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Development of a Modular 3D-Printed Pollen Trap for Bumble Bee Monitoring

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ABSTRACT

Accurate pollen collection is essential for understanding bumble bee foraging dynamics, assessing environmental risks and monitoring colony health. Effective monitoring systems provide critical insights into pesticide exposure, floral resource availability and pollinator health. This study compares the efficiency of two pollen trap designs, the newly developed JKI trap and the USDA 3D-printed trap, in collecting pollen from *Bombus terrestris* colonies. Field tests using traps with two entrance diameters (6.5 and 7.2 mm) showed that the JKI trap collected significantly more pollen than the USDA trap, with the statistical model predicting approximately 24 times higher yields ($p < 0.001$); no significant effect of entrance diameter on pollen yield was observed. The JKI trap's effective performance, coupled with its design flexibility and potential for adaptation across different *Bombus* species and pollinators, makes it a valuable tool for long-term ecological monitoring, floral resource assessments, and pesticide risk studies.

1 | Introduction

Bumble bees (*Bombus* spp.) are vital pollinators in both natural ecosystems and agricultural landscapes, playing a critical role in biodiversity conservation and crop production (Goulson et al. 2015). However, pollinators face numerous challenges, including habitat fragmentation, pesticide exposure and climate change (Potts et al. 2010; Blacquière et al. 2012). Assessing pollen foraging patterns and resource availability is essential for understanding colony health and mitigating risks to pollinator populations (Vaudo et al. 2020). In addition to yield, the botanical diversity of collected pollen provides critical insights into plant–pollinator interactions, habitat quality and nutritional resources (Dimou et al. 2006; Gehrig 2019).

Traditional pollen collection methods, such as direct sampling from returning foragers, are often invasive and time-consuming, introducing bias and potential colony disturbance (Judd et al. 2020). Automated pollen traps offer an effective alternative, enabling passive and standardised pollen collection (Dimou et al. 2006). However, behavioural differences between bee species may strongly influence trap performance. While honey bee (*Apis mellifera*) foragers typically return to the hive headfirst with compact corbicular loads that can be easily dislodged, *Bombus* workers often exhibit more variable entry behaviours, including lateral or backward approaches, particularly in confined entrances (Judd et al. 2020). Furthermore, bumble bees carry looser pollen pellets and show high interindividual variability in floral choices and pollen composition (Leonhardt and Blüthgen 2012), which may impact both collection efficiency and pollen diversity in samples.

While several pollen trap designs have been developed for both honey bees and bumble bees, their efficiency often varies across pollinator taxa due to such morphological and behavioural differences (Dimou et al. 2006; Judd et al. 2020; Kiljanek 2024).

The USDA 3D-printed pollen trap, for instance, has been applied in a few monitoring studies but may be suboptimal for larger *Bombus* species or solitary bees, highlighting the need for species-specific trap optimisation (Judd et al. 2020). The modular JKI design with a removable funnel insert was therefore tailored specifically to accommodate *Bombus terrestris* foraging behaviour and morphology.

To address these species-specific challenges, the development of non-lethal, flexible pollen trap designs aligns with recent advancements aimed at reducing stress on pollinators during field studies (Kiljanek 2024). Studies have demonstrated that 3D-printed traps can reliably dislodge corbicular pollen while minimising worker disturbance, but variations in pollen yield often reflect differences in design efficiency and species-specific requirements (Dimou et al. 2006; Kiljanek 2024). Beyond yield, analysing the botanical composition of collected pollen is crucial for ecological studies, as it helps assess floral resource diversity, monitor shifts in foraging preferences and detect possible exposure to environmental stressors (Vaudo et al. 2020; Gehrig 2019).

The present study evaluates the efficiency of the newly designed JKI pollen trap against the USDA trap in semi-controlled field settings. By addressing differences in design efficiency, this work not only aims to enhance pollen yield but also contributes to optimising pollen traps for use across various *Bombus* species and potentially other pollinators. Additionally, the findings inform future applications in floral diversity assessments, pesticide exposure studies and broader ecological monitoring efforts (Gehrig 2019).

2 | Material and Methods

2.1 | Trap Design

The JKI pollen trap is a modular, 3D-printed device developed for passive and non-lethal collection of corbicular pollen from *B. terrestris* workers. It is specifically designed to interface seamlessly with commercial hives from Biobest (Biobest Deutschland GmbH, Kissing, Germany) and can be custom-adapted to fit other hive systems through minor modifications of the mounting interface (Figure S1–S5).

At its core, the trap features a replaceable funnel-shaped pass-through insert that regulates ingress and egress through the hive entrance (Figure 1A). As bees walk through this fixed internal structure, the geometry and constriction points gently dislodge corbicular pollen loads from their hind legs without injuring the bees. Unlike the USDA 3D-printed trap described by Judd et al. (2020), which employs a vertical filter panel with three circular entrance holes and external dislodging ridges that bees must squeeze past when entering the colony, the JKI trap guides the forager through a pre-formed tunnel system with smoother contact points designed to remove pollen via natural walking movement rather than compression. This approach minimises resistance and allows natural bidirectional traffic.

Following prototype testing, a single funnel variant was selected for its reliable performance across variable worker sizes. The trap is attached to the hive using two PLA (polylactic acid) or aluminium hooks (Figure 1B), offering secure but easily removable installation without disturbing the colony. Dislodged pollen falls into a covered tray positioned beneath the entrance insert. This collection tray is magnetically held in place, though elastic bands may also be used in field settings.

All components were printed using polylactic acid (PLA; BASF Ultrafuse PLA), a biodegradable polymer commonly used for 3D printing. Although PLA has limited resistance to UV radiation and high humidity, previous tests conducted with this material in outdoor conditions over the course of 1 year did not reveal signs of mechanical degradation. In our study, the traps were deployed in protected areas (e.g., shaded nest entrances under rain covers), further reducing environmental exposure. For extended use under harsh outdoor conditions, more durable materials such as polyethylene (PE) may be considered. Detailed images of the trap are provided as Figure S1–S5.

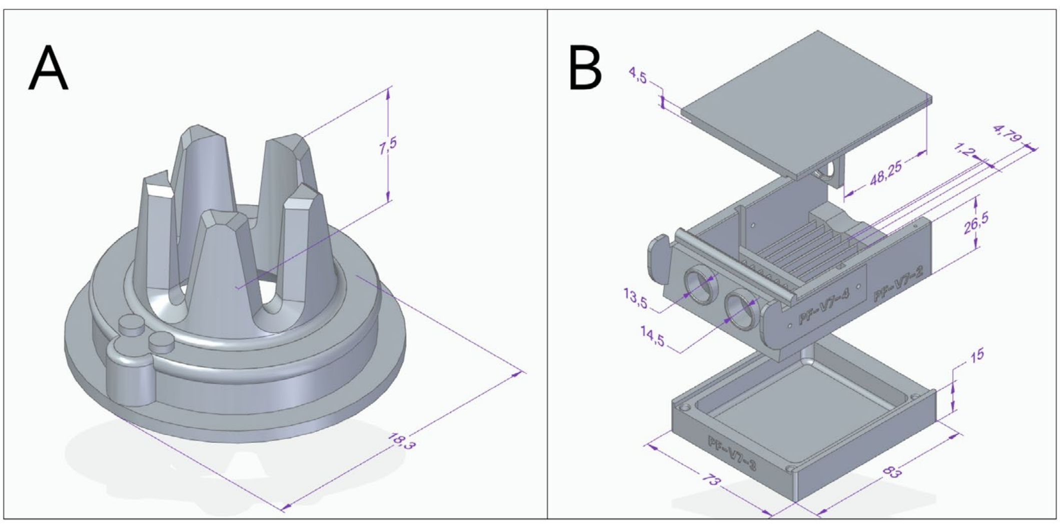

FIGURE 1 | (A) CAD rendering of the funnel-shaped pass-through insert used for pollen removal. (B) Exploded view of the trap components, including the entrance module, collection tray, lid and attachment hooks. [Colour figure can be viewed at wileyonlinelibrary.com]

2.2 | Experimental Design

Preliminary trap design tests and method optimisations were conducted from May to August 2024. The formal field trials were conducted over approximately 8 weeks, from 3 September to 25 October 2024, within the city of Braunschweig (Germany), adjacent to the Julius Kühn-Institut's experimental field area (~8.5 ha), which provided diverse floral resources including test crops, wildflowers and hedgerows. Additional forage was available from a nearby graveyard and residential backyards, offering a heterogeneous urban foraging environment for bumble bees. Five colonies of *B. terrestris* were housed in commercially available Biobest plastic hives enclosed in cardboard hulls. For weather protection, each unit was placed inside a standardised wooden hive typically used for honey bees (Hohenheimer Einfachbeute). The colonies were arranged equidistantly to minimise location bias. *B. terrestris* was selected due to its ecological relevance, widespread agricultural use as a generalist forager in Europe, and its established role as a model organism in pollinator research. Future trials are planned to assess the JKI trap's performance across other *Bombus* species and solitary pollinators.

Each hive was fitted with either a JKI or USDA pollen trap at the entrance, and traps were rotated weekly to mitigate colony-specific effects and minimise potential biases arising from individual colony foraging behaviour. Two entrance diameters—6.5 and 7.2 mm—were tested to evaluate their influence on pollen yield. Each week, both trap types and entrance diameters were systematically rotated across the five colonies, ensuring that each combination (trap type × entrance diameter) was equally represented throughout the study period (exact combinations per colony and week are documented in the raw dataset: DOI 10.17605/OSF.IO/JXBHK).

The JKI trap design featured modular, interchangeable funnel-shaped pass-through inserts. Several geometries were prototyped, and the final configuration—a compact insert with an outer diameter of 18.3 mm, entrance diameters of 6.5 or 7.2 mm and internal dislodging arms of 7.5 mm height—was selected for its consistent performance across the natural size range of *Bombus* workers (see Figure 1A).

Behavioural observations were conducted at each hive entrance between 10:00 and 14:00 CEST, a time window that includes the typical peak of *B. terrestris* pollen foraging activity under favourable weather conditions (Leonhardt and Blüthgen 2012). Each colony was observed for 10 min per session, and only under suitable foraging conditions (i.e., no rain, dry weather and ambient temperatures ≥ 15°C). Disturbance indicators, such as hesitations at the entrance or changes in foraging rates, were recorded but found to be minimal across all tested colonies. Additionally, colony development was monitored by recording weekly weight gain for each hive. These data were included in the statistical model as a fixed effect (`colony_weight_g`) and are available in the publicly shared raw dataset (see DOI: 10.17605/OSF.IO/JXBHK).

2.3 | Pollen Collection

Pollen samples were collected daily from each colony over the 8-week trial period. After each collection, fresh pollen weight was determined immediately. These daily yield values were used directly for statistical analyses without pooling across days. To prevent moisture loss, pollen samples were handled quickly and stored at −20°C. The archived samples are available for potential future palynological or residue analyses, which were not part of the present study.

2.4 | Statistical Analysis

Pollen yield data (g per daily sampling interval) were analysed using a Tweedie Generalised Linear Mixed Model (GLMM) with a log link to account for the right-skewed distribution and potential zero-inflation of pollen weights. The full model formula was as follows:

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pollen _ weight _ g~trap _ type* trap _ diameter
+colony _ weight _ g+sampling _ no+(1|week)
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Fixed effects included trap type, entrance diameter, interpolated colony weight and sampling number, while sampling week was modelled as a random intercept to capture temporal variability. Each observation represented pollen yield collected over a 1-day sampling interval.

Model diagnostics included simulation-based residual plots and checks for overdispersion to confirm model adequacy. The explanatory power of the model was assessed using marginal (fixed effects only) and conditional (fixed and random effects) R^2 values.

All analyses were conducted using R v4.4.0 (R Core Team 2024), with significance thresholds set at $\alpha = 0.05$. Post hoc comparisons evaluated pairwise differences in pollen yield across trap types and entrance diameters. Additional methodological details, including model comparisons, interpolation procedures and diagnostics, are available in Supplementary Method S1.

Environmental variables such as temperature and humidity were not included as covariates in the statistical analysis. This decision was based on the study design, which systematically rotated trap types across colonies and timepoints, ensuring that each trap was exposed to a representative and balanced range of field conditions. Our focus was on comparing relative trap performance under realistic, variable field conditions rather than attributing yield variability to specific weather parameters.

3 | Results

3.1 | Pollen Collection Efficiency

The JKI trap demonstrated significantly higher pollen collection efficiency than the USDA trap. Across all colonies and sampling weeks, the JKI trap yielded on average 15 times more pollen than the USDA trap (mean weekly yield: 1.18 vs. 0.08 g, respectively, Figure 2). This empirical trend was supported by statistical modelling: a Tweedie Generalised Linear Mixed Model predicted that the JKI trap collected approximately 24

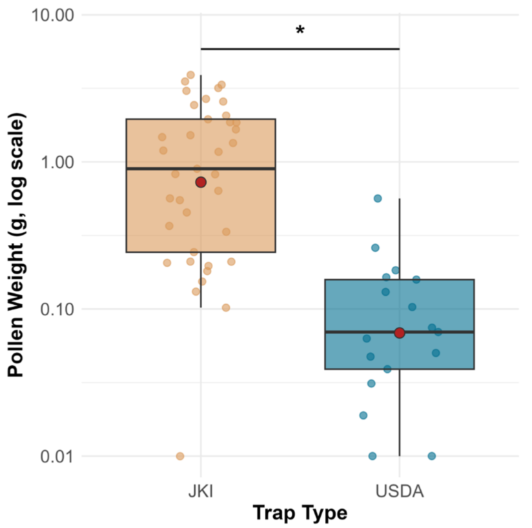

FIGURE 2 | Pollen collection efficiency of JKI and USDA pollen traps across all sampling events (log10 scale). Each point represents a single pollen collection event; boxplots show the distribution of fresh pollen weight per trap type. Red dots indicate the arithmetic mean per group. The JKI trap consistently yielded significantly more pollen than the USDA trap ($p < 0.001$, Tweedie GLMM). The y-axis is displayed on a logarithmic scale to accommodate the strong right skew in pollen yield. An asterisk indicates statistical significance between trap types. [Colour figure can be viewed at wileyonlinelibrary.com]

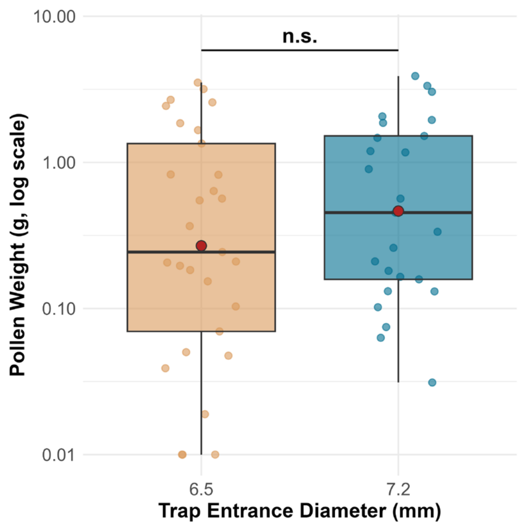

FIGURE 3 | Pollen collection by trap entrance diameter (6.5 vs. 7.2 mm) shown on a logarithmic scale. Each point represents a single pollen collection event; boxplots summarise the distribution of fresh pollen weight per entrance diameter. Red dots indicate the arithmetic mean per group. No significant difference was observed between the two diameters ($p = 0.54$, Tweedie GLMM). The y-axis is log10-transformed to account for data skewness. 'n.s.' indicates the absence of a statistically significant effect. [Colour figure can be viewed at wileyonlinelibrary.com]

times more pollen than the USDA design ($p < 0.001$). These consistent results highlight the robustness of the JKI trap under variable field conditions and its potential to improve the precision of pollen-based ecological monitoring and pollinator health assessments.

3.2 | Effect of Entrance Diameter

No statistically significant differences in pollen yield were observed between the 6.5 and 7.2 mm entrance diameters ($p = 0.54$, Figure 3). This finding suggests that entrance size does not substantially affect pollen collection, providing design flexibility and adaptability based on practical considerations, such as worker size variation within colonies or across different *Bombus* species. The absence of an entrance diameter effect also implies that optimising trap design beyond entrance size may be more critical for maximising efficiency.

3.3 | Statistical Model Summary

The Generalised Linear Mixed Model (GLMM) identified trap type as the most significant predictor of pollen collection efficiency, with marginal $R^2 = 0.724$ and conditional $R^2 = 0.765$, indicating that a large proportion of the variance in pollen yield can be explained by trap design. Entrance diameter and environmental variables, including temperature and humidity, had minimal influence on overall pollen yield, suggesting that the primary differences in collection efficiency stem from trap design rather than external factors.

4 | Discussion

The significantly higher performance of the JKI pollen trap—predicted to yield over 24 times more pollen than the USDA design—underscores the importance of species-specific, behaviourally aligned trap architecture. The USDA trap (Judd et al. 2020) uses a vertical filter panel with fixed-diameter entry holes and externally mounted ridges that forcibly scrape off pollen as bees enter through the passage. In contrast, the JKI design features a funnel-shaped insert that facilitates gentle pollen removal through a guided walking motion. This likely improves both pollen yield and forager acceptance. By accommodating worker size variation, the trap offers a standardised yet adaptable tool, consistent with earlier findings on the need for flexible monitoring designs in heterogeneous bee populations (Dimou et al. 2006). However, potential limitations such as forager disturbance, incomplete pollen removal or behavioural changes should be assessed. Future refinements may focus on optimising funnel geometry or material choice to further improve performance.

Previous applications of the USDA trap provide important context for interpreting our findings. While our results demonstrated that the JKI trap substantially outperformed the USDA design, it should be noted that the USDA pollen trap was originally developed for *B. huntii* (Judd et al. 2020), a species differing considerably in size and morphology from *B. terrestris*. Despite these differences, Kiljanek (2024) successfully applied a modified USDA trap with a 6.25 mm entrance diameter to *B. terrestris* colonies, achieving daily pollen yields ranging from 0.036 to 5.83 g under high floral resource conditions. These yields are comparable to those observed in our study for the USDA trap, confirming its basic applicability to *B. terrestris* under favourable circumstances. However, both studies highlight substantial variability and generally modest pollen yields with the USDA trap. In contrast, the newly developed JKI trap consistently achieved significantly higher pollen yields across a heterogeneous urban landscape, emphasising the importance of species-specific trap design optimisation for reliable ecological monitoring.

The substantial difference in average pollen yield between the JKI and USDA traps cannot be attributed to entrance diameter alone, as this parameter showed no significant effect in our trials. Instead, we propose that the internal architecture of the trap insert is the key determinant. The USDA trap (Judd et al. 2020) employs a fixed plastic barrier with four dislodging ridges positioned along the passage through which foragers must enter the hive. In contrast, the JKI trap features a funnel-shaped pass-through insert equipped with elongated, slightly curved dislodging arms (see Figure 1A). These arms extend beyond the inner rim of the funnel, guiding pollen-laden hind legs through a narrowing channel. As the corbicular pollen becomes fixated along the arm surface, the only available movement is for the bee to pull its leg through the constriction, thereby dislodging the pollen (see Figure S3). This mechanical dislodging mechanism appears to function more effectively across a broader range of worker sizes and may explain the consistently higher yields achieved with the JKI design.

Despite natural fluctuations in weather conditions during the study period, we did not include temperature, humidity or precipitation as covariates in the analysis. Since trap types and entrance diameters were systematically rotated across colonies and timepoints, each design experienced a balanced range of field conditions. Therefore, the substantial difference in pollen yield is unlikely to be attributable to environmental variables but rather reflects inherent trap performance under realistic foraging conditions.

Recent studies indicate that efficient pollen traps not only improve pollen yield but also enhance the accuracy of floral resource mapping, which is essential for understanding habitat quality (Gehrig 2019). Pollen analysis provides insights into plant-pollinator interactions and identifies key forage plants, particularly in degraded landscapes where floral resource scarcity affects pollinator health (Kiljanek 2024). Integrating pollen composition analysis with yield measurements would further increase the ecological value of the JKI trap, offering a more comprehensive view of pollinator diets and floral resource availability. Molecular or microscopic identification methods could be applied to future samples to track changes in foraging preferences over time or in response to environmental stressors.

Moreover, the adaptability of the JKI trap offers significant advantages in pesticide exposure studies, which rely on accurate pollen sampling to assess pollinator risk (Kiljanek 2024). The increased pollen yield enhances the reliability of detecting pesticide residues and evaluating sublethal effects on colony development (Hester et al. 2023; Strange et al. 2023). Future studies should combine pollen yield and residue analyses to assess not only how much pollen is collected but also its contamination levels. This approach could identify critical periods of pesticide exposure and inform better risk management strategies.

The lack of a significant effect from entrance diameter contrasts with findings in honey bee studies, where entrance size often influences pollen capture (Dimou et al. 2006). This difference may be attributed to morphological and behavioural differences between bumble bees and honey bees, such as foraging patterns or corbicular pollen attachment. Testing the JKI trap across other *Bombus* species and solitary bees is necessary to determine whether this effect generalises to diverse species or is specific to *B. terrestris*. Comparative trials with species like *B. pascuorum*, *B. lapidarius* or solitary bees would help determine the JKI trap's broader suitability and guide species-specific adaptations if needed.

Future studies should expand the scope of the JKI trap's application by validating its performance across different *Bombus* species and in diverse environmental settings, such as agricultural landscapes, urban environments and natural reserves. Additionally, integrating pesticide residue quantification and pollen composition analysis will allow for comprehensive monitoring of pollinator health and habitat quality. Cross-species validation and long-term monitoring will help establish the JKI trap as a key tool in both applied ecological research and pollinator risk assessments.

In summary, the JKI pollen trap demonstrated higher pollen collection efficiency compared to the USDA trap, making it a valuable tool for monitoring *B. terrestris* foraging dynamics and nutritional ecology. Its lack of sensitivity to entrance diameter enhances its design flexibility, while its adaptability across various conditions suggests broad applicability. By addressing potential limitations, validating its performance across additional species and integrating pollen diversity and pesticide residue analyses, future research can unlock its full potential in ecological monitoring and risk assessment. By addressing challenges observed in earlier USDA-based designs, the JKI trap offers a robust and scalable solution with strong potential for standardised pollen collection across different bumble bee species and environments.

Author Contributions

Richard Odemer: conceptualisation, methodology, supervision, software, formal analysis, data curation, visualisation, writing – original draft, writing – review editing, project administration, funding acquisition. **Marie Geiger:** investigation, writing – review editing. **Lars Geiger:** methodology, investigation, writing – review editing.

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Disclosure

During the preparation of this work, the authors used DeepL Write and ChatGPT to improve the structure, phrasing and clarity of selected text passages originally written by the authors themselves. These tools were employed to enhance language quality and manuscript organisation. Following their use, the authors carefully reviewed and edited all content to ensure accuracy, scientific integrity and consistency with the intended meaning. The authors take full responsibility for the content of the publication.

Ethics Statement

All applicable international, national and/or institutional guidelines for the careful handling and use of animals were followed. In the context of the article, none of the authors conducted studies with human subjects.

Conflicts of Interest

Lars Geiger is affiliated with GELALOG GmbH. GELALOG GmbH holds the commercial rights to the trap, including the STL files for 3D printing, and intends to market it commercially. However, his involvement did not influence the study design, data collection, analysis or interpretation. All other authors declare no competing financial or personal interests that could have influenced the work reported in this paper.

Data Availability Statement

The data that support the findings of this study are openly available in Open Science Framework at https://doi.org/10.17605/OSF.IO/JXBHK.

References

Blacquière, T., G. Smagghe, C. A. M. van Gestel, and V. Mommaerts. 2012. "Neonicotinoids in Bees: A Review on Concentrations, Side-Effects, and Risk Assessment." *Ecotoxicology* 21, no. 4: 973–992. https://doi.org/10.1007/s10646-012-0863-x.

Dimou, M., A. Thrasyvoulou, and V. Tsirakoglou. 2006. "Efficient Use of Pollen Traps to Determine the Pollen Flora Used by Honey Bees." *Journal of Apicultural Research* 45, no. 1: 42–46. https://doi.org/10.1080/00218839.2006.11101312.

Gehrig, R. 2019. "Representativeness of Pollen Traps: A Review of the National Pollen Network of Switzerland." *Aerobiologia* 35: 577–581. https://doi.org/10.1007/s10453-019-09593-z.

Goulson, D., E. Nicholls, C. Botías, and E. L. Rotheray. 2015. "Bee Declines Driven by Combined Stress From Parasites, Pesticides, and Lack of Flowers." *Science* 347, no. 6229: 1255957. https://doi.org/10.1126/science.1255957.

Hester, K. P., K. A. Stoner, and B. D. Eitzer. 2023. "Pesticide Residues in Honey Bee Pollen Collected in Two Ornamental Plant Nurseries: Implications for Bee Health and Risk Assessment." *Environmental Pollution* 333: 122037. https://doi.org/10.1016/j.envpol.2023.122037.

Judd, H. J., C. Huntzinger, R. Ramirez, and J. P. Strange. 2020. "A 3D Printed Pollen Trap for Bumble Bee (Bombus) Hive Entrances." *Journal of Visualized Experiments* 161: 61500. https://doi.org/10.3791/61500.

Kiljanek, T. 2024. "Application of 3D-Printed Pollen Traps as a Useful Tool for Exposure and Risk Assessment of Pesticide Residues on Bumblebees." *Chemosphere* 348: 140748. https://doi.org/10.1016/j.chemosphere.2023.140748.

Leonhardt, S. D., and N. Blüthgen. 2012. "The Same, but Different: Pollen Foraging in Honeybee and Bumblebee Colonies." *Apidologie* 43, no. 4: 449–464. https://doi.org/10.1007/s13592-011-0112-y.

Potts, S. G., J. C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger, and W. E. Kunin. 2010. "Global Pollinator Declines: Trends, Impacts, and Drivers." *Trends in Ecology & Evolution* 25, no. 6: 345–353. https://doi.org/10.1016/j.tree.2010.01.007.

R Core Team. 2024. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing.

Strange, J. P., S. R. Colla, L. D. Adams, et al. 2023. "An Evidence-Based Rationale for a North American Commercial Bumble Bee Clean Stock Certification Program." *Journal of Pollination Ecology* 33: 1–13. https://doi.org/10.26786/1920-7603(2023)721.

Vaudo, A. D., D. Stabler, H. M. Patch, J. F. Tooker, and C. M. Grozinger. 2020. "Bumble Bees Regulate Their Intake of Essential Protein and Lipid Pollen Macronutrients." *Proceedings of the Royal Society B: Biological Sciences* 287: 20200980. https://doi.org/10.1242/jeb.140772.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1.** Visual summary of model coefficients. **Figures S1–S5.** JKI pollen trap in the field. **Figure S1.** JKI pollen trap mounted on a Biobest bumble bee hive, featuring a transparent lid for visual inspection. **Figure S2.** Close-up view of the three inserts beneath the transparent lid, showing bidirectional bumble bee traffic. **Figure S3.** As bumble bees pass through the inserts, corbicular pollen is stripped from their hind legs. **Figure S4.** Corbicular pollen collected approximately 2 h after trap deployment during favourable foraging conditions in May 2024. **Figure S5.** Corbicular pollen collected approximately 24 h after trap deployment during favourable foraging conditions in May 2024.