Use of Social Bees and Solitary Bees As Bioindicators of Environmental Contamination

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Abstract

With an emphasis on the biology of bee nesting, their ecological functions, and their efficacy in determining heavy metal pollution, this review paper summarises current research on bees as bioindicators of environmental contamination. Review brought attention to the solitary nesting behaviours of species such as Epanthidium tigrinum and Megachile cephalotes, highlighting their preference for particular materials for their nests as well as their function as pollinators. It was investigated how resin serves many purposes in defense, disease resistance, and nest building, highlighting its ecological value. One paper talked about the abilities of wasps and bees, demonstrating how they interact with one another inside the nests and how sensitive they are to changes in their surroundings. Honeybees have been found to be useful bioindicators for pesticides and heavy metals because they incorporate toxins from the air, soil, and water into their products. Additionally, bee pollen has shown to be a trustworthy marker of pesticide residues, indicating the degree of local pollution. Furthermore, research examining the levels of heavy metals in bee products across different areas highlighted the potential of honey to serve as a biomonitor for pollution in the environment. One of the reviewed studies specifically measured heavy metal concentrations in pollen and Osmia bicornis L. bees across different habitats, demonstrating how variations in habitat proximity to pollution sources affect contamination levels, thereby underscoring the utility of solitary bees as effective bioindicators. The precise methods for assembling trap nests and gathering samples offered useful information for researching community dynamics and trophic relationships. Overall, this review summarises research showing that social bees and solitary bees are important for assessing the health of ecosystems and provide useful tools for environmental monitoring.

Keywords: Bee Bioindicators, Heavy metal contamination, Environmental Monitoring

1. Introduction

Because of their sensitivity to changes in their habitats and their involvement in pollination, which links them intimately to varied ecosystems, bees are important bioindicators in environmental studies (Skorbiłowicz et al., 2018). Because of their sensitivity, they serve as good environmental health indicators, demonstrating the effects of contaminants like pesticides and heavy metals (Conti and Botrè, 2001). Researchers can evaluate the quality of soil, water, and air in a variety of settings, from urban areas to natural habitats, by examining bees (Skorbiłowicz et al., 2018). This review paper covers new research on resin bees and cavity-nesting bees, emphasising their ecological importance, nesting biology, and potential use as bioindicators. The goals encompass consolidating research on the feeding

patterns, resin utilisation, nesting behaviours, and efficacy of these bees in observing environmental pollutants (Akram et al., 2022). Furthermore, by using trap nests and analysing bee products, the review hopes to shed light on methods for researching how bees react to environmental changes (MacIvor, 2017). Also, solitary bees, such as Osmia bicornis L., are found to be effective bioindicators of heavy metal pollution. This research measured heavy metal concentrations in pollen and bees across different habitats, illustrating how habitat proximity to pollution sources affects contamination levels. This underscores the utility of solitary bees in environmental monitoring (Zajdel et al., 2023). Because of their unique nesting habits and interactions with their habitats, resin bees and cavity-nesting bees are especially important in ecological studies and environmental monitoring (Akram et al., 2022). In addition to providing information about habitat quality and the effects of disturbances, they aid in pollination and ecosystem services (MacIvor, 2017). Sustainable land management techniques and conservation initiatives can benefit from an understanding of their behaviours and responses to environmental stressors (MacIvor, 2017). As a result, this analysis highlights how important it is for ecological research and environmental stewardship programmes to advance (Akram et al., 2022).

2. General Background on Resin Bees and Cavity-Nesting Bees

2.1 Nesting Biology and Ecology of Resin Bees

Study use trap nests to investigate the nesting habits of Megachile cephalotes and Epanthidium tigrinum has yielded important insights into these bees' solitary nesting habits, nest building materials, and feeding behaviours (Akram et al., 2022). Megachile cephalotes is a species of bee mostly found in Pakistan. Its solitary nesting habits are typified by the female bee building her own nests inside trap cavities. These carefully constructed nests demonstrate the species' versatility in nest building because they are made of mud and plant fibres, among other things (Akram et al., 2022). Certain nesting materials appear to be preferred by the bees, which could have an impact on the choice of nest site and the success of reproduction (Akram et al., 2022). All things considered, these investigations highlight the value of trap nests in clarifying the biology of solitary bee nesting, such as Megachile cephalotes and Epanthidium tigrinum. Our grasp of bee ecology and their contributions to ecosystem functioning is aided by their fundamental knowledge of nesting practices, nest construction materials, and feeding behaviours (Akram et al., 2022; Muniz et al., 2023).

2.2 Functional Roles of Resin in Bee Nests

Resin plays multifaceted roles in the ecology of cavity-nesting bees, significantly contributing to nest structure, defense mechanisms, and various other ecological functions. As a crucial building material, resin acts like natural cement for bees such as Megachile spp. and Osmia spp., who collect and manipulate it to reinforce cell partitions and outer layers of their nests. This enhances nest durability, protects developing larvae, and maintains stable environmental conditions. Additionally, resin functions as a defense mechanism against pathogens and parasites, with its antimicrobial properties inhibiting fungal growth, thereby preserving nest hygiene and reducing disease risks for larvae. Its sticky texture and chemical composition also deter predators, enhancing nest security. Beyond structural and defensive roles, resin aids in moisture regulation within nests, which is crucial for larval development, and may also contribute to chemical camouflage by masking nest odors to avoid detection by predators or parasites (Chui et al., 2021).

Despite the current understanding of resin's ecological functions, several knowledge gaps persist. Detailed studies are needed to elucidate the chemical composition of resins used by different bee species

and how variations impact nest structure and defense mechanisms. Research should explore the broader ecological impacts of resin use, such as its influence on microbial communities within nests and its role in shaping local biodiversity. Investigating how climate change affects resin availability and quality, and subsequently impacts bee populations reliant on resin for nesting, is crucial. Moreover, strategies for conserving resin-producing plant species and managing habitats to support resin-dependent bee populations require further exploration. Future research should integrate ecological, chemical, and conservation perspectives to comprehensively understand resin's roles in cavity-nesting bee ecology and inform effective conservation measures for these important pollinators (Chui et al., 2021).

2.3 Nesting Activity in Different Habitats

Research contrasting the nesting habits of cavity-nesting pollinators in agricultural and natural environments reveals clear variations impacted by habitat features and human activity. In agricultural landscapes, intensive land use practices frequently result in habitat fragmentation and a reduction in the number of bee and wasp nesting sites that are suitable. As a result, compared to natural settings, where a wider variety of nesting options are fostered by diverse flora and structural complexity, nesting densities and diversity are lower. Many kinds of dead wood, stems, and dirt are common nesting substrates found in natural ecosystems, which support a wide variety of cavity-nesting bee and wasp species. As a result of the abundance of nesting materials and the decreased disturbance from agricultural activities, these settings enable increased nesting numbers and species richness. Contrarily, agricultural environments usually lack these kinds of naturally occurring nesting facilities, which restricts cavity-nesting pollinators' ability to reproduce and maintain a healthy population (Bihaly et al., 2020).

In order to overcome these restrictions for cavity-nesting pollinators in agricultural environments, supplemental nesting habitats are essential. The quality of habitat can be improved and nesting opportunities increased by conservation efforts by implementing artificial nesting structures such as trap nests, nest boxes, or bee hotels. Strategically placed inside agricultural regions, these supplemental habitats replicate natural nesting circumstances and serve to enhance the availability of nesting resources (Staab et al., 2018).

In agricultural landscapes, supplemental nesting habitats—like bee hotels, trap nests, or nest boxes—are essential because they help cavity-nesting pollinators overcome significant obstacles. First of all, these buildings offer vital nesting places, which are frequently hard to come by in heavily farmed regions with restricted access to natural nesting materials like dead wood or soil substrates. The provision of safe and adequate conditions for egg laying and offspring rearing greatly improves the reproductive success of animals that nest in cavities. Second, by drawing a wide variety of cavity-nesting wasps and bees, these habitats support the conservation of biodiversity in agricultural environments. Because diverse pollinator communities aid in nutrient cycling, pest management, and pollination, they are essential to the resilience of ecosystems.

Thirdly, more habitats improve pollination of wild and farmed plants by providing a home for cavity-nesting pollinator populations. These settings promote efficient pollination, which raises crop yields and quality and helps wild plant species that are vital to the health of ecosystems reproduce. Therefore, including more nesting places into agricultural landscapes is essential to reducing habitat loss and fragmentation brought on by intensification of agriculture. In the end, agricultural productivity and environmental stability benefit from these initiatives, which increase the resilience and diversification of pollinator groups (Staab et al., 2018).

3. Bioindicators and Bees

3.1 Trap Nests

Trap nests are pivotal tools in the study of trophic interactions and community dynamics involving cavity-nesting bees, wasps, and their natural enemies. These artificial structures mimic natural cavities, enabling researchers to observe and quantify interactions within these ecological communities. Through studies conducted using trap nests, several critical insights have emerged (Staab et al., 2018).

Firstly, trap nests capture the nesting behaviors of solitary bees and wasps, revealing their preferences for nesting materials, strategies for selecting nest sites, and how they partition nesting resources among different species. Secondly, these structures allow researchers to investigate parasitism and predation dynamics, as natural enemies like parasitic wasps and predatory insects utilize trap nests to access their hosts, thereby affecting the reproductive success and survival of cavity-nesting pollinators (Staab et al., 2018).

Moreover, trap nests facilitate assessments of community diversity and species richness within specific habitats, offering insights into how environmental factors influence community structure and species interactions over time. Natural enemies, such as parasitoids and predators, play a crucial role in shaping these communities within trap nests. They regulate population sizes of cavity-nesting species, influencing community stability and diversity. Additionally, these natural enemies exhibit sensitivity to environmental changes such as habitat disturbance, climate variations, and pesticide exposure, reflecting environmental conditions and ecosystem health within trap nests (Staab et al., 2018).

Changes in the abundance or behavior of natural enemies observed within trap nests can serve as early indicators of shifts in environmental quality and ecosystem disturbances. This highlights their role as bioindicators of ecosystem degradation or recovery. Overall, understanding the dynamics among cavity-nesting bees, wasps, and their natural enemies within trap nests provides valuable insights into ecological interactions and ecosystem functioning. It emphasizes the importance of conserving natural habitats and managing agricultural landscapes to support diverse pollinator communities and maintain ecosystem resilience (Staab et al., 2018).

3.2 Honeybees as Bioindicators of Environmental Pollution

Because of their distinctive foraging style and capacity to gather contaminants from their surroundings, honeybees (Apis mellifera) are acknowledged as useful bioindicators of environmental contamination (Celli & Maccagnani, 2003). They unintentionally accumulate pollutants found in urban and agricultural settings as they gather nectar, pollen, and water from diverse floral sources. Pollutants such as neonicotinoids and organophosphates, as well as heavy metals like lead, cadmium, and zinc, accumulate in the tissues of bees, which includes honey, beeswax, and pollen. Honeybee products are dependable indicators of environmental pollution levels since they contain these contaminants. Research conducted worldwide has indicated a noteworthy association between the levels of environmental pollution and the amounts of pesticides and heavy metals in honeybee samples (Conti & Botrè, 2001). To precisely measure these pollutants, methods such as mass spectrometry and atomic absorption spectroscopy are used.

Case studies highlight how useful honeybees are for keeping an eye on environmental contaminants. Studies carried out in metropolitan areas have revealed higher concentrations of heavy metals like cadmium and lead in honeybee products, which can be attributed to industrial pollution and vehicle emissions (Skorbiłowicz et al., 2018). Analogously, investigations conducted in agricultural environments identify pesticides such as pyrethroids and neonicotinoids in honeybee specimens,

signifying exposure to agricultural methods (Kılıç Altun et al., 2017). There are benefits to using honeybees as bioindicators for environmental monitoring. Honeybee colonies offer extensive and ongoing monitoring of contaminants, providing valuable information on patterns of pollution in terms of both space and time (Celli & Maccagnani, 2003). Furthermore, collecting samples of pollen, honey, and beeswax is an economical and non-invasive way to support long-term monitoring initiatives (Conti & Botrè, 2001).

Because they offer vital information for evaluating environmental health, influencing legislation, and directing conservation activities meant to lessen pollution exposure for humans and ecosystems, honeybees are invaluable as sentinel species in environmental studies. To fully comprehend the ecological significance of honeybees in environmental health evaluations and to improve monitoring methods, more study is necessary (Celli & Maccagnani, 2003).

3.3 Bee Pollen as a Bioindicator

A useful method for identifying pesticide residues and other environmental pollutants is bee pollen. Pollen is a useful biomonitoring method for determining the levels of environmental pollution since bees unintentionally capture a variety of contaminants from blooming plants that are present in their foraging locations. Bee pollen is a common source of pesticide accumulation, including herbicides like glyphosate and insecticides like neonicotinoids and organophosphates (Oliveira et al., 2016). These substances, which are frequently employed in agricultural settings, have a long environmental half-life and can negatively impact pollinator health. Furthermore, heavy metals from industrial processes, car emissions, and contaminated soil can accumulate in bee pollen, including lead, cadmium, and arsenic (Oliveira et al., 2016).

Numerous studies demonstrate how well pollen works as a pollution indicator in the environment. To identify and measure pollutants in bee pollen samples, research procedures use sophisticated analytical techniques including liquid chromatography-mass spectrometry (LC-MS) and gas chromatography-mass spectrometry (GC-MS). The quantities of heavy metals and pesticide residues can be precisely measured using these techniques. Through the use of pollen to reveal geographic variations in pesticide usage and pollution levels, case studies have shown the use of pollen in environmental monitoring and provided insights into the environmental health of different regions. Pesticide residue variations are monitored over time by longitudinal studies, which take into account changes in agricultural practices and the effects of regulations. Furthermore, origins and patterns of contamination are identified through comparative examination of pollen samples from various land uses, such as agricultural versus urban regions (Oliveira et al., 2016).

Bee pollen informs scientists and policymakers about possible threats to pollinators and ecosystems, acting as an early warning system for chemical contamination. It makes it possible to evaluate environmental health and biodiversity implications on a larger scale than just honeybee colonies. To improve methods and comprehend the wider ecological effects of pesticide usage on pollinator populations and biodiversity, more research and monitoring are necessary. In order to support efforts to reduce hazards to pollinators and the health of ecosystems, bee pollen is a powerful biomonitoring tool for identifying pesticide residues and other contaminants in the environment (Oliveira et al., 2016).

3.4 Cavity-Nesting Bees and The Pollen Collected By Those Bees as a Bioindicator

In the Łowicz district in central Poland, pollen and bees (Osmia bicornis L.) from a variety of habitats were found to contain heavy metal contamination at varying levels. The study examined zinc, lead, and cadmium concentrations in urban, orchard, and berry plantation environments. The results showed that

metropolitan areas had far greater amounts of these heavy metals than berry plantations and orchards. The most polluted surroundings were found in urban areas, possibly as a result of emissions from vehicles and industries. On the other hand, berry plantations and orchards had comparatively lower pollution levels, indicating a less significant influence from human activity. In order to reduce ecological risks, the study emphasises the distinct effects of habitat types on the accumulation of heavy metals in pollinators and their foraging resources. It also emphasises the significance of habitat management and environmental monitoring (Zajde et al., 2023).

4. Heavy Metal Contamination and Analysis

4.1 Heavy Metal Pollution in Bees and Bee Products

Pollution by heavy metals in bees and their byproducts, such as pollen, honey, and wax, is a major marker of environmental contamination in many geographical areas. These materials, which are formed from bees, acquire heavy metals from a variety of sources in their surroundings, reflecting levels of local pollution and perhaps endangering ecosystems as well as human health (Conti & Botrè, 2001).

Bees mostly gather heavy metals from their foraging, and the amount they collect varies according to how close they are to sources of pollution like mines, factories, and cities. Honey serves as a storehouse for heavy metals that are taken up from nectar and water sources, providing information on local contamination trends and the hazards associated with human exposure. Significant amounts of heavy metals, such as lead, cadmium, and zinc, which are derived from soil, air deposition, and agricultural practices, are also present in pollen that bees gather. Conversely, beeswax acts as a long-term environmental exposure indicator by accumulating persistent pollutants such as insecticides and lipophilic toxins in addition to heavy metals (Conti & Botrè, 2001). Quantifying these heavy metal concentrations in bee products requires the use of analytical techniques such as Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), and Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). These methods offer accurate readings and make it easier to identify trace metals in complex matrices like honey, pollen, and wax (Kılıç Altun et al., 2017). Studies conducted on other continents have demonstrated regional differences in the quantities of heavy metal pollution in bee products. In comparison to rural settings, studies carried out in urban areas frequently show higher quantities of metals like lead and cadmium in bees and honey. To gain more insight into the specific effects of pollution on pollinators and agricultural ecosystems, localised evaluations investigate metal concentrations in connection to certain industrial or agricultural activities (Bayir & Aygun, 2022). Environmental monitoring and risk assessment depend heavily on the reliable analytical techniques used to analyse the quantities of heavy metals in bee products. Through the comprehension of local sources of pollution, these techniques aid in shaping policy decisions that protect pollinator health and the integrity of the environment. In order to mitigate the dangers associated with environmental contamination and improve our understanding of the dynamics of heavy metals in bee products, it is imperative that standardised procedures be employed in conjunction with continuous monitoring (Bayir & Aygun, 2022).

4.2 Honey as a Bioindicator for Heavy Metals

In order to determine the levels of environmental pollution and how they affect the quality of honey, the assessment of heavy metal contamination in honey samples has been thoroughly examined. Metals like lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), copper (Cu), and zinc (Zn) have been found and measured in honey using a variety of analytical techniques, including atomic absorption spectrometry

(AAS), inductively coupled plasma mass spectrometry (ICP-MS), and inductively coupled plasma optical emission spectrometry (ICP-OES). When determining trace metal concentrations, these techniques have a high degree of sensitivity and accuracy (Kılıç Altun et al., 2017).

For the purpose of evaluating the local environmental influences on metal contamination, honey samples are gathered from a variety of geographical regions, including urban, rural, and industrial areas. Research continuously shows that honey from urban and industrial areas contains higher than average amounts of lead and cadmium, which is likely due to pollution from other human activities, industrial discharges, and vehicle emissions. Similarly, honey from places close to mine operations and agricultural districts where these metals are common has varied concentrations of arsenic and mercury. Although bee health depends on trace levels of copper and zinc, honey from areas with extensive agricultural and industrial practices has been found to contain high concentrations of these elements (Kılıç Altun et al., 2017). Geographic differences in metal buildup are extensively addressed, with larger concentrations found in metropolitan areas as a result of industrial emissions and traffic, while lower levels are often found in rural areas, but these can also be influenced by agricultural practices such as the use of fertiliser and pesticides. Lower metal concentrations are generally reported in areas with stricter environmental laws, demonstrating the efficacy of pollution management measures (Bayir & Aygun, 2022).

The use of tainted fertilisers and pesticides, as well as metal-enriched soil and water supplies used in cultivation, all play a major role in the presence of metals in honey. The variable metal concentrations in honey in different places can also be attributed to naturally occurring geological formations that are rich in metals (Bayir & Aygun, 2022).

Monitoring the presence of heavy metal contamination in honey highlights the importance of honey as a bioindicator and offers important insights into environmental health. Strong environmental laws and ongoing monitoring are essential for reducing metal contamination, guaranteeing the safety of honey, and promoting ecosystem health. These results highlight how crucial it is to incorporate honey analysis into environmental monitoring systems in order to inform practical approaches to pollution mitigation (Bayir & Aygun, 2022).

5. Methodology for Setting Up Trap Nests and Collecting Samples

Artificial nesting resources, or trap nests, are essential to ecological studies of solitary cavity-nesting bees and wasps. These nests are placed strategically in a variety of settings, including woods, fields of crops, and cities. They are made of materials including bamboo, paper straws, and wood. varying species are accommodated by varying trap nest designs and placements, which affects occupancy rates and species diversity. Researchers may keep an eye on nest occupancy, see the materials used to build the nests, and follow the development of the nests by routine inspections (Staab et al., 2018).

Extensive methods include identifying species by physical characteristics or genetic analysis, documenting trophic interactions such as parasitism and prey capture, and dissecting nests after research to perform in-depth content analysis. Chemical examinations of the nest's components reveal information about the effects of environmental contamination. The interpretation of data obtained from trap nests plays a crucial role in ecological studies by providing insights into evaluations of species diversity, trophic relationships, and environmental sensitivities. There are numerous implications for ecological study, including pollination studies, environmental monitoring, and assessments of biodiversity. Understanding trapping behaviours, community dynamics, and the adaptive tactics of

cavity-nesting insects is greatly aided by trap nests. Their adaptability and efficiency in examining trophic interactions across a range of environmental contexts make them indispensable tools for evaluating the health of ecosystems and directing conservation efforts (Staab et al., 2018).

6. Conclusion

6.1 Summary of Key Findings and Implications

The several functions that bees—in particular, cavity-nesting bees—play in ecological research and environmental monitoring are highlighted in this article. Megachile cephalotes and Epanthidium tigrinum are two examples of solitary bees whose nesting behaviours were investigated. These bees used materials including dirt, glue, and plant fibres to build their nests. Particularly, resin fulfils a number of purposes, such as offering pathogen protection, chemical camouflage, and structural integrity. Still, there are a lot of unanswered questions about the complete ecological effects of resin use, which calls for more study (Akram et al., 2022).

Because of habitat fragmentation and a shortage of adequate nesting sites, studies comparing nesting behaviours in agricultural landscapes with those in natural environments reveal that cavity-nesting bees and wasps display reduced nesting activity in agricultural settings. It is imperative to establish additional nesting places in these regions in order to sustain pollinator numbers and improve biodiversity. Furthermore, trap nests offer insightful information about the composition of wasp and bee communities, emphasising the role that natural adversaries play in forming these groups. Trap nests are useful in ecological monitoring because these trophic interactions are sensitive markers of environmental changes (Staab et al., 2018).

Honeybees and the products they produce, including pollen and honey, are useful bioindicators of environmental contamination, especially when it comes to identifying pesticides and heavy metals. Case studies from different areas demonstrate notable pollution buildup, which reflects the state of the local environment. In particular, bee pollen is a trustworthy indicator of pesticide residues and provides a non-intrusive way to gauge environmental health and direct policy decisions. The amounts of heavy metal pollution in bees, honey, pollen, and wax vary significantly between different locales, according to heavy metal analysis. These metals can be found and measured with the help of methods like inductively coupled plasma mass spectrometry (ICP-MS) and atomic absorption spectrometry (AAS). Regional monitoring programmes are necessary because geographic variations emphasise the impact of local environmental conditions on metal accumulation (Conti and Botrè, 2001).

Solitary bees, exemplified by Osmia bicornis L. in the Łowicz district study, play a crucial role as bioindicators of environmental contamination. Unlike honeybees that create long-term stores of honey, solitary bees primarily collect pollen and nectar for immediate consumption and offspring provision. This behavior makes them sensitive detectors of heavy metals such as zinc, lead, and cadmium present in their foraging environments. Their short foraging distances and fidelity to specific nesting sites concentrate the accumulation of contaminants from local sources, providing precise insights into pollution levels within different habitats—urban areas, orchards, and berry plantations in this case. By monitoring the heavy metal concentrations in solitary bees, researchers can effectively gauge environmental health and the impact of human activities on ecosystems, guiding targeted conservation efforts and pollution management strategies (Zajdel et al., 2023).

6.2 Recommendations for Future Research Directions and Practical Applications

Future studies should examine the chemical makeup of resin, as well as its interactions with pathogens

and predators, and its ecological value in solitary bee nests. Strategies for the conservation of resin-collecting bees can be informed by an understanding of these factors. Furthermore, it's critical to design and implement plans to increase the number of nesting locations in agricultural areas. To support pollinator diversity and abundance, this involves protecting natural habitats and constructing artificial nesting sites (MacIvor, 2017).

To further our understanding of the multi-trophic interactions between solitary bees and wasps, trap nest approaches must be used and refined. Extensive research endeavours can yield significant insights into how environmental modifications impact these interplays. By incorporating bees and their products into larger environmental monitoring programmes, pollution levels may be continuously assessed, new toxins can be found, and the efficacy of environmental laws can be monitored. Longitudinal research conducted in different areas can shed light on patterns in heavy metal pollution and how it affects bee health. Establishing baseline contamination levels and identifying high-risk locations should be the goals of these research (Staab et al., 2018).

Environmental regulations and conservation initiatives should be guided by the results of studies on bee bioindicators. Maintaining healthy pollinator populations and ecosystem services requires putting policies in place to lessen pollution exposure and safeguard bee habitats. We can improve environmental monitoring and conservation techniques as well as our understanding of bee ecology by filling in these research gaps and putting practical actions into place (Staab et al., 2018).

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