

Use of Acoustic Emission (AE) to Detect Activity of Common European Dry-Woodboring Insects: Practical Considerations

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Abstract

Old house borer (*Hylotrupes bajulus*), Furniture beetle (*Anobium punctatum*), Deathwatch beetle (*Xestobium rufovillosum*), and Powder post beetle (*Lyctus* sp.) are common dry-woodboring insects occurring throughout Europe. We have deployed acoustic emission (AE) to assess activity of attack by these insects. Using available apparatus, adjusted to specific set-up, experiments were done in order to collect knowledge about the way of coupling and 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. With normal daily variations, temperature is the main influencing factor regarding insect activity, though for individual *Hylotrupes*-larvae, significant phases of inactivity were found. With regard to minimum temperatures for detection, all species show a marked decrease in the number of registered hits at about the same temperature. Recommendations are given for practical use of AE for detection of activity of woodboring insects in relation to coupling, temperature, time of day, and measurement duration.

Keywords: Acoustic emission, AE, wood, insects, woodworm, detection, activity, temperature, coupling

1. Introduction

Old house borer (*Hylotrupes bajulus*), Furniture beetle (*Anobium punctatum*), and Deathwatch beetle (*Xestobium rufovillosum*), and Powder post beetle (*Lyctus* sp.) 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 decided 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 many (scientific) publications [1][2][3][4]. 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. [5][6]). 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 [7]. This manuscript deals with the results of several 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 from 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.
- Powder post beetle (*Lyctus* sp.):
One sample was taken from a SHR-collection of several halved stems (ca. 35 x Ø 10 cm). This sample was also used as such.

2.2 Experiments

Three 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 were 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.
3. With a new active *Hylotrupes*-block and the halved stem suffering from *Lyctus* attack, different ways of coupling were tested consecutively on the same sample. Coupling the AE-sensor magnetically to a screw introduced into the sample is regarded as the reference

method. Secondly, coupling by means of a specially designed clamp was tried. The third method was coupling by using the touch wave guide, delivered with the apparatus. Because of the presence of a single larva only, the measuring period for *Hylotrupes* was set to about 24 hours; for *Lyctus* (multiple larvae) it was about 5 hours. The intention was to find out whether information (hits, events) may be lost when using the clamp or the touch sensor in comparison to the reference method and whether this differed between insects.

2.3 Apparatus

Acoustic emission events were registered with an AED-2010 (AEC, Fair Oaks, USA). Standard way of coupling between the AE-sensor and the samples was through the supplied magnet and a metal screw in the sample. Based on preliminary work, the test setup used sensitivity level G5 (total gain 84 dB). 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 this test, 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. 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.

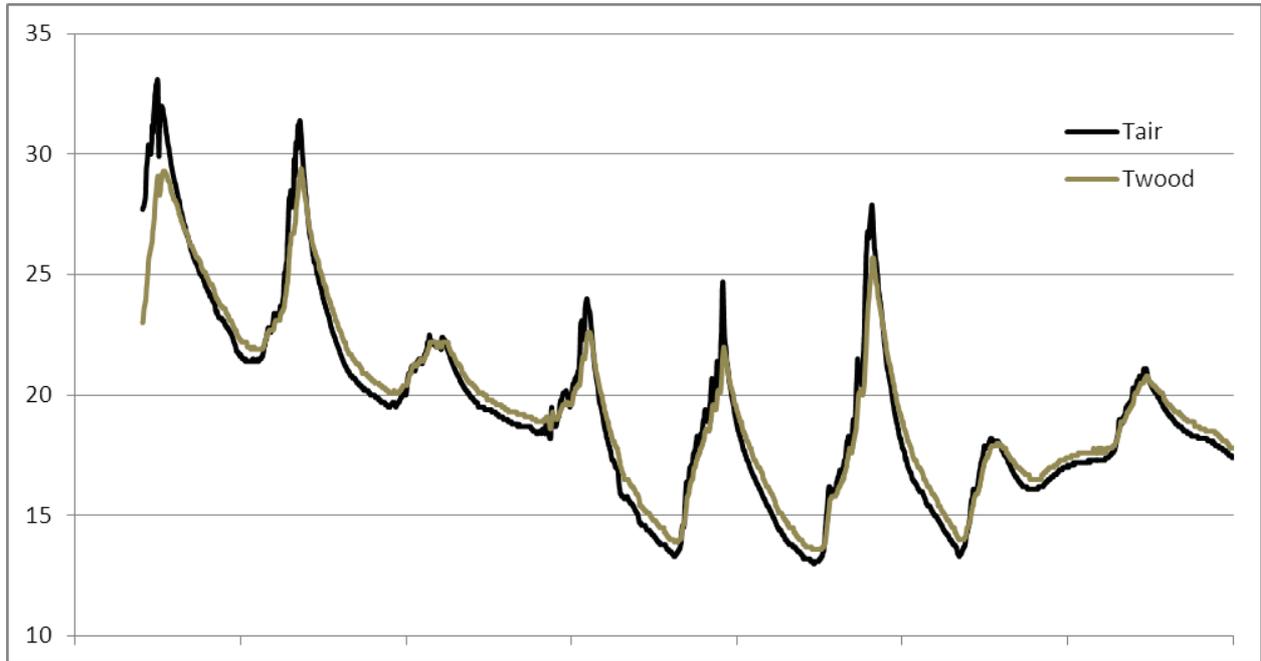


Figure 2. Variation in temperature of air and inside wood during 8-day test

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

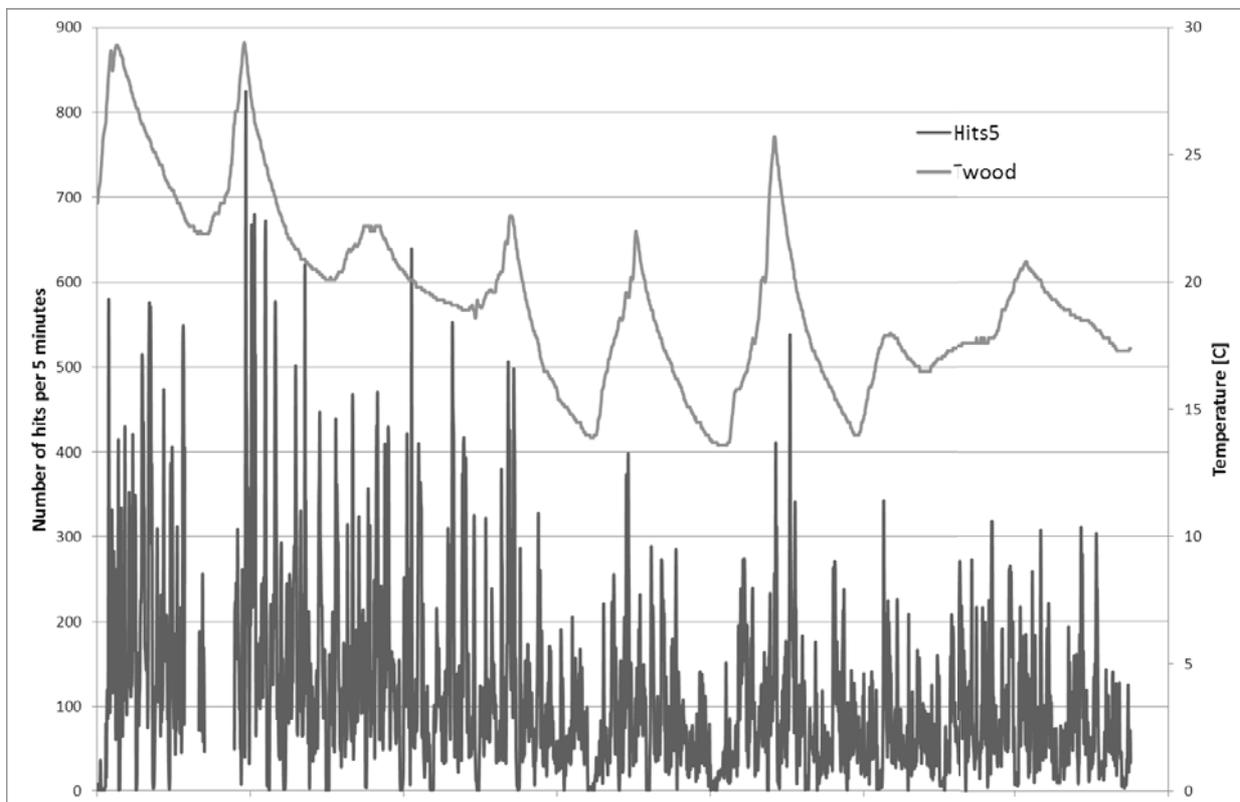


Figure 3. Comparison of internal wood temperature with activity data of *Hylotrupes*

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 [5]. 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.

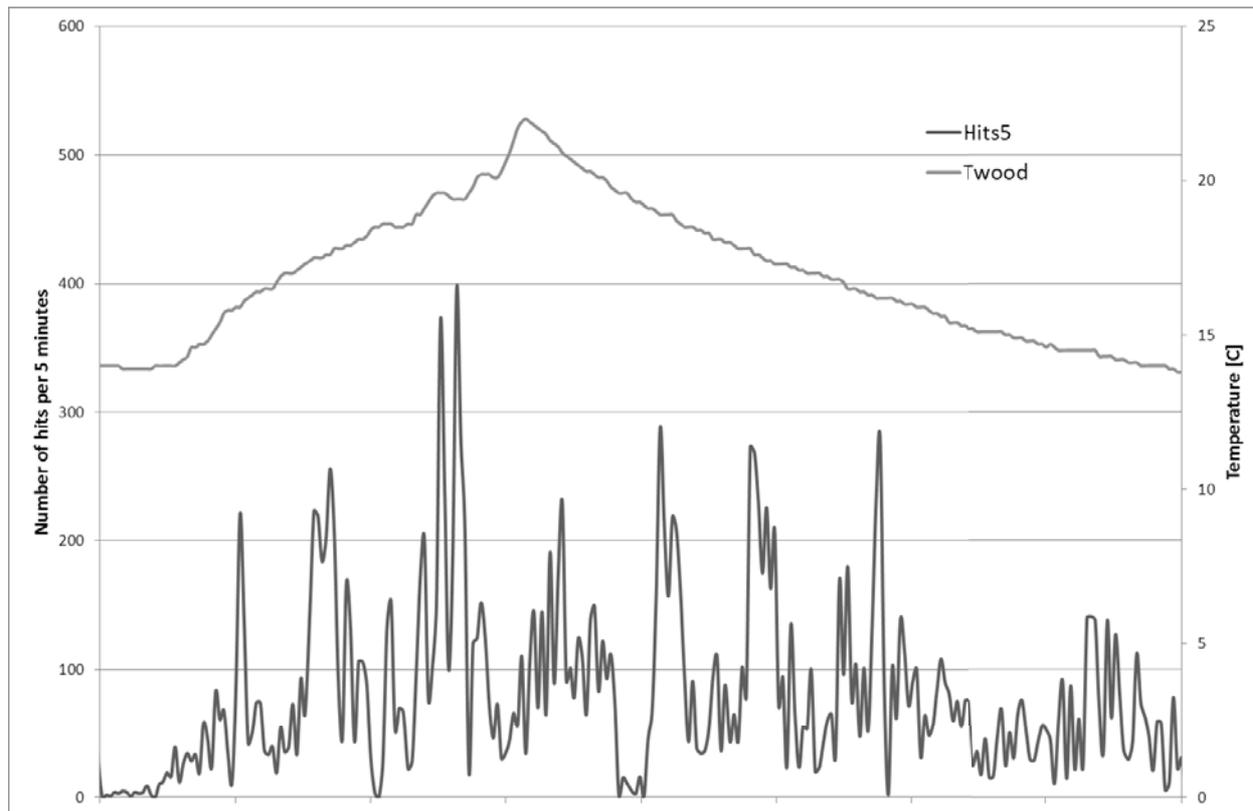


Figure 4: Zooming in on day 5 of 8-day-test

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 [5] 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 at locations close enough to the point of measurement.

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 previous level.

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 activity of the larvae of *Lyctus* stopped at a slightly higher level than the other three species. Hardly any AE-events were registered at a temperature of 4 °C. This fits into the general belief that Lyctid beetles are of tropical origin.

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 [8]. 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 [9]. 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 show differences with regard to their lower temperature activity limit: *Anobium* and *Xestobium* stay active almost to freezing point, while *Lyctus* sp. 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 (wood) temperatures of 10 °C or more.

3.3 Coupling methods

Results of this experiment are presented in Table 1. In the table the average number of hits per 5 minutes is given and this number is compared to the magnet-screw as reference method, which is set to 100%.

Table 1. Comparison of results for three coupling methods

Coupling	<i>Hylotrupes</i>		<i>Lyctus</i>	
	hits/5 min	%	hits/5 min	%
Magnet-screw	191	100	162	100
Clamp	145	76	64	40
Touch sensor	55	29	11	7

Using the magnet on a screw gave the highest counts, which corroborates the idea that this is the best way to convey the vibrations from the substrate to the sensor. The clamp and the touch sensor picked up less of the vibrations and this decrease was more marked in *Lyctus* than in

Hylotrupes. The latter produced stronger vibrations, which are probably further beyond the threshold value than those of *Lyctus*. Thus, these vibrations are less prone to fall below this minimum level when the coupling is weaker.

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.

Coupling to the infested piece is best done by attaching the magnet to a screw in the wood, giving the better basis for vibrations to travel from the substrate to the sensor. When the clamp is used or the touch sensor, the number of hits decreases significantly, depending on the insect at hand. This decrease should be born in mind when using these coupling methods. On the other hand, especially the touch sensor enables measurement without any intrusive measure for the wood piece, which is clearly an advantage when dealing with valuable objects.

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