Proceedings of the Eleventh International Conference on Urban Pests 2025
AF-Borgen, Academic Society, Lund, Sweden
William H Robinson, editor

INDICATOR SPECIES FOR IDENTIFYING HIDDEN CONSTRUCTION DAMAGE IN HISTORIC BUILDINGS

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Abstract As cultural heritage, historic buildings require special efforts to preserve them. Hidden damages that develop over long periods of time and remain undetected, may cause immense loss. An externally visible settlement of species whose presence draws attention to damage inside the structure can give hints to this hidden damage. In a castle in North Rhine-Westfalia (Germany) which was built in the 13th century, an infestation of *Lasius brunneus* (Formicinae) was found below a crack in the middle of an oak ceiling beam. Research into the history of the castle revealed that several renovations were carried out during the following centuries. The ants' remains below the beam contained pieces of captured insects, empty pupae cases, and large amounts of typical lens-shaped droppings of *Xestobium rufovillosum* (Ptinidae). The young larvae of *X. rufovillosum* require wood that is rotten by fungus. This led to the finding that the interior of the beam was affected by fungal infestation followed by woodworm infestation and therefore no longer met the static requirements of a ceiling beam. Further investigations revealed that the building was hit by two bombs during World War II and that repairs were delayed. Similar cases of construction damage in cultural heritage which became apparent through the activity of ants were repeatedly found in the past. The examples demonstrate that in the event of an infestation, the history of the building must be researched, including the building materials, subsequent renovations, damage and the use of the building.

Key words *Lasius brunneus*, *Xestobium rufovillosum*, damage to historic buildings

INTRODUCTION

Wood has been used as building material since ancient times and at least the heartwood can survive for centuries if it is protected from permanent moisture (Scheiding et al 2015). In order to preserve historical buildings for future generations, regular inspection of the building structure is necessary to detect damage early (Grosser 1985, Kempe 2009, Binker et al. 2014). Historic buildings are valuable cultural assets from past eras. Depending on the building structure and intended use, these buildings give shelter to a specific arthropode fauna which rarely causes significant damage (Hickin 1975).

The sudden appearance of a new arthropod species in such a building may be a sign of hidden degradation in the structure. Young queens of various ant species build their nests in damp wood that has been infested by fungi (Pospischil 2010, 2014). They do not differentiate between suitable wood in nature and in buildings and should not be seen as typical pests but rather as indicator species that draw attention to hidden damage in the building structure. Various species of checkered beetles (Cleridae) and parasitoid wasps hunt wood and stored product pests whose larvae they can locate inside the wooden structures (Heinze 1983, Hickin 1975, Niehuis 2013, Weidner & Sellenschlo 2010).

MATERIAL AND METHODS

The building under review is a moated castle in North Rhine-Westphalia that was built in the 13th century. In the 14th century, the building was converted into a brick fort. In the 16th and 18th centuries, further renovations were carried out inside and on the outside of the building.
The ceiling beam where the ant infestation was found is located on the north-east side of the hall on the first floor above the stage. It is a several centuries old oak beam with a dimension of approximately 40 x 40 cm. On the sides, the beam is embedded in the outer walls, which are 150 cm thick. On the outside, there are iron wall anchors on the masonry, which are obviously connected to the beams. Given that the building is 10 meters wide, we assume that the beam is almost 10 meters long. Around these iron wall anchors the external facades on both the northwest and southeast sides are densely covered with ivy.

The beam is separated from the ceiling by a narrow gap and from a static point of view the beam does not pose a short-term danger. Nevertheless, it is advisable to replace the beam during the next restoration within one to two years. There are notches on the upper edge of the beam, which were probably used in the past to support a wooden ceiling. There is a deep crack in the middle of the beam, under which wood dust and gnawing particles from the ants accumulate on the floor of the stage.

Sapwood was only present in small quantities at the edges of the beam during the inspection with old remains of longitudinally cut feeding tunnels of the common woodworm beetle *Anobium punctatum* (De Geer, 1774) (Pospischil 2000). No active infestation by this species was found in the building.

Since no living ants were found at the time of the inspection, the species was identified based on the remains of dead specimens in the gnawing debris that was swept up under the beam and sucked out of the cracks and crevices from inside the beam with an aspirator. At the transition of the beam into the masonry there was also a deep notch in which particles from the interior of the beam had accumulated over a longer period of time. These samples were examined in the laboratory under high magnification.

RESULTS AND DISCUSSION

Below a crack in the middle of the beam and in the area of the external walls, gnawing particles of ants were found on the floor, which contained the remains of captured insects and empty pupae cases. Remains of workers and alates were also found in the samples from the interior of the beam, which allowed the ant species to be identified as *Lasius brunneus* (Latreille, 1798). The large amount of gnawing particles and exuviae at both ends and the middle of the beam indicated that the colony populated the entire interior of the beam. The ants' main food was the excretions of aphids, which were found in large quantities in the ivy on the outer wall. *Lasius brunneus* occurs frequently in hardwood forests in rotten trunks, but it has no further special requirements in habitat. The young queens settle also in decayed construction timbers with sufficient humidity at the front or inside a building. The wood serves only as a harborage and not as food. The ants move mostly hidden in cracks and crevices and the infestation only becomes noticeable with the first annual flights (Klotz et al. 2008, Pospischil 2010, 2014). Since the last 10 years *Lasius brunneus* was the most common ant species which was sent to the author for identification and the colonies did nearly always act as indicator species for any hidden moisture damage.

The crack in the middle of the beam reaches into the interior of the beam. A large amount of gnawing and wood particles was found besides exuviae and parts of dead ants. The particles were sampled for further investigation using an aspirator. The wood particles consisted of brown-rotten wood whose cellulose content had largely been degraded probably caused by the dry rot fungus *Serpula lacrymans* after the intrusion of moisture. After the roof was repaired and the beam dried out the fungus died off (Grosser 1985).

Large amounts of typical lens-shaped droppings of the deathwatch beetle *Xestobium rufovillosum* (De Geer, 1774) were found inside of the beam. In addition to the lens-shaped droppings, there were also remains of deathwatch beetles. Due to the solid outer shell of the beam, the hatched beetles of the following generations remained inside the beam and mating took place inside with the help of knocking sounds (Cymorek 1969, Pospischil 1998).

The development of the larvae is only possible in wood that is at least partially infected by the fungus. The fungus-rotten heartwood part of oak can also be used as food by the larvae (Bletchly 1967, Cymorek 1969. Hickin 1975, Pospischil 1998).

In addition to the lens-shaped droppings, there were also remains of deathwatch beetles. as well as two living larvae and molt remains of the carpet beetle *Attagenus pellio* (Linnaeus, 1758). Alive larvae and exuviae of the carpet beetle *Attagenus pellio* (Linnaeus, 1758) were also present inside of the beam. This species belongs to the Dermestidae and their larvae feed on mummified insects and their exuviae and is a sign that the infestation inside the beam has existed for a large number of years.

CONCLUSION

The degradation of wooden constructions shown in this example has been found in a large number of historic buildings in recent decades, including in the wooden structures of the bell towers of various cathedrals. The origin of this damage to historic buildings often dates back decades and in several cases could be traced back to bomb hits during World War II and delayed repairs to the roofs. In most cases, the hidden degradation of the wood substance is only discovered at an advanced stage during restoration. The cause of the damage can be identified by the insects found and the degradation of the wood inside the beam.

At least the first two instars of *X. rufovillosum* require wood that is rotten by fungus, we therefore assume that fungal damage occurred inside the beam due to moisture.

Various ant species of the subfamily Formicinae build their nests in damp and rotten wood, making them typical indicator species for hidden damage in wooden structures. Examples are: *Lasius emarginatus*, *Lasius fuliginosus* and various species of the genus *Camponotus*, which also play a role as indicator species for possible hidden structural damage (Lebas et al.2019, Seifert 2018). These species play an important role in preservation of historic buildings together with predators like checkered beetles and parasitoid wasps that specifically hunt drywood pests.

The examples presented in this paper demonstrate that, in extreme cases, the causes of structural damage can date back decades. Due to long-term damage of statically relevant wooden structures, the performance of affected buildings is no longer guaranteed.

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