HYBRID: MINI-REVIEW AND CASE STUDY

NOTE TO CHEW ON: INSECT DAMAGE TO MUSICAL INSTRUMENTS

Running title: Insect damage to musical instruments

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16 **Abstract**

17 Insects have a diverse range of ecologies that leaves many pre-adapted to exploiting manufactured
18 products as food sources, including musical instruments. To review what is known and to make
19 recommendations for preventing and managing insect damage to musical instruments, we conducted
20 a systematic search and a narrative review of the area. Of 339 papers, only eight peer-reviewed
21 publications met the inclusion criteria, and all were on xylophagous insects causing damage to wooden
22 instruments. To supplement this material, we report a case of damage to the key pads (composed of
23 felt enclosed in fish buoyancy bladder skin) of a clarinet by carpet beetles (*Anthrenus verbasci*
24 (Dermestidae)), the first reported case of non-woody damage and the first instance of insect damage
25 rendering an instrument unplayable. To avoid such damage, regular inspection of instruments is
26 recommended, and rapid treatment of any insect infestations in the immediate environment that
27 could extend to affecting stored instruments. Instruments themselves can be extremely expensive,
28 and if insects are still present these should only be treated by an expert; instrument cases can be more
29 easily dealt with, by heat treatment (black plastic bags in the sun) or application of a residual
30 insecticide.

31

32 ***Keywords:*** insect, musical instrument, carpet beetle, damage, non-woody

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1 Introduction

Insects will eat any organic material in the natural environments to which they are adapted, and are also thus also pre-adapted to consuming any organic material in our more recently created *artificial* environments – including musical instruments made from natural organic materials.

Various wood species are used to make a range of instruments including guitars, bowed string instruments, flutes, clarinets, oboes, bassoons, and keyboard instruments. Other organic material features in the reeds used for some woodwind instruments, horsehair in bows, and fish buoyancy bladder skin, leather or felt for pads on woodwind instruments. There have been reports of insect infestations and/or damage in plantations for oboe cane,[1] and brazil wood,[2, 3] reinforcing the potential insect threat even to finished musical instruments and their accessories. Furthermore, the potential for wood borers to damage pianos was reported already in 1918,[4] but without specific details.

Insect damage to musical instruments is therefore possible, however there has been no systematic search and narrative review conducted to characterise the current evidence-base to establish what is known about the topic, and potentially therefore make recommendations to avoid such damage. The present review aims to fill this gap by answering the questions 1) which insects are reported to infest and/or damage musical instruments? and 2) what damage is done to specific instruments due to insects? By answering these questions, we will be able to formulate recommendations for the prevention, detection and management of instrument insect infestations.

We also report on a recent, unique case of damage to a clarinet due to carpet beetle (*Anthrenus verbasci* (Dermestidae) attack in Adelaide, South Australia. These beetles are globally recognised domestic pests, feeding on any natural, dry, source of protein such as carpets, clothing, and insect collections. Eggs are laid in or near these food sources, usually in dark, undisturbed places, where the hairy brown ('woolly bear') larvae generally emerge in spring. They feed voraciously, attaining a length of up to half a centimetre, and leave behind their tell-tale, characteristic exuviae at each moult. They will often wander away from the food source to pupate, and infestations may therefore

be detected first at this stage. The emergent adults are positively phototactic, so are commonly seen near windows; they feed in flowers and therefore do not cause further damage, but obviously must also be controlled to break the cycle of infestation. These beetles have not previously been recorded as damaging the organic components of musical instruments.

2.1 Findings: Literature review

Based on a systematic search of Scopus and Web of Science (all databases), in October 2019 (see Supplementary Materials for details, including citation and reference list searching), 339 articles were identified; five of which met the inclusion criteria,[5-9] with three additional relevant articles[10-12] identified through screening of the citation and reference lists of the included studies (Figure 1). The three articles[10-12] appear to report some of the same instruments in each article. Details of each of the studies are summarized in Supplementary Material 2.

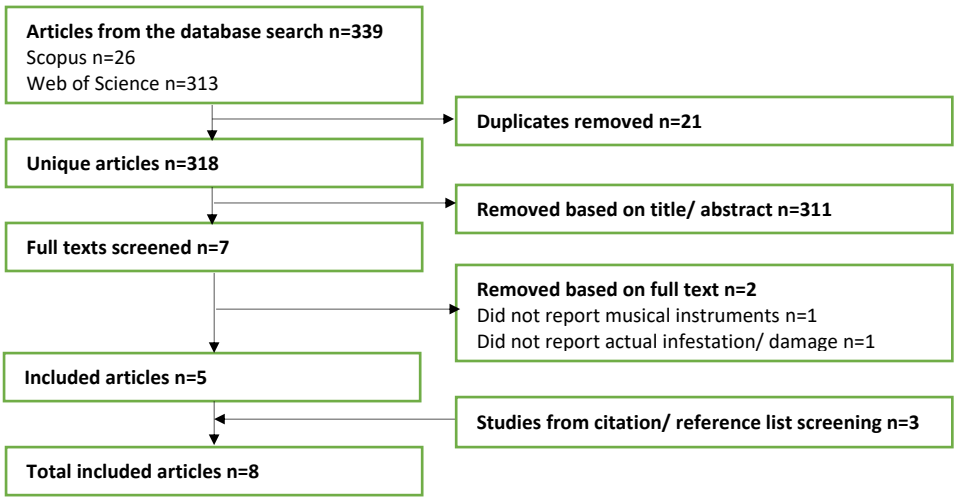

Figure 1: Flowchart of study inclusion/ exclusion

The instruments examined were violins,[9-12] cellos,[10-12] an African drum,[7] pianos,[6] and the only surviving paper organ (built 1494).[5] A museum's collection of musical instruments was also examined,[8] but did not report specific instruments. Two additional studies[5, 7] report on instruments held within museums but do include specifics about the instruments, while the source or storage of the instruments in the remaining studies was not reported.

Four of the eight included studies[5-7, 9] detected larvae within the instrument. Damage in all cases consisted of holes in the instrument, with wood pulp also detected for one.[7] None of the reports indicated that the damage impaired the function of the instrument.

Detections were made using computer tomography (CT) in five studies,[5, 9-12] and acoustic emission in another[7]. In two articles[7, 9] the instrument damage was known prior to examining the instrument, with the focus of these studies being on testing the validity of detection methods. While larvae were detected using CT[5, 9] the species could not be confirmed, although larvae were reported as "powderpost" beetles in one study.[5] Another study[10-12] reported that the damage observed in their instruments was due to *Anobium domesticum* (Ptinidae, Coleoptera) despite not identifying any insects themselves. Additionally , two pianos were reportedly that were infested with *Cryptotermes dudleyi* (Kalotermitidae, Blattodea).[6]

2.2 Findings: Case report. First reported case of non-woody insect damage to an instrument

The first documented case of non-xylophagous insect damage to any musical instrument, in the peer-reviewed literature, is reported. The case is also the first insect damage reported to render the instrument unusable, the first reported case of insect damage to a woodwind instrument, and the first report of insect damage confirmed to have occurred in a domestic setting.

The case occurred in Adelaide, Australia in an apartment where instruments were kept unused for at least 18 months, at a temperature range between 18 and 28^{O}C. The damaged instrument was a Buffet R13 B-flat clarinet, purchased in 2008, and valued at approximately AUD 6 000. The clarinet is made of African blackwood, *Dalbergia melanoxylon*), with key pads made of fish buoyancy bladder skins encasing felt, and cork and small felt pieces also forming part of the clarinet. Other instruments were also stored unused in the apartment: a piccolo made of African blackwood; a nickel silver piccolo; a silver flute; and a brass saxophone. All instruments had cork and felt parts, and the pads on the piccolos and flutes were the same as those of the clarinet, while the saxophone pads were made of leather. These pads sit below the keys to form a seal between the main body of the instrument and

111 the key (see Figure 2A), to alter the length of the tube and therefore the pitch produced. Many
112 wooden reeds for the saxophone and clarinet were within the apartment.

113

114 Figure 2: A. One of the damaged clarinet pads, placed next to the key it should sit below. Note the fish
115 buoyancy bladder skin covering below the key (arrow) *(Credit: Jessica Stanhope)*. B. Some of the carpet
116 beetle specimens (larvae and adults) collected within the apartment *(Credit: Gary Taylor)*.
117

118 In August 2019, larval and adult carpet beetles (*Anthrenus verbasci* (Dermestidae), Coleoptera) were
119 detected within the apartment and all instruments were checked for damage (Figure 2B). The clarinet
120 had four damaged pads (e.g. Figure 2A) with debris scattered around the site for a couple of
121 centimetres. Two larval exuviae were also found within the case. There was no damage to the other
122 instruments, despite the piccolo and flute being kept within the same set of draws. Damage to pads
123 renders the instrument unplayable because of air leakage, but was not noticed earlier because the
124 instruments had not been used for over a year. Adult carpet beetles and lacewing larvae with adult
125 beetle exoskeletons on their backs had been detected in the apartment in the previous year; carpets
126 and clothing were treated, but the association with potential damage to musical instruments had not
127 been made at that time. To control the outbreak and prevent further damage, the exteriors of all
128 instrument cases were sprayed with residual insecticide.

To confirm that the *A. verbasci* larvae were responsible for the damage observed, we confined a larva to a clean empty container with nothing but a clean-edged 4x3mm rectangular piece of felt pad available in the container. The larva found the pad within minutes. Clear feeding damage was visible along the edge within 24h, confirming the association between the instrument damage observed and the *A. verbasci* larvae responsible.

3 Discussion

Our systematic review of the literature identified that only xylophagous insect damage and infestations had been reported in the peer-reviewed literature, and that these were in pianos, African drums, violins, cellos and a paper organ. None of these existing reports indicated that instrument function was impaired by the damage, and in some cases the damage was only detectable using CT.

To supplement the existing evidence base we also report a case of damage by carpet beetles to the non-woody organic key pads of a clarinet. This is the first reported cases of non-woody insect damage to any instrument in the peer-reviewed literature, and also the first where damage rendered the instrument unusable, the first for a woodwind instrument, and the first confirmed to have occurred in a domestic setting.

The potential damage caused by insects to museum collections is well known to entomologists and museum curators, but the potential damage to musical instruments, particularly to the pads of instruments, is under-recognised. The issue of musical instrument damage, especially for bows and pads, is anecdotally well known among musical instrument repairers, in fact carpet beetles are often referred to as 'bow bugs'. Despite this awareness among repairers, the potential instrument damage of insects is rarely discussed with and/or among musicians, and entomologists may not be aware of the problem in this occupational group specifically.

There may be publication bias regarding the reports of instrument damage to musical instruments. Most previously reported cases involved museum specimens,[5, 7, 8] and/or new, non-invasive/destructive approaches to detecting damage to, or infestation of, instruments.[5, 7, 9-12] These

types of reports are of interest due to the value of the museum specimens where museums internationally require information about potential risks and monitoring strategies, while new technologies may assist curators, as well as instrument repairers. Where damage is visible without such technologies, such as to clarinet pads or string instrument bows, these cases may go un-reported. By reporting the case of damage to clarinet pads here, we are working towards combating this likely publication bias. Biologically, there is no reason to suspect that *any* biological component of *any* instrument would not be susceptible to insect damage, although non-organic components (e.g. metal) would clearly not be.

Musical instruments can be an expensive investment, with for example string instruments by Stradivarius worth tens of millions of dollars. Although the care of the instrument is typically discussed with students and new instrument owners, the potential damage by insects is rarely, if ever included. Insect damage is unlikely to occur when instruments are played regularly, however strategies to minimise the risk of damage are required when instruments are not played for extended periods. These strategies include using surface spray around the instrument case, ideally with residual insecticides, such as combinations of cypermethrin/imiprothrin. It is also important to keep the house free from potentially damaging insects, and to treat immediately when detected. If an outbreak of insects is detected, then musical instruments should be checked for potential damage, and monitored until the outbreak has cleared.

If instrument infestations are detected, for bow hair it is recommended that all remaining bow hair be cut off, sealed within a bag and disposed of. The instrument case for any instrument may contain eggs; hence it is recommended that the case (with the instrument removed) be sealed within black plastic bags and placed in sunlight for several hours, and that insecticide be used in the case. If insect infestations are detected in a house, the eggs, larvae and/or adults may also be elsewhere; hence treatment of the whole house is recommended. This treatment may include the use of insecticides as above, vacuuming all carpets, and washing all clothes containing natural fibres at 60^{o}C or greater.

Where this might not be possible, the clothes can be placed loosely in a black plastic bag and sealed before leaving in sunlight for several hours. Alternatively, insect pests in any life stage can be eradicated by placing infested objects in a freezer for two weeks (as is practiced for insect collections under attack from museum beetles), but obviously this approach is not suitable for all materials because of the damage that such treatment could entail. An additional innovative approach is low oxygen treatment, whereby the object to be treated is encased in airtight plastic, and a commercially available oxygen scavenger product is introduced thereto. Insects in any life stage are thereby killed through hypoxia, a treatment that can be applied to furniture, wooden sculptures, panel paintings, and other objects.[13] Fumigants, other biocides, and radiation provide additional treatment options; for a recent review of Integrated Pest Management in a museum or collection context, see Querner.[14] Regardless of the approach used, it is vital to remove all carpet beetles, including the eggs and larvae, if further outbreaks are to be prevented. Entomologists and pest controllers should be aware of the potential for domestic musical instruments to be damaged from insects, and where any relevant outbreak is detected, ask the clients about whether they have any musical instruments that may be at risk. While to date documented reports have only included wood and now also clarinet key pads, any natural fibre on a musical instrument or musical accessories may be at risk.

The existing evidence has been summarised, and a new case reported to illustrate the range of materials in musical instruments potentially subject to insect attack. To strengthen this evidence base, we recommend research be extended to surveys of musicians regarding their experiences with insect damage to their instruments; and experiments to determine, with greater rigour, the parts of musical instruments that are at risk of insect damage from specific insects. Such an additional information could help owners and pest controllers better check and treat musical instruments, to protect these assets.

Acknowledgements

203 The authors would like to thank Prof. Jonathan Gressel and two anonymous reviewers for feedback
204 that helped to improve an earlier version of the manuscript. The specimen photographs are by Dr.
205 Gary Taylor (The University of Adelaide), and Jake Robinson (University of Sheffield) produced the
206 graphical abstract.

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