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Catch of *Reesa vespulae* in Heritage Environments

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Simple Summary: The skin beetle *Reesa vespulae* is regularly found beyond North America where it originated, having arrive in Europe in the mid-20th century. Initially associated with stored food products, the beetle causes damage in museums attacking hides, furs, dried plants and zoological collections. Although still only found in a small fraction of museums, it is occasionally present in large numbers. A single female can continue to breed meaning its presence can persist over long periods of time. In infestations larvae are trapped more frequently, suggesting *R. vespulae* may range widely in search of food.

Abstract: The skin beetle *Reesa vespulae* is regularly found beyond North America where it originated. The larvae cause considerable concern in museums as it damages hides or furs in addition to being a special source of damage to collections of dried plants in herbaria or collections of insects and other zoological specimens. It arrived in Europe in the mid-20th century and was associated mostly with stored food products, but over time it has become recognised as a museum pest. Although still uncommon and may only be observed in a small fraction of museums, where the insect is found in large numbers it can cause problems. As a single female can continue to breed because the beetle is parthenogenetic, presence can persist over long periods of time. Although small populations in museums are typically found as the adult, the larval forms are more common where a site is infested by high numbers, perhaps because the larvae and adults must range more widely for food. Although *Reesa vespulae* can be controlled using pesticides, it is also possible to kill the larvae within infested materials through freezing or anoxia.

Keywords: parthenogenesis; skin beetle; trapping; museum pests; IPM; Austria

1. Introduction

Reesa vespulae (Milliron, 1939) belongs to the family *Dermestidae*. Since the mid-20th century it has spread beyond its native habitats in North America [1], now often found in homes, warehouses and museums worldwide. The beetle represents an example of a continuing threat from biological invasions and the widening risk from beetles that attack stored products [2,3]. These skin beetles (or in German more distinctively Amerikanischer Wespenkäfer, the American wasp beetle) are considered pests because they can damage stored products such as grain, cereal, dried food, but also animal hides and can be a special problem in the heritage environment as dermestids are often associated with animal materials such as leather and skin, wool, fur and dried insect collections, which makes natural history museums especially vulnerable [1,4,5]. It was initially described from wasp nests in Minnesota as *Perimegatoma vesuplae* by Milliron in 1939. The beetle spread widely from the mid-20th century, with the first records of *R. vespulae* outside its native range, from New Zealand in 1942 [6]. It was found in Europe through the 1950s [7–9]. In the UK it was discovered in association with a grass seed store in the 1970s [10], in the Czech Republic [11] and most recently Bulgaria [12]. *Reesa vespulae* is currently prevalent throughout much of Europe, Australia, New Zealand, South America, and North Africa [13]. In Germany of the 1980s it increased twenty-fold in food stores,

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though the relatively slow rate of development meant that it was only a problem where seed was stored for more than a year [14]. However, restrictions on the range of allowed pesticides in the European Union has created some concern [11].

A number of neobiotic animals have been of concern to heritage managers in recent years, such as the rise of insects that damage heritage landscapes and the destructiveness of *Rhynchophorus ferrugineus* (Olivier, 1790), the red palm weevil [15]. There has additionally been an increase in termites that attack wooden structures or live plants or museum objects [15,16]. In European museums a few species have been noted as spreading in recent years: *Attagenus smirnovi* (Zhantiev, 1973), the brown carpet beetle [17], *Ctenolepisma calvum* (Ritter, 1910), the ghost silverfish [18], *Gastrallus pubens* Fairmaire, 1875 [19,20] and *Thylodrias contractus* (Motschulsky, 1839), the odd or tissue paper beetle [21]. These seem to reflect a widespread and increasing problem for the heritage environment [22] (here museums, libraries, art galleries and associated store rooms). *Reesa vespulae* is an important and potentially damaging pest for zoological and herbarium collections, with the larvae being especially destructive to these materials (Figure 1c). They are particularly common in entomological collections where they prefer *Lepidoptera* [23]. The beetle was likely present in continental Europe from the 1960s, with a possible record from Norway and reached Southern Finland (Tampere and Turku) [24]. Today it has become part of a more general concern in museums internationally [23,25–29]. The beetle can be found among fluff and dust under furniture [30], or the spaces beneath display cases. Such hidden locations may provide one of the reservoirs from which re-infestations develop [23]. *Reesa vespulae* can also grow on dead birds in roof areas [23], or can breed outside the museums in wasp nests [26].

Figure 1. (a) Adult female *Reesa vespulae* - size: 2.9 mm (b), larvae and (c) damage to an entomological collection. Credits: (a) Adult beetle Udo Schmidt https://en.wikipedia.org/wiki/Reesa#/media/File:Reesa_vespulae_(Milliron,_1939)_(31097148261).png, (b) *R. vespulae* larvae collected in Finland, Pekka Malinen, https://www.gbif.org/occurrence/4036519301 (licensed under http://creativecommons.org/licenses/by-sa/4.0/, (c) Damage by *R. vespulae* Pascal Querner.

As *R. vespulae* is a parthenogenetic species [1], and to date no males have been found. This means that a single female individual can give rise to a new population, so pest control techniques based on mating disruption are not effective. This has certainly raised concern about its ability to spread in museums from a remnant single individual female [23,29]. The life cycle has been outlined by Bahr and co-workers [7,31] who observe that larvae develop at 25 °C over 1–1.5 years at 23 °C: 2 years, and at 15–21 °C over 3 years. The adults live 6–14 days at room temperature and after 2–3 days they start laying, on average, 24 eggs. The eggs hatch as larvae typically after 3 weeks at 18 °C. There is no development below 13 °C. The long life-cycle suggests that small increases in temperature could shorten the this cycle and increase the abundance and the potential threat to collections under a warmer climate.

In recent decades there have been changes in the pest management and in European museums it is likely that this has altered the presence and distribution of insect pests [32]. A concern about harmful pesticides has led to softer approaches to the control of insects under contemporary IPM regimes [32]. This comes at a time when warmer conditions under a changing climate might shorten the insect life cycle or increase their activity [17,33]. There is an increasing international exchange of exhibitions among major museums, which can allow insects to travel with loaned exhibitions and

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additionally special exhibitions mean the use of associated display materials that can introduce new pests. In 2020, the COVID-19 pandemic led to the temporary closure of many museums and historic houses. This widened the range of habitats available to insects in museums at a time when there were few staff available to undertake IPM [34].

In early observations of the introduction of *R. vespulae* to Europe it was evident that the insect posed a risk to museum collections [24]. This paper examines recent records of its increasing presence in the heritage environment, especially in Austria, but links it to observations from other European countries and more widely. Its growing presence in at least one country of Central Europe along with ready exchange and loan of exhibitions, means that there is a risk of further spread and infestation, especially on the continent. We explore recent catches from traps and observations that provide information about the increased potential for infestation.

2. Materials and Methods

This study benefited from insect monitoring that forms part of IPM procedures now adopted in many museums and historic libraries. The trapping data came from over 90 museums with continuous monitoring programmes in Austria that often began as early as 2014. The study examines the trapping records where *R. vespulae* were found, most specifically from 17 buildings in Vienna and seven further afield from Lower Austria, Salzburg and Vorarlberg. At most sites both sticky blunder traps (type Catchmaster) and pheromone traps for webbing clothes moths (type Finicon). Traps were distributed at floor level at regular intervals along the edges of rooms and checked three to four times a year. In addition, some adventitious trapping in 2020 (started 15 May 2020 and last collection 20 April 2021) from a small entomological collection at the University of Vienna. Small light traps were also used at this location in the winter season (L-trap, https://deffner-johann.de/de/l-trap-insektenfalle-klebefalle-mit-fotoluminiszens.html). Identification is relatively easy because *R. vespulae* is quite distinctive as an adult (Figure 1a) and even the larval form is quite characteristic (Figure 1b) and well described [Kadej et al.].

The study also used a number of datasets that reflect observations of catches of *R. vespulae*. In particular the Global Biodiversity Information Facility [35] and WhatsEatingYourCollection (WEYC) [16]. Personal contacts with museum entomologists were also valuable in assessing the breadth of the threat from *R. vespulae* and are mentioned in the text as personal communications or in the acknowledgements.

Statistical methods often adopted non-parametric approaches to reflect the integer nature of insect catches, so the Mann-Whitney test was used to compare catches from different locations. Additionally results were reported as medium and dispersion as lower and upper quartiles ($\mathcal{Q}_1$ and $\mathcal{Q}_3$).

3. Results and Discussion

3.1. Overall Catch

Figure 2a shows the change in the number of buildings with the catch of *R. vespulae*. in given years since 2014 from the Austrian monitoring progamme. There is an increase in both the number of buildings where the beetle was caught along with an increase in the catch rate per building (Figure 2b). However, these results are rather biased as a large proportion (⅓–⅔) of the total catch in some years comes from a single building and there are many instances where no beetles are caught. These observations arise from 25 Austrian buildings out of 94 that are regularly monitored. There were 18 buildings from Vienna where 100 examples of *R. vespulae* (both as adults and larvae) were caught. Outside Vienna there were 5 buildings with *R. vespulae* and 17 examples of the beetle or larvae were caught. A Mann-Whitney test suggested that there was no difference (p_2>0.5) in the catch numbers from the Viennese and non-Viennese buildings. In recent years (2022–2023) the catch from these Austrian heritage buildings was on average quite low, typically just over one insect per building (Figure 2b). However, examining the buildings where *R. vespulae* was found exaggerates the cauch rate. The *R. vespulae* catch from the 94 different Austrian heritage buildings studied, many since 2014,

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shows that only 25 have revealed any catch of *R. vespulae*, i.e., 30%/ However, just recently (2024) an example has been found in the library of Klosterneuburg Abbey, just to the north of Vienna. In the Austrian heritage buildings, on a year-by-year basis there are 46 annual periods when the beetle was caught from a record that spans 630 building-years i.e., ~7%.

The proportion of museums where *R. vespulae* has been reported is a little lower elsewhere. In the UK the WEYC database contains 367 different buildings, yet only 19 reports are associated with finds of *R. vespulae* (i.e., ~5%). If this is determined on a year-by-year basis, which better accounts for the varying periods covered by the building records, the WEYC data, in terms of building-years, catches are found 41 out of 1354 (3%). In the UK the WEYC data suggests that *R. vespulae* is reasonably well-known as a heritage pest though not necessarily reported often. There are strangely few records from London where catch of other insects is frequently well recorded [36]. In Berlin only one out of 20 buildings regularly investigated has a standing population of the beetle [personal communication Bill Landsberger]. These percentages give a general impression that most museums are free of the pest, although we should emphasise that the frequency at which it is encountered in Austria appears to be higher than elsewhere. It seems that although it is not causing damage in Austria, *R. vespulae* has become more common over the last five years.

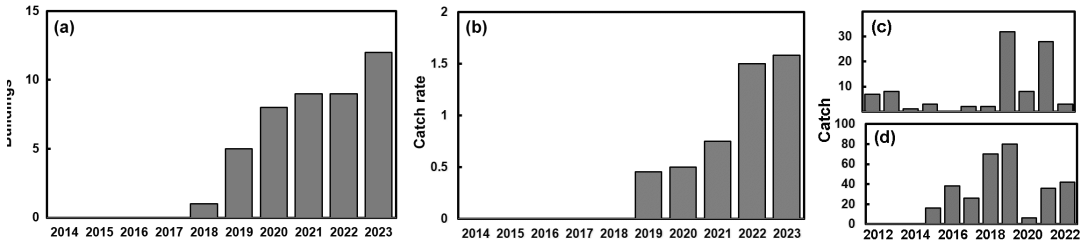

Figure 2. (a) The number of buildings where *R. vespulae* was trapped, from a total of 24, although only 2w buildings were included over the period 2014–2020. (b) Average catch rate for the sum of both adult and larval *R. vespulae* in the studies buildings in Austria. (c) Annual numbers of *R. vespulae* reported from a museum in Birmingham and (d) Annual numbers of *R. vespulae* reported from a museum store in Northern Ireland.

Despite the substantial fraction of Austrian museums reporting *R. vespulae*, none of the these museums have especially large numbers, with only the Albertina, a collection of modern art, having annual catches into double digits. Here *R. vespulae* has been trapped from 2020–2023, so has persisted over a number of years. The most serious infestation occurred in a small entomological collection in Vienna, which suffered very badly from *R. vespulae*. It was not part of the regular monitoring programme and traps were only put out from spring of 2020; set over the periods 15 March–22 July, 22 July–10 September and 10 September–20 April the following year. The blunder traps only caught *R. vespulae* in the March–July period (41 examples). Spring is a season when it is typically of found in food stores [37]. A light trap deployed at floor level over the entire period trapped 17 examples of *R. vespulae*.

At three provincial locations in the UK, (i) Cardiff, (ii) the West Midlands (Birmingham) and (iii) County Down in Northern Ireland there are more than 20 records of *R. vespulae*. Changes in catch over time from the West Midlands and County Down in Northern Ireland are shown in Figure 2c and 2d and suggest catch has been variable, but rather persistent. The average catch rate each year for the museum in Birmingham over the years 2012–2022 was 8.5, but the catch numbers were highly skewed, so central tendency might better be represented as the median i.e., 3 (Q_1=2; Q_3=8). In Northern Ireland the catch numbers were higher with an average of 39.25 and median of 37 (Q_1=23.5; Q_3=49) for the years 2015–2022. They were even higher for the two years 2017–2018 in Cardiff, which averaged 89.

In Berlin, there has been a stable population since 2017, at only one location (out of almost 20), near a container harbour at Westhafen (personal communication Bill Landsberger). In Bavaria it is not found in any museum that was monitored (personal communication Stephan Biebl). Information

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from the south of France, also suggests that *R. vespulae* is not very frequent (personal communication Fabien Fohrer). In Norway no special concern is apparent on changes in the populations of *R. vespulae* in heritage environmets (personal communication Anders Aak), while in Sweden, natural history museums, in both Stockholm and Malmo, have found the insect (personal communication Niklas Apelqvist). Further afield in New Zealand 43 beetles, 52 larvae and 18 casings were discovered in nine locations in Auckland Museum, between September 2017 and August 2018 [27].

3.2. Larvae and Adults

As seen in Figure 2a, the catch from Austrian heritage buildings was on average quite low, typically just one insect per building. Additionally these were mostly caught as adults; only seven larvae were found in a total catch of 117 individuals. This represents just 6% of the catch. The low catch for larvae is illustrated in Figure 3, with all the Austrian buildings lying close to the x-axis. A similar proportion was found for the year-long trapping at the Viennese entomological collection where ten larvae were collected from a total of 152 individuals, and while large numbers of beetles were caught, larvae again represented some 6% of the catch.

There was a proportionally greater presence of the larvae in the museum in Birmingham across the years 2012–2022, as here larvae for the period averaged at 18% of the total, but as can be seen in Figure 3 the numbers varied year-by-year. The situation is very different in Northern Ireland, revealing especially high proportions of larva year-by-year and averaged to 88% of the total catch. The two years in Wales (2017–2018) showed that 64% were present as larvae and the single year (2017–2018) in Auckland showd the proportion as 55% [27]. These last three locations where the catch was high show much creator proportions trapped as larvae as seen by points that appear to align themselves along a steeper trend. This was also true of an infestation in the National Museum of Ireland – Natural History from 2004, where a predominance of larvae (woolly bears) were trapped, although typically found under, rather than on sticky traps [23].

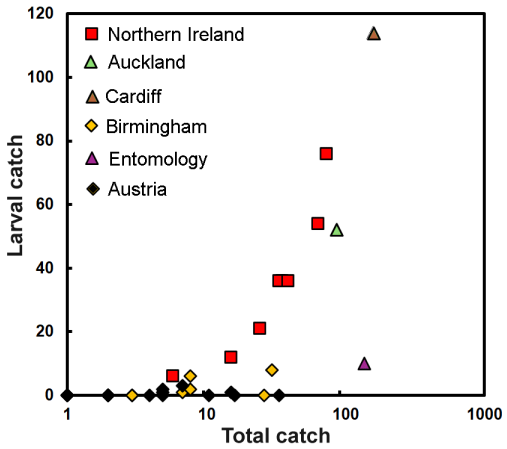

Figure 3. The annual number of *R. vespulae* larvae as a function of total catch at various buildings, with the exception of the Austrian samples, which are small and here cover the length of the record 7–9 years.

Large infestations thus reveal more larvae, so it may be that they move away from the center of infestations to avoid predation, but also gain more access to food resources as both the adults and larva are seen to range more widely.

3.3. Implications for Heritage Environment

Trapping and monitoring museum pests is a key part of IPM. However, some have observed a preoccupation with issues such as these may lead to failures in addressing changes in practice required to manage insect pest problems [38]. This makes it important to interpret the observations in a way that is useful for treating the pests. Initially, it is important to interpret the data in terms of

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relevant metrics or pest occurrence indices [39,40]. It is of particular relevance to consider that Vaucheret and Leonard [23] suggest that "individuals which were caught on the traps did not always match adequately with the areas where active infestations were discovered through visual inspections". Thus insect catch was not necessarily a reliable indicator, so regular visual inspections remain an important back-up.

There has long been a sense that problems with *R. vespulae* are increasing [25]. We have shown that although once unknown in Austrian museums there are now around twenty that regularly report the beetle in low numbers. The global spread of *R. vespulae* is probably "the result of multiple introductions into the different zoogeographic regions, and secondary translocations therein" [1]. This means a greater awareness of the insect is required. There is a potential that changes in climate, a more globally derived visitor base, exchange of collections from wider geographic areas could also contribute to increases in its presence. Changes in the layout of collections would be particular occasions when it is important to avoid transferring the insect [23]. Given the prevalence of damage to entomological collections with pinned insects [41], regular inspections of these seem especially important. More generally it is also sensible to look within taxidermy and herbarium collections, along with vulnerable textiles. In Auckland Museum, *R, vespulae* were attracted to areas where staff store and consume food [27]. However, at the same time it was noted that the beetle is attracted to dark, quiet collection spaces that are rarely accessed [27]. This can mean that it may also be museum stores that are vulnerable because of a lack of human activity. The growing proportion of larvae in larger catches might be a useful indicator for infestations of *R. vespulae*

The levels of infestation and changes and their drivers over time seem important to established if a programme of eradication is planned. Once complete continued awareness and regular inspection and cleaning is especially relevant in areas of current or earlier infestation [23].

Management can take advantage of the long growth cycle and the high level of activity in spring. There is little evidence that the beetles fly in Austrian museums as they do not seem associated with windows. However Parry [42] found one at the window in a Glasgow house, but did not observe it flying [personal communication Parry]. Flight has been suggested under Czech conditions as the beetle has been found in light-traps near a breeding site [43]. As a parthenogenetic species [Nardi and Hava, 2021], and no males are found. This means that a single female individual can give rise to a new population, and pest control techniques based on mating disruption are not effective. This raises concern about its ability to spread in museums from a remnant single individual female [23,29].

Reesa vespulae can be controlled by freezing or anoxic environments. Arevad [44] suggested that the larvae of *R. vespulae* were killed on exposure to -20 °C for an hour. Bergh and co-workers [45] exposed the beetle larvae in blocks of seasoned oak (20×20×20 cm) at -20 °C for 72 h, which ensured total mortality. Most were killed at temperatures some 5 °C warmer, but in materials such as wool these more modest degrees of freezing were less effective, so -20 °C may be the safer choice. In anoxic environments of almost pure nitrogen (i.e., oxygen below 1%), 99% of the *R. vespulae* larvae were killed after some 50 h [46]. Pesticides such as pyrethrins, pyrethroids and organophosphates have been used in seed stores [11]. However, there is increasing reluctance to use pesticides in the heritage environment, but recently pyrethroids were used in the entomological collection in Vienna that had become infested.

4. Conclusions

The presence of *Reesa vespulae* in museums and libraries is widespread, although still comparatively rare in terms of the number of properties where it is found. Although it was recognised in 1970 that this insect posed a risk to museum collections, its presence in Austrian heritage environments has only become apparent over the last five years. However, with the exception of a small entomological collection there has been little evidence of damage to collections in Austria. Its growing presence in one country in Central Europe, often in Natural History Museums and their store rooms, along with ready exchange and loan of exhibitions, there is a risk of further spread and infestation. In other countries the frequency of occurrence may be lower, but where it occurs the numbers trapped can be high and lead to serious and damaging infestations.

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The increasing observation of *Reesa vespulae* in museums suggests a need for greater vigilance. Trapping may not always catch the beetles so visual inspections of likely habitats are important. Larvae are likely to be a good indicator of infestation and potential damage because in Austria though they have grown more common infestations are rare and the larvae remain uncommon. The beetle can persist over years despite attempts to eradicate them as *R. vespulae* is a parthenogenetic species and no males are found. This has certainly raised concern that a remnant individual female can retain the ability to spread the insect within a museum.

The low frequency of occurrence has limited research in the museum environment, so more observations are needed. Research might consider that little is known about flight dispersal, seasonal behaviour and the resilience of populations under museum conditions. Given the rather lengthy life cycle it may well be that in future warmer conditions the cycle could be reduced from two years to one potentially exacerbating the risk to vulnerable collections.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Figure S1: title; Table S1: title; Video S1: title.

Author Contributions: Conceptualization, P.B. and P.Q.; methodology; formal analysis, P.B.; investigation, P.Q.; writing—original draft preparation, P.B.; writing—review and editing, P.B. and P.Q.; visualization, P.B.; project administration, P.Q.; funding acquisition, P.Q. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The data from the traps is given in the supplementary table, although the names of the heritage buildings have been anonymised.

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Conflicts of Interest: The authors declare no conflicts of interest.

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