17.1.2017

Steidle, J.L.M. 2000. Host recognition cues of the granary weevil parasitoid *Lariophagus distenguendus.* Entomologia Experimentalis et Applicata 95(2): 185-192.

Steidle, J.L.M. and J. Ruther. 2000. Chemical used for host recognition by the grain weevil parasitoid *Lariophagus distenguendus*. Journal of Chemical Ecology 26(12): 2665-2675.www.whatseatingyourcollection.uk Accessed 17.1.2017

Zimmermann, O. 2005. Untersuchungen zur biologischen Bekämpfung der Kleidermotte *Tineola bisselliella* (Hummel 1823) und anderer tineider Textilschädlinge (Lepidoptera: Tineidae) mit parasitoiden Hymenopteren. PhD thesis, Johannes-Gutenberg-Universität Mainz.