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Use of Acoustic Emission (AE) to detect activity of common European dry-woodboring insects: some practical considerations

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Use of Acoustic Emission (AE) to detect activity of common European dry-woodboring insects: some practical considerations

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ABSTRACT

Old house borer (*Hylotrupes bajulus*), Furniture beetle (*Anobium punctatum*), and Deathwatch beetle (*Xestobium rufovillosum*) are common dry-woodboring insects occurring throughout Europe. With the aim to prevent unnecessary use of biocidal products, to protect valuable wooden elements and objects from unwanted influences, and to have a more objective method, SHR has started to study the use of acoustic emission (AE) to assess activity of attack by these insects. This manuscript deals with the results of some experiments done in order to collect knowledge about the influence of (low) temperature or possible daily rhythms on the activity of the insects. Such knowledge is crucial for a trustworthy application of AE detection for European dry-woodboring insects in practice. Based on an 8-day-test with *Hylotrupes* with normal daily variation in temperature it is concluded that under these circumstances, temperature is the main influencing factor regarding insect activity. For individual larvae, phases of inactivity exist with a duration of up to 30 minutes. In practice, where probably more than one larva is present at one specific time, in the absence of AE events, measuring periods may need to be extended to at least these 30 minutes.

With regard to minimum temperatures for detection, the insect species studied show small differences in behaviour at low temperature. Because the number of registered hits for all species shows a marked decrease at temperatures becoming lower than 10 °C, it is recommended that decisive assessments using AE for detection of activity of these dry-woodboring insects should be done at (wood) temperatures of 10 °C or higher.

Keywords: acoustic emission, AE, woodworm, detection, activity, temperature, insects

1. INTRODUCTION

Old house borer (*Hylotrupes bajulus*), Furniture beetle (*Anobium punctatum*), and Deathwatch beetle (*Xestobium rufovillosum*) are common dry-woodboring insects occurring throughout Europe. In The Netherlands, as in many other European countries, a substantial part of the attacks by these insects is countered with biocidal products. The use of these products is being discouraged, based on the firm belief that we should use them not more than strictly necessary. Also, when elements or objects are concerned, which are valuable either from historical or other points of view, this kind of treatment might change the treated material in an undesirable and even irreversible manner. One way to approach this dilemma is to opt for other methods to put an end to the attack, but without the environmental or other drawbacks. Still, tension remains between the treatment firm on one hand, which likes to deliver a guaranteed result, and the keeper of the monumental timber construction or museum piece on the other hand, who likes his object to be cured, but only influenced as little as possible, if at all. Especially in those situations, where it is difficult to visually assess the presence of live attack, it is a godsend to have a method which more objectively can do that job.

At SHR a process was started to develop a method for a ‘Woodworm Detector’, for which it was felt that acoustic emissions (AE) would be useful. Detection of insect activity using AE has been the subject of many earlier experiments and tests. They have been reported about in IRG as well as in other scientific publications, e.g. Pence *et al.* 1954, Fujii *et al.* 1989, Scheffrahn *et al.* 1993, and Lemaster *et al.* 1997. Although legitimised by the economic damage done worldwide, the vast majority of these however deal with termites or stored products pests and only a few concern the aforementioned dry-woodboring insects (e.g. Pallaske 1986, Staalduinen *et al.* 2001). Our own preliminary investigations showed that active attack by these well-known European woodborers indeed can be detected using the right setup. However, even less information is to be found about the influence of temperature or perhaps daily rhythms on the activity of these specific insects. Such knowledge is crucial for a trustworthy application of AE detection for European dry-woodborers in practice (Creemers, 2012). This manuscript deals with the results of some experiments done in order to collect that knowledge.

2. EXPERIMENTAL

2.1 Materials

The results presented here refer to infested material of the insect species mentioned earlier:

- Old house borer (*Hylotrupes bajulus*):
  Larvae were harvested in the *Hylotrupes*-culture of the Institute of Wood Technology and Wood Biology of the ‘von Thünen Institute’ (vTI) in Hamburg. For further development they were transferred, one larva each, into pine feeder blocks (ca. 7 x 5 x 4 cm), which were used as test samples.
- Furniture beetle (*Anobium punctatum*):
  Two samples were taken from a collection of infected wood pieces at vTI: a small stem (ca. 40 x Ø 6 cm) and a quartered stem (ca. 30 x Ø 13 cm). These samples were used as such.
- Deathwatch beetle (*Xestobium rufovillosum*):
  Three samples were chosen from the same collection at vTI: a branch (ca. 40 x Ø 4 cm), a piece of structural wood (ca. 25 x 8 cm) and a halved stem (ca. 20 x Ø 7 cm), the latter pre-inoculated with a white-rot fungus. These samples were also used as such.

At present an experiment is carried out with material infected with Powder post beetle (*Lyctus* sp.) obtained from a Belgian industrial producer, but this test has not been completed yet. Only preliminary data are available.

2.2 Experiments

Two different kinds of experiments were carried out.

1. With one of the most active *Hylotrupes*-blocks, an 8-day test was done in the upper glass hallway to the SHR laboratory. The sample was shielded from direct sunshine, but temperatures in the hallway showed a considerable daily movement, thus simulating normal thermal variation in a roof space.
   The intention of this test was to find out whether a *Hylotrupes* larva would show some kind of daily activity rhythm and whether there would be shorter or longer periods of inactivity, possibly leading to conclusions about minimum measuring times in practice.
2. Using climate cabinets, samples were first kept at a temperature of 20 °C during a period of about a week. Then the temperature in the cabinets was lowered to levels of (18), 15, (12), 10, 8, 6, 4, 2, and 1 °C successively and kept at each level for a minimum of two days.

Temperature was lowered until no AE events were registered anymore. When this situation had occurred, temperature was increased in the same way, 1 °C at a time, until AE events started again. For *Hylotrupes*, all active blocks were used, measuring AE events each time consecutively for 15-20 minutes on each block, coupling and leaving them inside the cabinets as much as possible. For *Anobium* and *Xestobium* the most active sample was chosen and AE events measured continuously on the one sample staying inside the cabinet.
These tests are done in order to find advice on the low temperature threshold for trustworthy analysis in practical circumstances and whether there are differences between the insect species concerning this aspect.

2.3 Apparatus

Acoustic emission events were registered with an AED-2010 (AEC, Fair Oaks, USA). Coupling between the AE-sensor and the samples was mainly done using the supplied magnet and a metal screw in the sample. With the *Hylotrupes* blocks sometimes an AEC specially designed clamp was used. Based on preliminary work, the test setup used sensitivity level G5 (total gain 84 dB) with the bandpass filter in. All counts were accumulated over 60 second intervals and then passed on to a computer running the AED-software. Fig. 1 shows the setup in the 8-day-test.

Figure 1: Overview of setup of 8-day-test with *Hylotrupes*

During tests, registration of Temperature (T) and Relative Humidity (RH) around the samples was done every 5 minutes with an Eltec GD11 T/RH monitor (SHR/45q), additionally equipped with an external temperature probe, which itself was placed inside a spruce block, measuring ca. 7 x 5 x 4 cm. Although it was concluded from a preliminary test that changes in temperature settings would take only about one hour to reach the inside of the wood, the extra probe was meant to check the lag in adaptation of temperature inside the wooden samples.

For the low temperature tests two Elbanton climate cabinets (SHR/173a-b) were used, solely regulating temperature, not RH.

3. RESULTS AND DISCUSSION

3.1 Daily rhythm test

Fig. 2 shows the variation in temperature in the glass hallway during the almost eight days of the test, as registered by the Eltec monitor. As expected, the internal wood temperature T_{wood} lags a little behind the air temperature T_{air} and also, the highest and lowest values for T_{air}.are ´cut off´ in T_{wood}. The wooden substrate effectively decreases the variation.

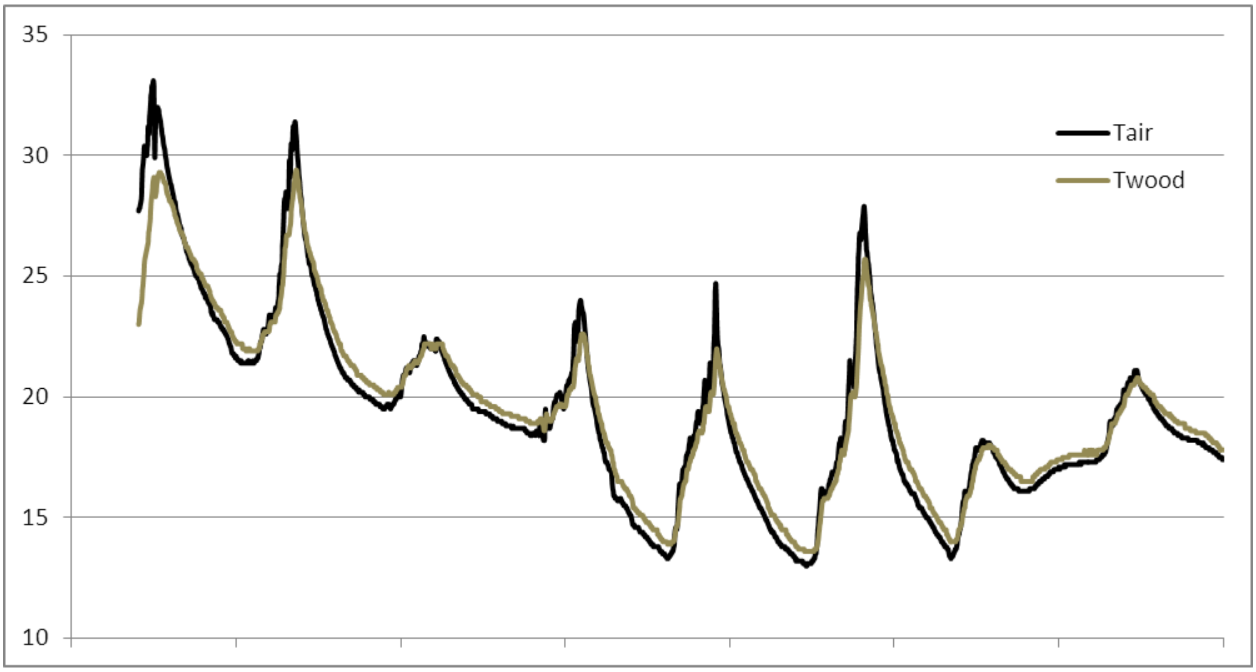

Figure 2: Variation in temperature of air and inside wood during 8 day test with *Hylotrupes*

In Fig. 3 the internal temperature T_{wood} is linked to the activity measurements, expressed as number of hits per 5 minutes.

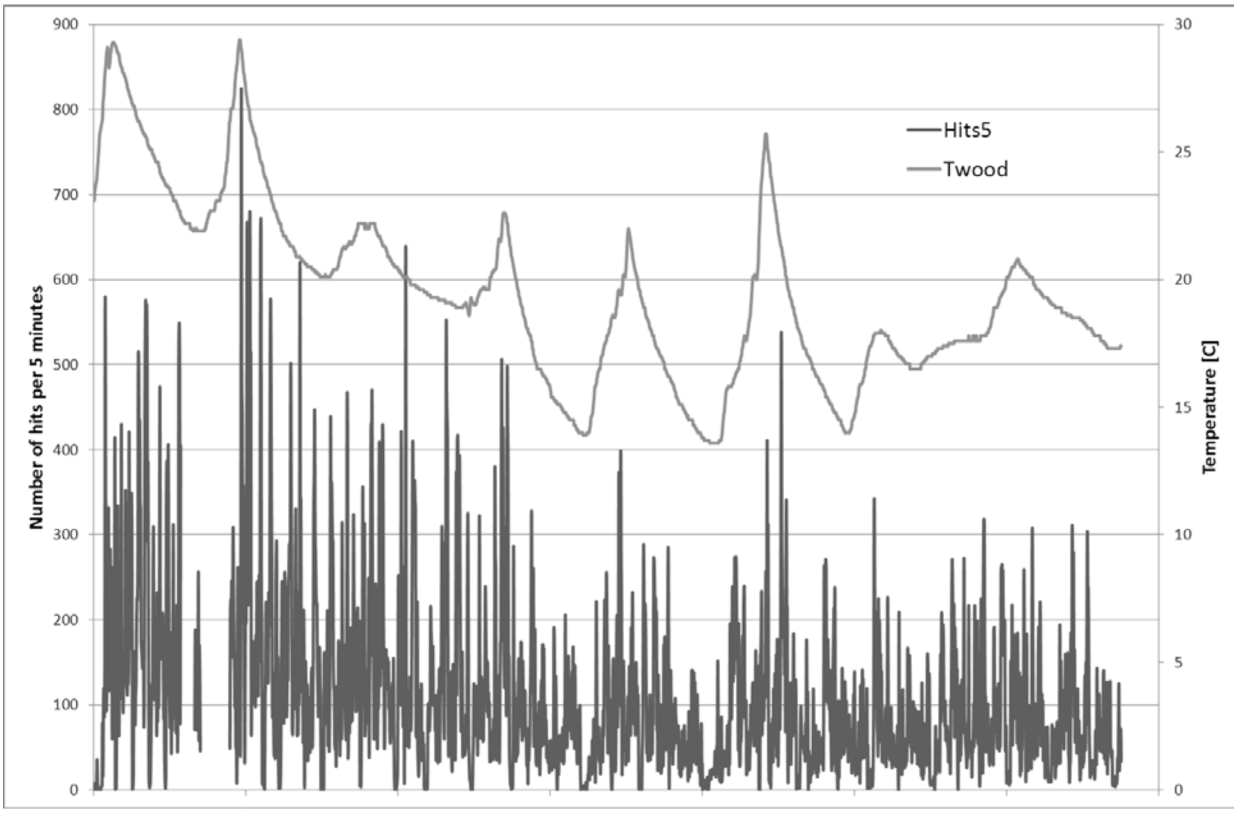

Figure 3: Comparison of internal wood temperature with activity data of *Hylotrupes*

It is obvious, that temperature has a decisive influence on activity of the larvae. The registered numbers of hits are higher in the beginning, when T_{wood} during the day almost reaches 30 °C. During the last two days of the test, when T_{wood} hardly exceeds 20 °C, the number of hits is almost halved, indicating less frass and movement by the larva. Note, that some of the peak numbers of hits coincide well with the peaks in temperature. This influence of temperature coincides with the findings of Pallaske (1986). He kept his larvae under alternating conditions of 12 hours 18 °C and 12 hours 25 °C, and in these circumstances measured clearly more activity during the warmer phases.

Looking more closely at one day, e.g. the 5th (Fig. 4), there seems to be no apparent daily rhythm other than the influence of temperature. Pallaske (1986) used autocorrelation functions to find temporal patterns and concluded that under conditions of fluctuating temperatures periods of activity of various lengths alternate with other periods of (almost) complete inactivity. Also during our measurements such periods of (near) inactivity were found, which had durations of up to about 30 minutes. This indicates that in practice in the absence of registered AE events measuring periods of at least that time period could be necessary. However, in the test only one block with a single larva was studied and in practice in most cases there will be several at the same time.

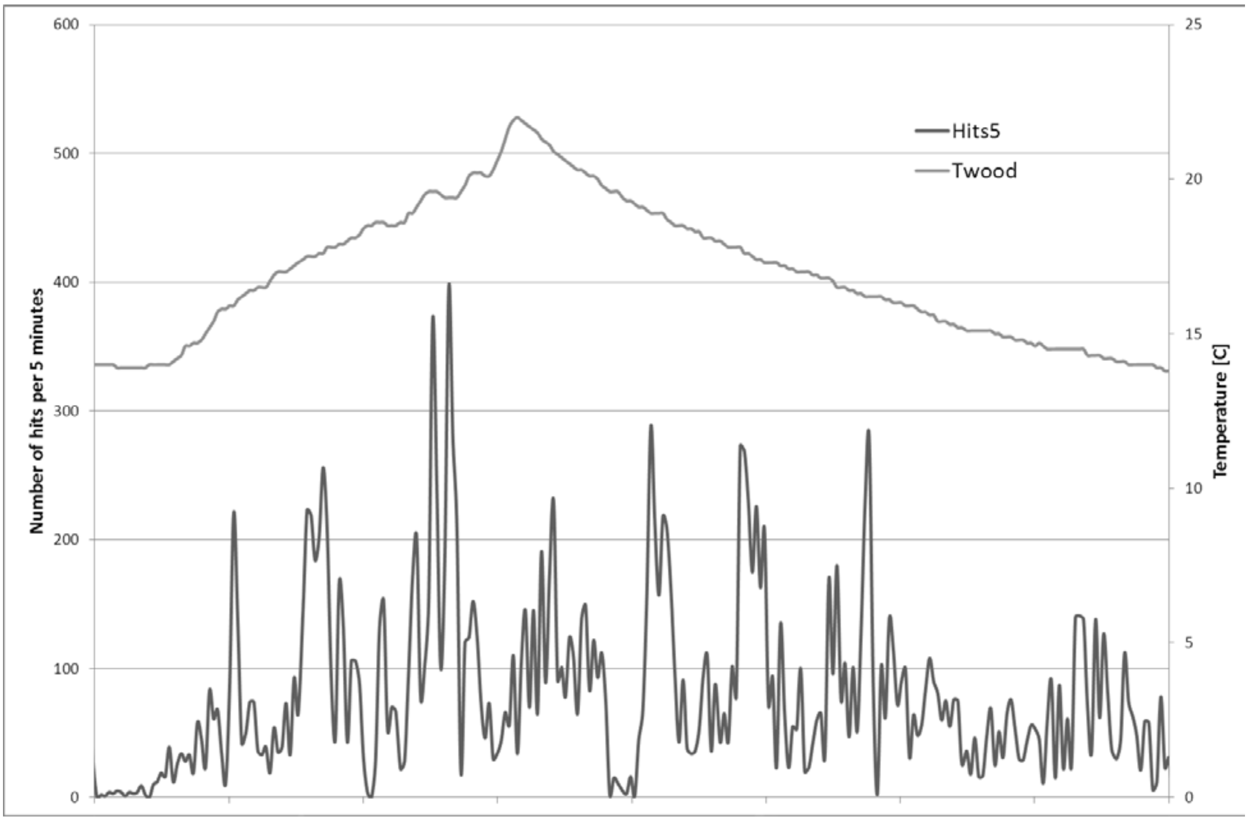

Figure 4: Zooming in on day 5 of 8-day-test with *Hylotrupes*

3.2 Low temperature test

For *Hylotrupes*, activity of the single larva in each of the blocks continued right down to a temperature of 6 °C, starting to falter, but not stopping at 4 °C. At the 2 °C level no AE events were registered anymore. When increasing the temperature again after that, AE events did not reappear at the 3 °C level, but new AE events were registered at 4 °C.

When testing *Anobium*, activity quite regularly decreased when temperature was lowered below 10 °C. In order to stop the activity completely, we had to go down to 1 °C. Increase of temperature to 2 °C after two days however did not immediately result in renewed activity of the larvae. Only when temperature had been increased to 5 °C (in 1 °C steps) the renewed activity started to come to a level comparable to the one before.

Activity of *Xestobium* was about halved, every time the temperature was lowered from 10 °C down to 8, 4, 3, and 2 °C respectively. As with *Anobium*, it took further lowering to 1 °C to halt activity (almost) completely. When increasing temperature again, activity was slowly starting again at 2 °C, but not lagging as much as *Anobium*.

The preliminary data for *Lyctus* suggest, that activity of these larvae stops at slightly higher level than the other three species. Hardly any AE events are registered at a temperature of 4 °C.

Coming from the realisation of global warming, the behaviour of insects at low temperatures has been studied more intensively since the end of last century, which has even led to the need for more specific definitions in this field (Hazell and Bale 2011). The question is mainly about the risk of (unwanted) insect species possibly spreading to regions where they can do harm, but were not present before (Bradshaw and Holzapfel 2010). Understanding and knowing the upper and lower developmental temperature limits of an insect would enable risk inventories of such spreading based on (already known) geographical and meteorological data. Lower temperature limits critical for full development are however different from – and most probably even lower than – the low temperature activity limit looked for here, so this recently developed knowledge cannot be used to corroborate our findings.

With regard to the aim of these low temperature tests the results found lead to the following observations. The insect species studied here show differences with regard to their lower temperature activity limit: *Anobium* and *Xestobium* stay active almost to freezing point, while *Lyctus* sp. (preliminary observation) is suspending activity already at 4 °C. For all insect species however a distinct decrease in registered hits was observed when the temperature became lower than 10 °C, indicating that for trustworthy results these AE measurements should preferably take place at temperatures of 10 °C or more.

4. CONCLUSIONS

Detection of insect activity using AE can be applied to our main European dry-woodboring insects: Old house borer (*Hylotrupes bajulus*), Furniture beetle (*Anobium punctatum*), Deathwatch beetle (*Xestobium rufovillosum*), and Powder post beetle (*Lyctus* sp.).

In order to make effective use of this technique under European circumstances the following practical considerations are given.
Under circumstances with normal daily variation in temperature, temperature itself is more of an influencing factor regarding insect activity than the specific time of day (as urged by internal circadian rhythms): put simply, the higher the temperature, the more AE events. Thus, measurements at the end of the afternoon of an average day might return better results than the ones done at early morning. During the day however, individual larvae show phases of inactivity of up to 30 minutes. This means that in practice, where probably more than one larva is present at one specific time, in the absence of AE events, measuring periods may need to be extended to at least these 30 minutes.
With regard to minimum temperatures for detection, the insect species studied show small differences in behaviour at their low temperature limit. Because the number of registered hits for all species shows a marked decrease at temperatures lower than 10 °C, it is recommended that decisive assessments using AE for detection of activity of these dry-woodboring insects should be done at (wood) temperatures of 10 °C or higher.

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