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A lure to take the biscuit: A *Stegobium paniceum* pheromone trial at the Royal Horticultural Society herbarium

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Abstract

There has been no commercially available pheromone lure in the UK for monitoring biscuit beetle for many years. The Royal Horticultural Society's herbarium at Wisley has trialled a new lure to attract male *Stegobium paniceum* (Linnaeus, 1758).

The RHS herbarium, although annually frozen, still suffers from an infestation of *Stegobium*. A seven-week trial using Stegobinone lure traps was undertaken across the herbarium collection area. Control traps, without lures, were placed close to lured traps. Many more *Stegobium* were attracted to the traps containing the lures than the control, with beetles continuing to be caught long after the manufacturer's recommended replacement period. The lure has proved highly effective, and the trial at the RHS has identified the epicentre of the infestation, enabling targeted treatment.

Keywords: biscuit beetle, drugstore beetle, Stegobinone, Stegobiene, pest control, Hiresis®.

Introduction

The herbarium collection at the Royal Horticultural Society (RHS) Garden Wisley specialises in cultivated plant diversity. It is home to over 83,000 specimens of pressed plants, numerous plant portraits, dried fruits and seeds, and also provides an environment in which *Stegobium paniceum* (Linnaeus, 1758) (biscuit beetle or drug-store beetle), the traditional pest of dried plant collections, thrives. Due to pest treatments in the past, in which specimens were painted with mercuric chloride, the older collections remain unaffected by the beetles, while the more recent specimens, lacking pesticides, are frequently damaged by the beetles.

A synthetic analogue of Stegobinone, the female *Stegobium paniceum* pheromone, has been produced and is commercially available in both the United States and Japan. Samples of the synthetic pheromone were received by the third author (JS) at a Trade Fair, and a trial was formulated to see if it was effective. Many of the earlier attempts to reproduce the pheromone had failed to lure sufficient quantities of the adult male beetles, and proved too costly to manufacture, so were taken out of production. The trial took place at three sites known to harbour *Stegobium paniceum*: a commercial bakery; a pet food manufacturing plant; and a museum (the RHS herbarium collection).

Stegobium paniceum: the biscuit or drug-store beetle

This beetle was known to the ancient Egyptians, and has been found within entombed burial materials, some dating to over 4000 years before present. Panagiotakopoulu (2003) found the remains of 17 *Stegobium* in a well-preserved deposit of wheat from a Middle Kingdom tomb at el-Gebelein, Egypt (earlier than 2049 BCE). Later, Elizabethan explorers played an interesting role in its spread, as it was conveyed around the world in sailors' biscuit rations on-board ships. Known as '*hard tack*', this biscuit broke many a sailor's tooth. Made primarily of flour and baked three times, this nutritionally poor food was favoured by biscuit beetle. *Stegobium* are particularly fond of starch, and bore into dried vegetable material, the starchier the better (Aitken, 1975) (see Figure 1). Living in symbiosis with a yeast, adult females secrete a layer of the yeast fungus on the outer surface of their eggs; it is passed on to the emerging larvae during hatching, and it is carried internally in a special organ. This enables the beetles to survive on a range of nutritionally poor foods. Each female lays about 60 eggs singly and, given warmth and high humidity, the life cycle can be rapid: 20 weeks at 20°C, 12 weeks at 25°C, and 6 weeks at 30°C (Adams, 1993; Lefkovitch, 1967; Pinniger, 2015: p.31). A study by Rumball and Pinniger (2003) indicated that wild strains of *Stegobium* (as opposed to those kept under laboratory conditions) are likely to be far more tolerant of cold conditions (Solomon and Adamson, 1955), and this can seriously affect any temperature measures taken for pest control. The adults are short-lived and it is the larvae that do the most damage to collections. Due to their high starch content, herbarium specimens have habitually been infested by *Stegobium* (Croat, 1978; Harvey, 2001). More information and illustrations of the beetle can be found in Pinniger (2015: p.31), Rumball and Pinniger (2003), on the website of the Natural History Museum (Natural History Museum, 2014), the website 'What's Eating Your Collection' (Birmingham Museums and Art Gallery, n.d.), and on the Central Science Laboratory reference card IC/286 (Adams, 1993).

Most stored-product beetles produce pheromones to attract mates. *Stegobium paniceum* females lure males using an attractant pheromone, Stegobinone (2,3-dihydro-2,3,5-trimethyl-6-(1-methyl-2- oxobutyl)-4H-pyran- 4-one) (Kuwahara et al., 1975). Kodama et al. (1987a; 1987b) (including a co-author from Fuji Flavor Ltd) studied the synthesis of Stegobinone, particularly the discovery of isomers that inhibit or reduce a male response. This resulted in a very early pheromone trap being sold commercially, the Fuji Trap 87, which was trialled at RBG Kew (Rumball and Pinniger 2003)). Although effective, the synthetic pheromone produced in both this and the other early anobiid beetle traps made by AgriSense in 1996 proved too expensive to synthesise for the relatively small quantities required by the public to make it commercially viable (Rumball and Pinniger, 2003; White and Birch, 1987; Mori, 2010). Fuji Flavor Co., Ltd have recently been able to produce a synthetic analogue of this, known as Stegobiene (2,3-dihydro-2,3,5-trimethyl-6-[(1E)-(1-methyl-1-buten-1yl]-(2S, 3R)-4H-pyran- 4-one), which is said to be a longer-lasting mimic (Fuji Flavor Co., Ltd., n.d.). It is this, the Hiresis® trap, that has been trialled here.

Figure 1: Damage caused by the biscuit beetle. Note the frass and damaged petals of this Lupinus L.. Image: Yvette Harvey © RHS 2017.

Preventative conservation measures at Wisley

The collection is housed within the Laboratory at RHS Garden Wisley, and contained within a suite of rooms at the back of the building that were built on top of an old lecture theatre. The collection based at Wisley commenced in the early 1900s, primarily with specimens of British plants made by student gardeners. This was housed in the first floor Science Library, until it was later moved downstairs and contained within wooden cabinets. Historic material

was donated to the collection in the 1930s. By 2006, metal cabinets replaced the old, and an annual freezing regime was initiated to reduce numbers of *Stegobium* infesting the collection.

Conditions are cramped, and the collection area is shared with staff. The building has single-glazed windows, water ingress issues, and there are considerable environmental fluctuations (see Figures 2 and 3). The heating is centrally controlled, and, as with similar old buildings, the herbarium has unlagged pipes that carry hot water throughout the collection area. The heating is switched on and off every 12 hours from October to May (Figure 3), and there are similar temperature fluctuations during the summer as the building lacks air conditioning (Figure 2). Staff working within the collection area require an appropriate temperature during the winter and, as a

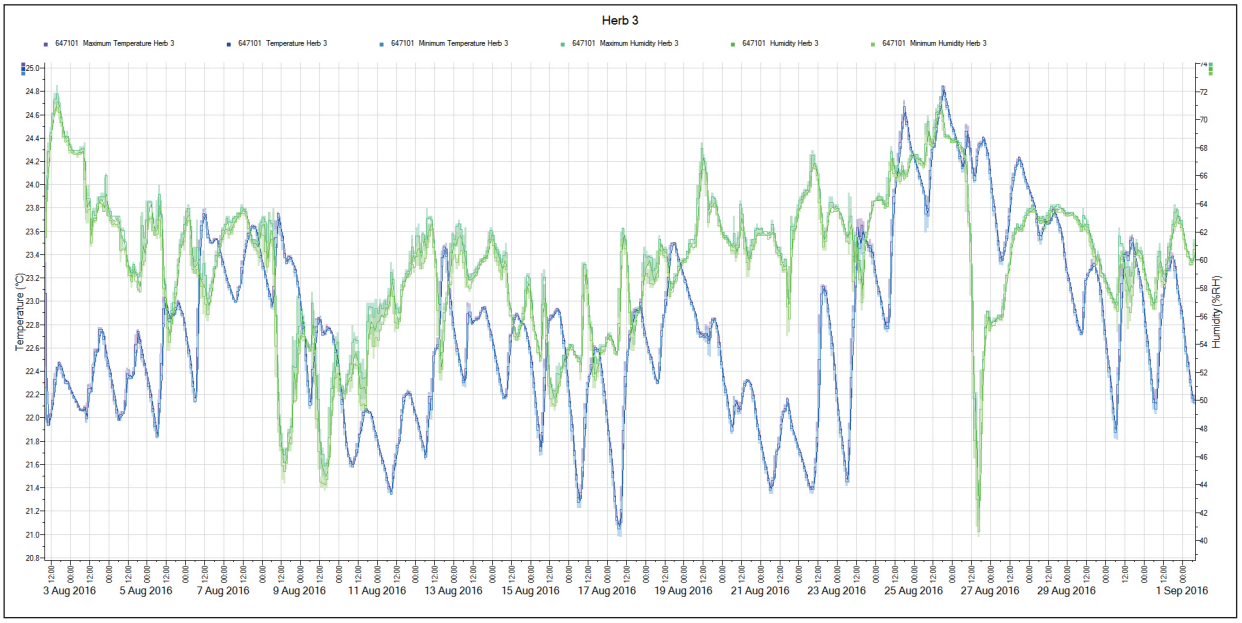

Figure 2: Temperature and humidity readings during part of the trial, August 2016. Heating is switched off during the summer months.

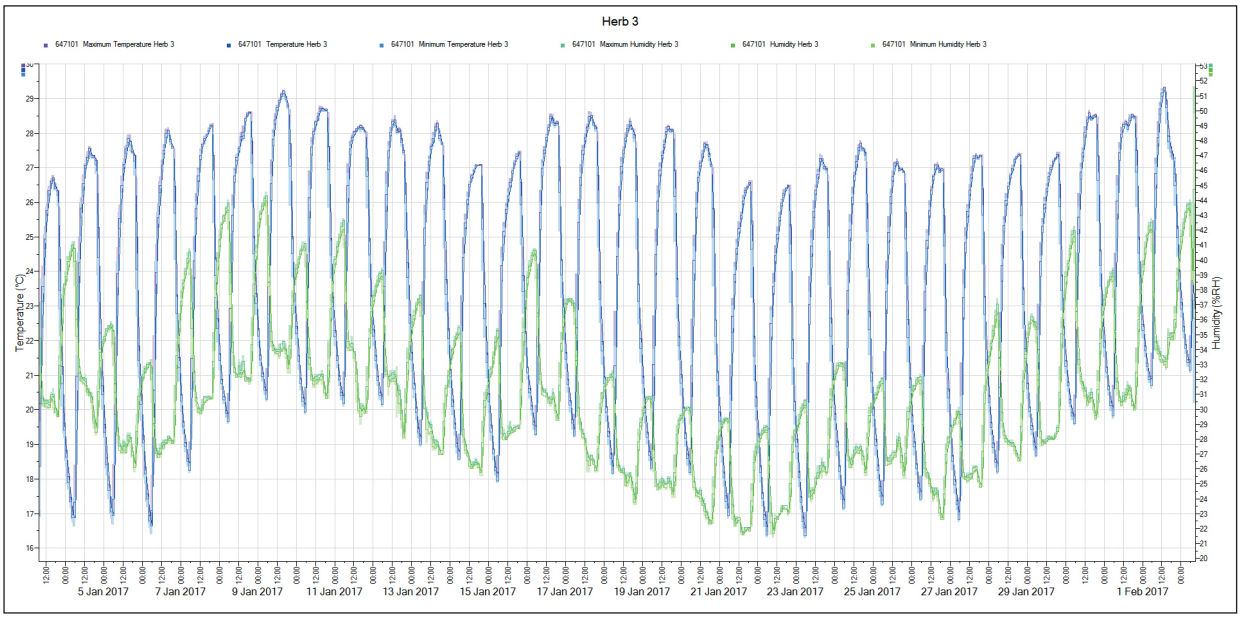

Figure 3: Temperature and humidity readings during January 2017. Heating is switched on between early morning and late afternoon, and off during the night.

consequence, adjust the temperature of the radiators as required.

A number of measures have been undertaken to reduce/discourage insects. Food is banned from the herbarium, and drinks are only permitted in sealed cups. Specimens are bagged within the cabinets to prevent easy access to a wandering insect, and the cabinet doors have tight seals. All material entering the collection is frozen on arrival and before finally being incorporated into the collection. The entire collection is frozen on an annual cycle, including the backlog of un-accessioned material stored on top of the cabinets. Each freeze treatment is at -30°C for 72 hours or more. Floors and cabinet interiors and exteriors are sprayed with a synthetic pyrethroid (Vazor® Cypermax Plus) when numbers of insects found in adjacent traps indicate a need for treatment.

The pheromone trial

Although they don't pose a direct threat to human health, biscuit beetles can be a significant pest in the food industry and are also damaging in museum and herbarium collections (Pinniger, 2015: p.31). What has been lacking until now is a widely available pheromone to monitor sexually active males before they encounter a female. Having received samples of the Hiresis® trap from Fuji Flavor Co. Ltd., John Simmons (JS) formulated a small trial to establish if the new pheromone worked effectively. For this, JS selected three different sites: a large bread bakery, a large animal feed plant, and a museum collection. All sites were known to harbour *Stegobium paniceum*. The trial was undertaken over a six-week period at these three sites, during August and September 2016.

The Hiresis® trap comprises a pheromone analogue contained within a small capsule that has a plastic upper cover and paper base, stuck to a glued cardboard trap. It was decided to discard the manufacturer's cardboard trap in case this was the lure rather than the actual pheromone. Instead, lures were stuck on alternative commercially available crawling insect monitor glue pads, held within a commercially available hanging frame (the Demi-Diamond trap). The frames were not necessarily hung as recommended; some were placed flat on surfaces. At site 1, the bakery, the pheromones were placed as recommended by the manufacturer, with the paper surface downwards; at site 2, the pet food manufacturer, half the lures were placed the correct way, and half upside down; at site 3, the museum collection, they were all placed upside down. This was to test if the lure still worked even if placed in a non-conformist way. Identical traps lacking the lures were placed in close proximity (circa 1 metre away) to the lured traps (see Figure 4), again, to check if the trap itself was the lure and not the pheromone. 20-30 traps were placed in each site, in 10-15 locations.

During the trial period traps were checked weekly and cumulative totals for each trap were made.

Figure 4: Paired traps, one with a lure and one without on top of a block of cabinets at The RHS herbarium (site 3). Image: Yvette Harvey © RHS 2017.

Results and observations from the RHS herbarium (site 3)

The results seen in Table 1 demonstrate that a noticeably larger number of *Stegobium* were attracted to the lure traps than to the control traps without lures. The trap captures within the collection rooms have also indicated where the epicentre of the infestation is likely to be (see Figure 5). This enabled RHS staff to target specific areas for treatment. It should be noted that there were a few beetles found on the traps without the pheromone, but the assumption is that they were just trapped as an insect would be caught in a normal blunder trap.

The RHS has kept both lured and control traps in situ, undertaking quarterly trap counts, and at the time of writing, 11 months from the start of the trial, the lure traps are still attracting beetles (Figure 6). This is considerably longer than the manufacturer's recommended lure replacement period of one-month.

As seen on the graph (Figure 7), traps are not functioning as an effective control, since the catch numbers are still escalating and are yet to plateau out or drop. These traps will continue to monitor the

Table 1. Results from pheromone (blue columns) and non-pheromone traps (white columns) at the RHS herbarium during the trial period.

Trap	05-Aug		12-Aug		19-Aug		30-Aug		02-Sep		12-Sep		16-Sep	
1	0	0	1	0	3	0	4	0	4	0	4	0	5	0
2	0	0	0	0	1	0	2	0	2	0	4	1	4	1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	0	1	0	3	0	4	0	4	0	4	0
5	0	0	0	0	0	0	0	0	0	0	0	0	1	0
6	0	0	3	0	4	0	11	0	13	1	15	1	18	1
7	0	0	0	0	0	0	0	0	1	0	1	0	1	0
8	0	0	0	0	0	0	0	0	1	0	1	0	1	0
9	0	0	0	0	0	0	0	0	1	0	1	0	1	0
10	0	0	1	0	1	0	1	0	1	0	1	0	1	0
TOTAL	**0**	0	**6**	**0**	**10**	**0**	**21**	**0**	**27**	**1**	**31**	**2**	**36**	2

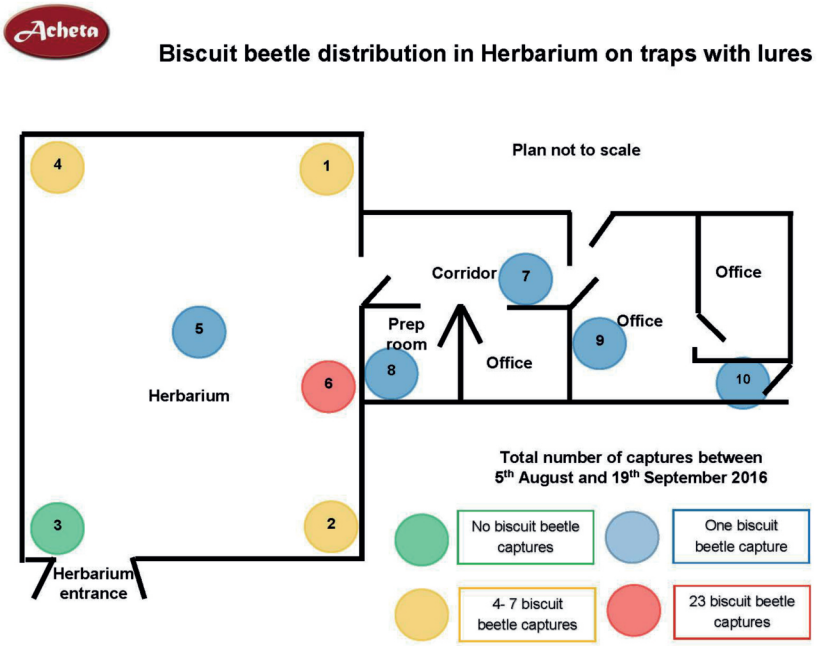

Figure 5. Map of the collection area showing where traps were placed and the hot-spots of insect activity, indicated by the numbers trapped. © Acheta consulting Ltd.

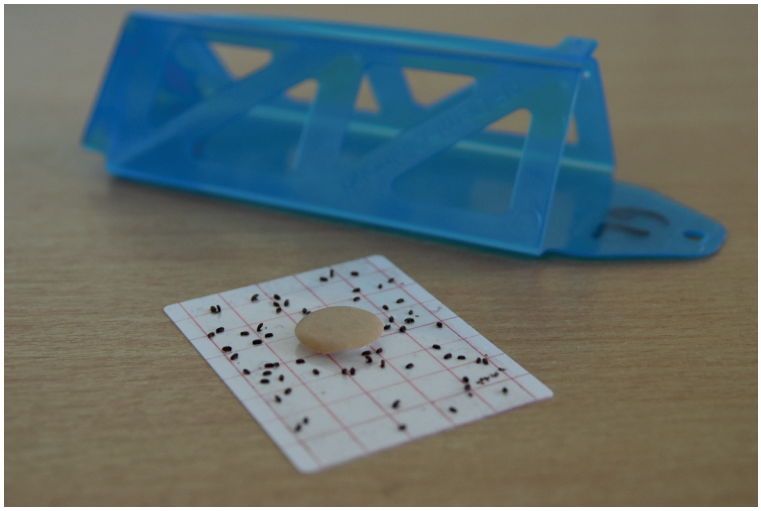

Figure 6. Sticky pad covered with Stegobium at The RHS herbarium. Image: Yvette Harvey © RHS 2017.

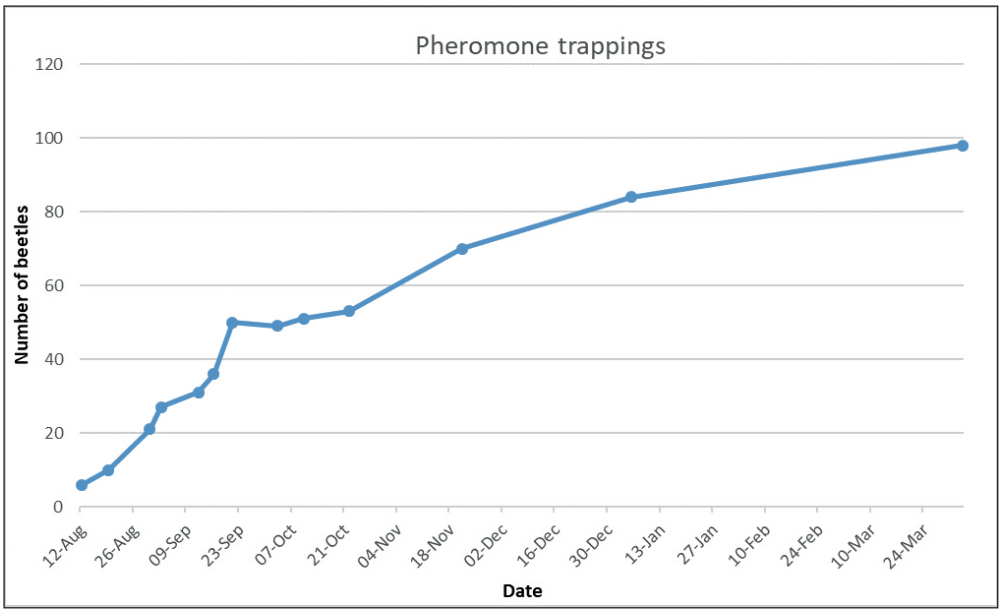

Figure 7. Results from lured traps at the RHS herbarium, during and beyond the trial period (aggregated data).

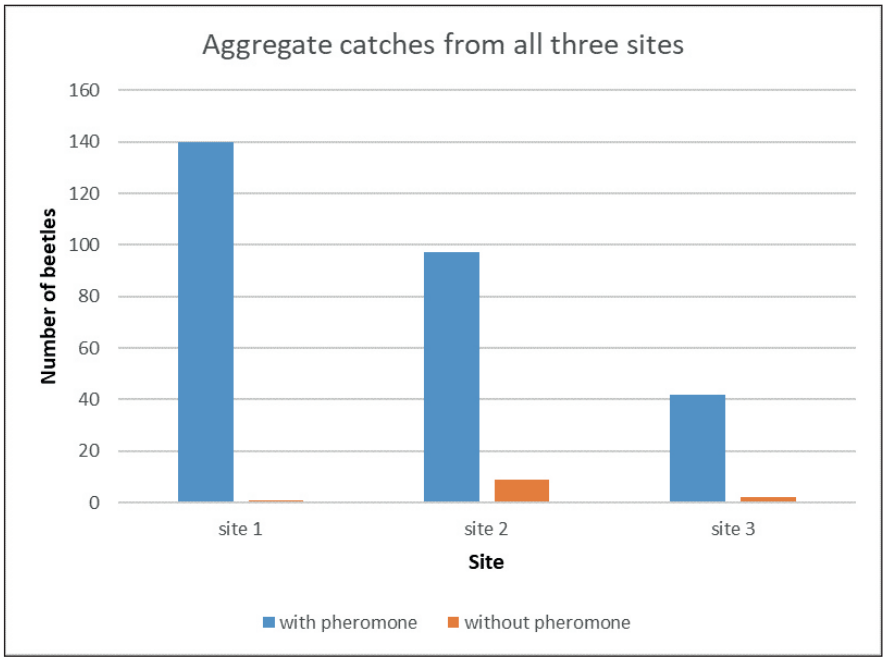

Figure 8: Comparison of catches from all three sites. Site 1 - Bakery (11 lures); site 2 - animal food manufacturing plant (15 lures); and site 3 - RHS herbarium (10 lures).

situation until the RHS herbarium collection is moved into a new storage facility, planned for 2020/2021 (all material moving to the new facility will be decontaminated prior to installation). Looking at additional beetles per trap after the trial finished, fewer beetles were trapped over the winter months than during the late summer months, when daytime temperatures can reach 28°C in parts of the herbarium due to the heating pipes within the collection area. This may have been as a result of the floors and cabinet tops being sprayed with a synthetic pyrethroid, Vazor® Cypermax Plus in the month following the end of the trial. Interestingly, *Stegobium* were the only insects present on the traps, as opposed to the mixture that is normally found on the herbarium's blunder traps.

Comparison between sites

The graph illustrating the aggregate catches across sites (Figure 8) clearly demonstrates the effectiveness of the pheromone monitoring traps at all three sites. The bakery (site 1 with 11 lures), had particularly high numbers, with the majority of beetles being found in the vicinity of the bread cooling plant. It is likely that this is due to less stringent cleaning in this area. Similarly, high numbers of beetles were trapped at the animal food manufacturing plant (site 2 with 15 lures). This site does not have rigid cleanliness regulations as for human consumption, so the beetles have been able to thrive in accumulated food debris.

Conclusions and further work

Although this trial is too small to be statistically analysed, the results strongly support that the Stegobiene lure works effectively and can be used to monitor the presence of *Stegobium* and highlight activity hot-spots within a museum collection or building. This new lure will hopefully enable Integrated Pest Management (IPM) staff to undertake monitoring across stores and buildings more easily, highlighting *Stegobium* hotspots and improving targeted treatment. However, at the time of writing, this product was only available from the manufacturer in Japan and through Insects Ltd. in the USA. Contact has been made with a number of UK-based pest control companies to see if is possible for them to stock Hiresis® traps in the UK and/or Europe.

Footnote

Unfortunately, there is a complication with the use of pheromone lures for pest control in Europe. In May 2017, the European Commission discussed at the 'Standing Committee on Biocidal Products' a proposal for a European Union (EU) Commission decision on the status of lured monitoring traps under Article 3(3) of the EU Biocidal Products Regulation 528/2012 (BPR) (Council of the European Union, 2012), and whether monitoring traps using an attractant were to be considered Biocidal Products.

The Commission advised the meeting that it would not take a decision on monitoring traps under Article 3(3), and that this would be left to each Member State to decide on a case by case basis and take control measures as appropriate. In the UK, the HSE considered this in June 2017. The position previously established under the Biocidal Products Directive 98/8/EC (BPD) is that traps purely for monitoring purposes to assess the necessity or success of pest management measures, clearly labelled, sold and used as such, are not within scope of the Regulation, and this will remain the UK position whilst they consider this further.

Acknowledgements

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References

Adams, R.G., 1993. *Biscuit Beetle (Stegobium paniceum (L.)). Central Science Laboratory reference card 1C/286*. Harpenden: Central Science Laboratory.

Aitken, A.D., 1975. *Insect Travellers. Volume 1. Coleoptera. MAFF Technical Bulletin 31*. London: HMSO.

Birmingham Museums and Art Gallery, n.d. *What's eating your collection?* [online] Available at: <http://www.whatseatingyourcollection.com/>.

Croat, T.B., 1978. Survey of herbarium problems. *Taxon*, 27, pp.203-218.

Council of the European Union, 2012. *Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products Text with EEA relevance*. [online] Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012R0528> [Accessed 20 July 2017]

Fuji Flavor Co., Ltd., n.d. *Hiresis®*. [online] Available at: <http://www.fjf.co.jp/en/ecomone/product/hiresis/index.html> [Accessed 20th July 2017].

Harvey, Y.B., 2001. Grey biscuits, flying carpets and cigarettes: an integrated pest management programme in the herbarium at Kew. *In* Kingsley, H., Pinniger, D., Xavier-Rowe, A. & Winsor, P. (*eds*), 2001. *Integrated pest management for collections. Proceedings of 2001: A Pest Odyssey*. London: James & James Ltd. pp.57-62.

Kodama, H., Mochizuki, K., Kohno, M., Ohnishi, A., and Kuwahara, Y., 1987a. Inhibitor of male response to drugstore beetles to Stegobinone by its isomer. *Journal of Chemical Ecology*, 13(8), pp.1859-1869.

Kodama, H., Ono, M., Kohno, M., and Ohnishi, A., 1987b. Stegobiol, a new sex pheromone component of drugstore beetle *Stegobium paniceum*. *Journal of Chemical Ecology*, 13(8), pp.1871-1879.

Kuwahara, Y., Fukami, H., Ishii, S., Matsumura, F., and Burkholder, W.E., 1975. Studies on the isolation and bioassay of the sex pheromone of the drugstore beetle *Stegobium paniceum*. *Journal of Chemical Ecology*, 1, pp.413-422.

Lefkovitch, L.P., 1967. A laboratory study of *Stegobium paniceum*. *Journal of Stored Product Research*, 3, pp.235-249.

Mori, K., 2010. *Chemical synthesis of hormones, pheromones and other bioregulators*. Chichester: John Wiley & Sons Ltd.

Natural History Museum, 2014. *Fact sheet: the biscuit beetle – Stegobium paniceum*. [online] Available at: <http://www.nhm.ac.uk/natureplus/community/identification/blog/2014/12/17/fact-sheet-the-biscuit-beetle--stegobium-paniceum> [Accessed 20 July 2017].

Panagiotakopoulu, E., 2003. Insect remains from the collections in the Egyptian Museum of Turin. *Archaeometry*, 45(2), pp.355-362.

Pinniger, D.B., 2015. *Integrated Pest Management in Cultural Heritage*. London: Archetype Publications.

Rumball, N., and Pinniger, D.B., 2003. Use of temperature to control an infestation of biscuit or drugstore beetle *Stegobium paniceum* in a large economic botany collection. *Collections Forum*, 18(1-2), pp.50-58.

Solomon, M.E., and Adamson, B.E., 1955. The powers of survival of storage and domestic pests under winter conditions in Britain. *Bulletin of Entomological Research*, 46(2), pp.311-355.

White, P.R., and Birch, M.C., 1987. Female sex pheromone of the common furniture beetle *Anobium punctatum*. *Journal of Chemical Ecology*, 13(7), 1695-1706.