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Using Physical Evidence of Microwasp Emergence in Bee Hotels as a Novel Way to Detect Parasitism

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ABSTRACT

Parasitoid visitation occurs in both natural and artificial Hymenopteran nesting cavities, such as those that occur in bee hotels. Detection of parasitoids emerging from these cavities can provide information on the extent and abundance of their associated hosts. However, adaptive bee hotel management may be required to prevent these structures from becoming a population sink if extensive parasitoid emergence is detected. Detection of the invertebrates that emerge from occupied cavities in bee hotels can be hard to determine. Microwasps, one group of parasitoids, can be even harder to detect due to their small size. In this research, we proposed a non-destructive, early in the field detection method to estimate microwasp parasitoid abundance and presence from the observation of emergence holes. Bee hotels were deployed in areas subject to ecological restoration within the Cumberland Plain Woodland of the Greater Sydney Region. The emergence of bee hotel occupants was recorded, with target taxa identified to genus. Emergence of the microwasp Eulophidae cf. *Beornia* in most cases resulted in no emergence of a primary occupant. However, in a few novel cases, Eulophidae cf. *Beornia* did emerge alongside *Pison* and *Anterhynchium* wasps. When Eulophidae cf. *Beornia* emerged from cavities, while the sealed entrances remained intact, small emergence holes were detected in the front and rear sealed cavities. These emergence holes offer a way for practitioners that use bee hotels to estimate microwasp parasitoid presence and abundance. Understanding this can also provide insights into the presence and abundance of their associated hosts. This method can indicate if the deployed bee hotels are supporting invertebrate populations, or overly facilitating parasitoid numbers, resulting in the bee hotel acting as a sink. Early detection of excessive parasitoid numbers can allow for practitioners to employ adaptive management actions to ensure the bee hotels are supporting local populations.

1 | Introduction

Bee hotels, an artificial nesting structure that is typically deployed to support native bee populations, have also been found to support other species such as parasitoid wasps (MacIvor and Packer 2015; Prendergast 2023; MacIvor and Salehi 2014; Henry et al. 2023; Drapeau Picard et al. 2024). Concerns have arisen that the highly aggregated nesting cavities in bee hotels may cause higher than naturally occurring parasitism rates (Rosenheim 1990; MacIvor and Packer 2015). However, it is

important to keep in mind that parasitism occurs naturally, and when an ecosystem is rich and abundant in parasites, it is equally as rich and abundant in hosts (Hudson et al. 2006). Detection of parasitoids in bee hotels can therefore provide insight into their associated hosts and the trophic dynamics within an environment.

In assessing the effectiveness of deploying bee hotels to provide habitat for cavity nesting bees as part of restoration efforts, we also made observations of the emergence holes left behind

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by microwasps from Eulophidae cf. *Beornia*. Eulophidae is one identified parasitoid wasp of bee hotels; however, research is limited (Lotfalizadeh et al. 2025; Nascimento and Garófalo 2014; Vicens et al. 2022; Torretta and Marrero 2019; Lankford et al. 2025; Drapeau Picard et al. 2024). The wasps within this family are incredibly small, most less than a few millimetres in length (Bouček 1988). It can be hard to visually monitor bee hotels in general to be able to determine what emerges from them. Due to the small size of Eulophids in particular, it can be incredibly difficult to detect the presence of this microwasp.

In this article we propose a non-destructive, early detection method that involves observing these emergence holes in the field to estimate microwasp extent and abundance. This method avoids the destructive nature of current research methods, which involve the removal of deployed bee hotels or nesting cavities from the field, ultimately preventing cavity nesting occupants from emerging into the environment (MacIvor and Packer 2015; Prendergast 2023; Drapeau Picard et al. 2024). This information immediately informs the observer, allowing practitioners to adapt methods to ensure bee hotels are supporting local populations.

While parasitism occurs naturally within cavity nests, excessively facilitating their populations in bee hotels may result in negative outcomes for their hosts. This can result in the deployed bee hotels acting as a population sink, instead of supporting the intended outcome of boosting local populations and supporting biodiversity. By detecting these emergence holes, this evidence can then be used to inform decisions involving the suitability of using bee hotels to support invertebrates in different areas, as well as survey often overlooked trophic dynamics.

2 | Methods

Thirty-four bee hotels made of untreated native hardwood (45 mm x 180 mm x 175 mm, HxWxD) and a metal roof were deployed across 17 20 m x 150 m plots, within areas undergoing restoration in the Cumberland Plain Woodland, across the Greater Sydney Region. These plots consisted of four undergoing revegetation, five undergoing weeding, and eight undergoing natural regeneration, with all areas protected with cattle exclusion fencing. However, one natural regeneration plot was removed from the study in February due to prescribed burns, and another site was removed from its allocation of natural regeneration in March and re-allocated to weeding.

Two bee hotels were attached to pre-existing trees within each plot at least 50 m apart, 1.5–2 m off the ground (Figure 1). Bee hotels were deployed from October 2022 and collected June 2023. Bee hotel cavity diameter sizes included 3 mm (×7), 5 mm (×9) and 7 mm (×5). Initially there were 715 cavities available in total, but the removal of two bee hotels in February for prescribed burns reduced this number to 630. Cavity sizes that were 5 mm and 7 mm were lined with paper straws. Due to the small size of the 3 mm cavity, there was no straw lining placed inside. Every four to nine weeks, bee hotels were monitored in the field for nest caps indicating occupied cavities, with occupied straws removed and replaced with empty straws. For the 3 mm cavity size, the entire bee hotel was replaced if all cavities showed signs of occupation. Occupied straws and bee hotels were collected and stored in the lab. Collected straws were placed back into bee hotels, and all occupied cavities were covered with a plastic tube, with insects emerging for identification until the end of February 2024. Upon emergence into the tube, wasps were identified to genus (Bouček 1988; Carpenter and Brown 2021; Nastasi et al. 2023).

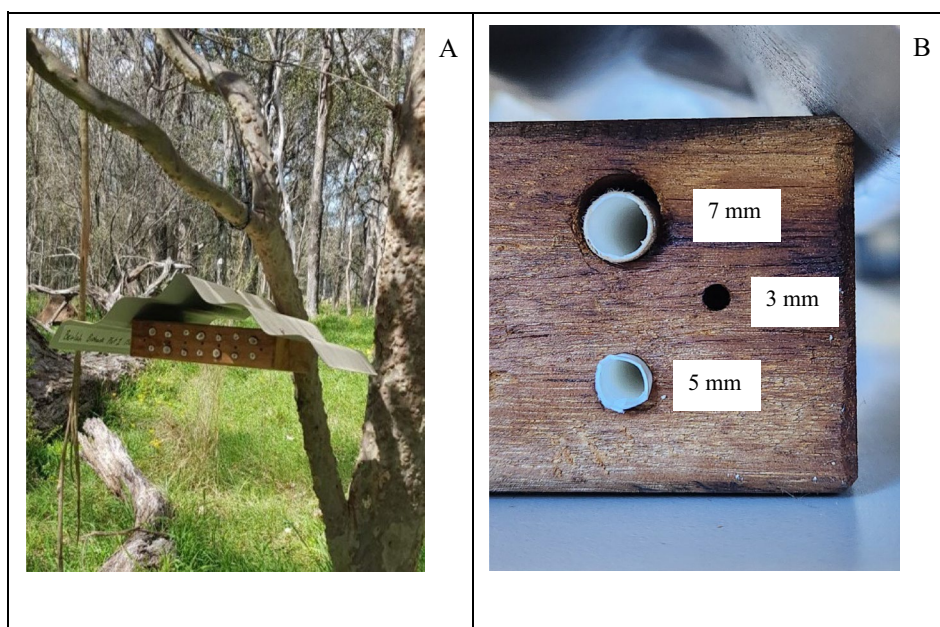


FIGURE 1 | Bee hotels were attached to pre-existing trees 1.5–2 m off the ground in the Cumberland Plain Woodland (A). Cavity size diameters within the bee hotels were 3 mm (×7), 5 mm (×9), and 7 mm (×5) (B).

TABLE 1 | Total number of Eulophidae cf. *Beornia* that emerged and the number of cavities emerged from, according to cavity size.

Cavity Size	Number of cavities emerged from	Number of Eulophidae cf. <i>Beornia</i>
3 mm	25	98
5 mm	31	254
7 mm	43	503



FIGURE 2 | Size comparison between *Anterhynchium* (left), *Eulophidae* cf. *Beornia* (middle), and an Australian \$1 coin (right).

3 | Results

3.1 | Bee Hotel Occupation

Of the cavities available, 304 of the cavities were sealed with a nest cap that suggested occupation by either bees or wasps. From these occupied cavities, there were 1110 wasps that emerged from 186 cavities, and 27 native bees that emerged from six cavities. However, 104 of the occupied cavities resulted in only parasitoid wasps emerging.

3.2 | Eulophidae cf. *Beornia*

Eulophidae cf. *Beornia* emerged alone from 95 cavities. Eulophidae cf. *Beornia* also emerged alongside a single live individual of *Anterhynchium* (Vespidae) twice from two 7 mm cavities, and alongside three live individuals of *Pison* (Crabronidae) twice from two 7 mm cavities. Of the 1110 wasps that emerged, 855 of these were Eulophidae cf. *Beornia*. All nesting cavity sizes had Eulophidae cf. *Beornia* emerge from them (Table 1). Eulophidae cf. *Beornia* emerged from all sites in which bee hotels were deployed, except from within one plot where only a single Hymenopteran-occupied cavity occurred. Eulophidae cf. *Beornia* individuals that emerged during this study are 1 mm in length (Figure 2).

3.3 | Physical Evidence of Parasitoid Wasp Presence

Examination of cavities where Eulophidae cf. *Beornia* emerged revealed emergence holes at the sealed off cavity entrances and

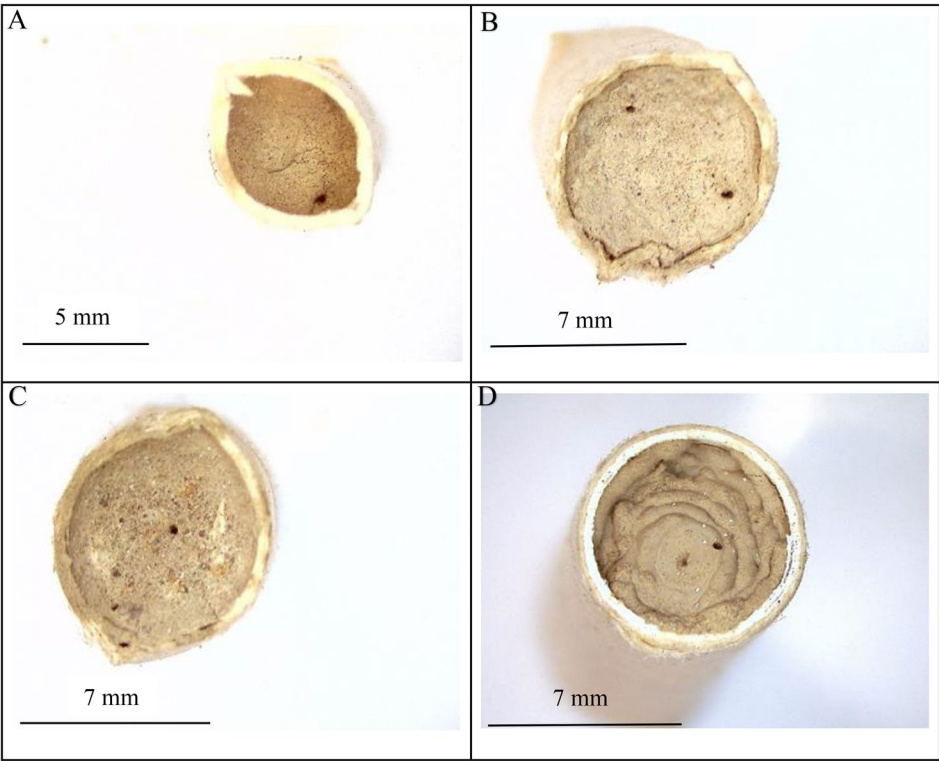


FIGURE 3 | Cavities parasitised by *Eulophidae* cf. *Beornia* exhibited small emergence holes within the front (A, B, C) and rear cavity coverings (D). These holes were observed in bee hotel cavities with a diameter of 5 mm and 7 mm.

exits (Figure 3). The holes, while visible to the naked eye, are small, approximately 0.5 mm in diameter.

4 | Discussion

It can be difficult to observe the emergence of invertebrates from bee hotels, particularly for an insect as small as Eulophidae cf. *Beornia* (Bouček 1988). Emergence holes left behind by microwasps provide an opportunity to detect parasitoid presence without the need for persistent observation or destructive research methods. However, holes may occur in nest caps for other reasons, such as from age, general weathering, or unfinished nest caps. While consistent evidence of small holes can be used as an early indicator of microwasp parasitoid presence, it is important to consider these factors when adopting this method.

Estimations on parasitoid populations can also provide information on the abundance and extent of their hosts (Hudson et al. 2006). Parasitoids are dependent on the presence of their hosts, with parasitoid abundances tied to the impacts on their hosts from changes in the landscape (Klaus et al. 2024; Grass et al. 2018). For example, Eulophidae cf. *Beornia* was not detected from one site, most likely due to the overall lack of cavity uptake by primary nesting Hymenopterans. This host dependency means a failure to detect evidence of parasitoid microwasps may indicate a loss of their host from the environment. Identifying the specific hosts of Eulophidae cf. *Beornia* will allow us to determine what primary nesting cavity species are present when microwasp emergence holes are detected.

Eulophidae cf. *Beornia* was detected parasitising *Pison* and *Anterhynchium* nesting cavities. Eulophidae has been found acting as parasitoids on nesting cavities in bee hotels; however, the discovery of Eulophidae emerging alongside a live primary occupant is a novel occurrence (Lotfalizadeh et al. 2025; Nascimento and Garófalo 2014; Vicens et al. 2022; Torretta and Marrero 2019; Lankford et al. 2025; Drapeau Picard et al. 2024). While hosts associated with bee hotels have been identified in other countries, further research into hosts in Australia is still required to establish connections between parasitoid emergence hole detection and hosts (Lotfalizadeh et al. 2025; Nascimento and Garófalo 2014).

Parasitism occurs throughout bee hotel studies, with the highly aggregated structure of bee hotels identified as particularly attractive to parasitoids and other parasites (MacIvor and Packer 2015; Prendergast 2023; MacIvor and Salehi 2014; Henry et al. 2023; Drapeau Picard et al. 2024; Rosenheim 1990). Choice of construction materials can also influence Eulophidae occupation, with paper cavities more attractive compared to bamboo or reeds (Lankford et al. 2025). Bee hotels that facilitate parasitism beyond natural levels risk turning these structures from a population source to a sink. This can exacerbate any negative impacts already affecting cavity nesting populations.

Adaptive management is required when deploying bee hotels, with consistent observations required to determine that bee hotels are supporting local populations and biodiversity. Bee hotels that are mobile are useful for this purpose, as not

all locations may benefit from bee hotel deployment. As well as this, different materials used to construct bee hotels may cause different results, meaning that it is up to practitioners to trial which materials and locations are best. However, it is important to remember that parasitoids are a natural and important part of an ecosystem, and a failure to detect them may indicate a greater loss of both parasitoids and their hosts from the environment.

Author Contributions

Caragh Threlfall: writing – review and editing. **Ian Oliver:** writing – review and editing. **Elise Oakman:** conceptualization, investigation, funding acquisition, writing – original draft, methodology, writing – review and editing. **Dieter F. Hochuli:** writing – review and editing, conceptualization. **Tanya Latty:** writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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