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Causes and Response Strategies for the Decline of Honey Bee Populations in the Process of Urbanization

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Abstract:
Honey bees are extensively studied pollinators of significant ecological importance. Their role in plant pollination is crucial for maintaining biodiversity and ensuring global food security.. However, their populations are declining sharply in highly urbanized areas. Given that urbanization is an inevitable trend in social development, balancing human development with honey bee survival has become a critical challenge. Existing research often focuses on monitoring honey bee populations and identifying influencing factors, with insufficient in-depth studies on technological approaches to promote human-bee coexistence within the urban context. Urbanization introduces threats such as pesticide use in urban greening, industrial pollution, and the urban heat island effect, which endanger honey bees. Strategies like Integrated Pest and Pollinator Management (IPPM), urban beekeeping (including optimized greening and hive installation), and the "Canopy System" show positive results. However, challenges remain, including low adoption rates of relevant management models and the high cost hindering the widespread application of some technologies. Future technological developments are expected to favor the creation of intelligent, systematic solutions, integrating multidisciplinary technologies and strengthening ecological corridor planning. Furthermore, integrating technology, policy, and public education is essential. This review covers the importance and conservation value of honey bees, the threats posed by urbanization and their causes, the effectiveness of existing conservation technologies, policies, and future directions, aiming to provide references for promoting sustainable urban development characterized by harmonious human-bee coexistence.

Keywords: Urbanization; Pollinators; Honey bees; Population decline; Human development.

1. Introduction

The vast majority of successful plant pollination relies on animals, accounting for approximately 85% of all pollination events, with insects responsible for about 88% of this total [1]. Among these pollinating insects, the genus Apis within the family Apoidea is the most extensively studied and ecologically significant group. Due to their high sociality and broad foraging characteristics, honey bees play an indispensable role in maintaining plant diversity and ensuring global food security [2]. However, a sharp decline in honey bee populations in urban areas in recent years has been well-documented, particularly evident in countries with high levels of urbanization. Yet, urbanization remains an inevitable trend in contemporary societal development. Therefore, ensuring the survival safety of honey bee populations while meeting human development needs has become a critical challenge urgently requiring solutions from both biological and social sciences. Currently, a considerable body of research literature exists on the status of honey bee populations, but most focus on population monitoring and discussions of influencing factors. In-depth research on how to promote coexistence between honey bees and humans through technical means within the context of urbanization remains insufficient. This paper reviews the importance and conservation value of honey bees, the main threats and their causes posed by urbanization and industrialization to honey bees, and the effectiveness of existing conservation technologies. Based on this, potential future directions for technological development are proposed.

2. Impact on the Ecological Environment and Human Production and Life

2.1 The Contribution of Honey Bees to the Natural Ecosystem

Honey bees hold an irreplaceable position in maintaining the biodiversity of native flowering plant communities. Taking the Western Honey Bee (*Apis mellifera*), the most common species in the genus Apis, as an example, this “super generalist” species affects 88.9% of flowering plant communities in its native range (Europe, Africa, and the Middle East) and 61.3% in introduced regions [3].

The pollination services provided by honey bees not only directly sustain and promote the reproduction and renewal of flowering species but also indirectly support the survival of species that depend on flowers for habitat and food sources, such as herbivores and seed-eating animals.

2.2 The Contribution of Honey Bees to Human Life

Beyond maintaining ecological stability, honey bees also play a key role in the development of human agriculture, the pharmaceutical industry, and other fields. Honey bees provide crucial pollination services for global agriculture, maintaining stable crop yields. A decline in their populations would seriously threaten agricultural development and even food security.

Furthermore, products such as honey, beeswax, propolis, and royal jelly are widely used in nutrition, medicine, and cosmetics. These products possess multiple functions, including antibacterial, anti-inflammatory, and antioxidant properties, and have been used extensively by humans as natural medicines since ancient times [4]. Bee products also demonstrate preventive and potential therapeutic effects against various viruses.

3. Threats to Honey Bees from Urbanization and Causes thereof

3.1 Use of Plant Protection Products (PPP) in Urban Greening Threatens Bee Safety

Urban greening involves the extensive use of pesticides and insecticides. Due to factors such as land cover and human activities, pesticide concentrations in urban soil, air, and waterways can actually be higher than in rural areas. The probability of pesticide use is relatively higher in cities with a greater degree of urbanization. Furthermore, approximately 90% of urban ground surface is impermeable, leading to significant deposition of pesticide residues. Pesticide residues in soil can be absorbed by plant roots and transferred to edible parts frequently contacted by honey bees.

Numerous experimental reports in bee toxicology confirm the toxicity of PPPs to honey bees. Additionally, pesticide exposure reduces bee immune function and increases parasite infection rates. Harm caused to honey bees includes, but is not limited to: developmental delays, impaired immune systems, and shortened adult lifespans. Honey bees consuming pollen containing MPF and fluvalinate exhibit a microsporidian infection rate more than double that of unexposed honey bees. Moreover, PPP residues have been detected in various bee-related matrices [5]. Forager honey bees disseminate PPP residues within the hive, thereby exposing other individuals and leading to impaired development and physiological functions for the entire colony. This affects the queen’s egg-laying capacity and egg quality, ultimately weakening the overall health of the hive. This demonstrates the significant impact of PPPs on honey bees of all age classes and functional categories.

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3.2 Industrial Pollution Causes Honey Bee Poisoning

Similarly, industrial and traffic emissions associated with urbanization generate substantial air pollutants (carbon oxides, nitrogen oxides, etc.). Exposure to urban air pollution impairs honey bees‘ olfactory learning and memory, reducing their ability to locate floral resources and their pollination efficiency. Contaminants such as microplastics, heavy metals, and particulate matter (PM) have been detected in various tissues of pollinating insects. The release of these substances within organisms can lead to endocrine disruption and even carcinogenic effects, impairing growth and reproduction.

The Urban Heat Island (UHI) effect greatly promotes the unidirectional development of the urban ecological environment. This consistent selective pressure leads to reduced bee species diversity. For every 1 degree Celsius increase in temperature, bee abundance can decrease by 41%. Concurrently, UHI causes higher temperatures in urban areas compared to surrounding areas, thereby attracting the migration of non-native bee species that compete with local honey bees for resources [6].

4. Scientific and Management Measures for Honey Bee Conservation in Urban Areas

4.1 Integrated Pest and Pollinator Management (IPPM)

As mentioned previously, the excessive or improper use of PPPs poses a serious threat to non-target pollinators like honey bees. IPPM can largely address this issue. IPPM can be viewed as an expanded framework of Integrated Pest Management (IPM). Its core concept involves using biological control, cultivation practices, and products derived from natural organisms to manage agricultural pests, thereby minimizing pesticide harm to pollinators and supporting sustainable agriculture. IPPM serves as an important approach for coordinating the relationship between insect pollination services and pest control measures, and is also a key policy for maintaining ecosystem stability and functional diversity.

Research has proven that under an IPPM management model, the average bee visitation rate in watermelon fields increased significantly (especially for wild honey bees), watermelon yield increased by approximately 26%, and profit grew by about 4513 USD per hectare [7]. This approach reduces pesticide use, protects the ecological environment, and simultaneously provides cost savings and economic benefits for farmers.

Nevertheless, the adoption rate of IPPM remains low in practice, with farmers still reliant on chemical pesticides. Reasons include limited knowledge bases, the less immediate short-term effectiveness of IPM compared to pesticides, complex registration processes for biocontrol products, and difficult market access. In addition to the aforementioned factors, the low adoption rate of the IPPM management model is closely associated with land ownership structure, policy subsidy biases, and supply chain pressures. In regions with fragmented land ownership, small-scale farmers lack a foundation for unified and coordinated management, making it difficult to establish large-scale IPPM implementation systems. Policy subsidies tend to favor chemical pesticide use, while subsidies related to biological control are insufficient and application procedures are cumbersome, which undermines farmers' motivation to transition. Meanwhile, short-term assessment criteria for crop appearance and yield imposed by purchasers in the agricultural product supply chain force farmers to rely on fast-acting chemical pesticides to avoid market risks. Even with awareness of IPPM's long-term benefits, farmers are reluctant to adopt the model due to short-term profit pressures, further hindering its promotion and implementation.

4.2 Urban Apiculture Development

4.2.1 Urban Greening

While reducing insecticide use, managed beekeeping in cities presents a potential major direction for future human-bee coexistence, with urban greening being the primary component.

A three-year controlled experiment in Bydgoszcz, Poland, concluded that the abundance and species richness of honey bees in wastelands were 63.2% and 47.0% higher, respectively, than those in parks [8]. This indicates that current urban green spaces like parks are not optimal for bee survival and also points towards a general direction for bee conservation strategies in urban areas. Firstly, incorporating urban wastelands into the focus of urban ecological conservation is crucial. Furthermore, flower abundance and richness are closely linked to bee species diversity. Therefore, the priorities of urban greening standards should be reconsidered, prioritizing flower density and diversity over aesthetic appeal.

Meanwhile, rooftop gardens represent a highly popular trend in recent years, significantly increasing vegetation coverage in urban buildings and thereby reducing the impact of UHI. Suitable vegetation density can even lead to an Urban Cool Island (UCI) effect, contributing to the development of bee-friendly cities.

The three plant types with the highest overall value for plant-pollinator communities are pine forests, oak forests, and managed olive groves, with the pollination efficiency of managed olive groves being higher than that of abandoned ones. This knowledge suggests that increasing the abundance of specific plants in urban areas can aid bee conservation. Different regions should adapt strategies based on local conditions to balance the optimal approach for urban bee protection. Simultaneously, planting more native vegetation and reducing non-native species can effectively lessen competition for resources between non-native and local honey bees, and influence plant-pollinator networks by stabilizing ecosystem structure.

4.2.2 Hive Construction within Cities

Given adequate urban greening, the most rapid method is the direct, managed introduction of a baseline bee population.

Government involvement in regulation and community zoning management is essential. A hive registration system can facilitate real-time monitoring and adjustment of hive numbers and density, allowing for timely plan modifications. With proper beekeeping practices, the urban environment does not pose significant risks to honey bees. This approach also provides data assurance for honey quality from urban hives. Moreover, urban hive construction saves honey transportation costs, fostering mutual benefits for ecological conservation and human societal development. Concurrently, the role of honey bees as mobile air quality monitors is well-established, with numerous studies demonstrating the accuracy and effectiveness of using bee populations to assess air quality [9]. In this regard, governments can promote beekeeping policies and establish related social practice activities, encouraging broader public participation in building bee-friendly cities while serving promotional and educational purposes [10]. Meanwhile, in-depth follow-up research is highly necessary to investigate whether potential pollutants in bees can enter the human body through the food chain.

4.3 „Sky Curtain System“ for Reducing Industrial Air Pollution

During urban construction or demolition projects, large air-supported membrane structures (commonly known as „Sky Curtain Systems“) can enclose the entire construction site. This effectively contains dust and particulate matter generated during construction, protecting air quality and plant surfaces in surrounding areas and reducing the direct impact of pollutants on honey bees. This technology widely utilizes dust control nets, spray systems, and other related technologies that help reduce air pollution caused by industry. Used in conjunction with eco-friendly dust suppressants, it can reduce escaping dust by over 90%, effectively lowering air pollution from construction site dust and significantly reducing noise pollution from construction sites. This contributes to improving the quality of life for urban residents while aiding in the protection of the urban ecological environment and bee populations. However, this technology is primarily deployed in eastern Chinese cities and is not yet widely used. The high cost of these large air-supported membrane structures significantly reduces the possibility of widespread adoption.

5. Conclusion

In addressing the issue of bee population decline induced by urbanization, a series of integrated management strategies and practices currently employed have demonstrated positive outcomes, offering effective pathways to tackle core challenges such as traditional pesticide overuse, natural habitat loss, and industrial pollution. Implementing Integrated Pest and Pollinator Management (IPPM) has significantly reduced the use of harmful chemicals in agricultural environments. This not only directly mitigates pesticide toxicity and immune suppression in honey bees but also synergistically enhances crop pollination efficiency and agricultural economic benefits, achieving a win-win situation for ecological conservation and agricultural production. Targeting urban habitat degradation, optimizing green space management strategies, prioritizing the protection of wastelands, and enhancing the abundance and diversity of native flowers, coupled with the promotion of rooftop greening and urban beekeeping, have effectively rebuilt food resources and nesting sites required by pollinators. These measures enhance the carrying capacity and resilience of urban ecosystems and foster public participation. Regarding industrial pollution control, employing techniques such as enclosed construction dust suppression technology helps suppress the dispersion of particulate matter and harmful substances at the source, directly improving air quality necessary for bee survival. Looking ahead, the evolution of relevant technologies will tend towards building systematic and intelligent solutions, deeply integrating IoT monitoring, bioinformatics, and ecological engineering to enable real-time sensing and precise intervention for hive health and habitat quality. Concurrently, cross-scale ecological corridor planning and green infrastructure development based on nature-based solutions will be strengthened to improve the connectivity and stability of urban ecological networks. Future research needs to focus on more deeply integrating technology, policy, and public education to promote the development of self-sustaining urban ecosystems where humans and honey bees coexist harmoniously. This requires continued exploration of cost-effective, easily promotable technical

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models and enhanced synergy and integration with urban management policies.

References

[1] Travis, D.J., Kohn, J.R. Honey Bees (Apis mellifera) decrease the fitness of plants they pollinate. Proceedings of the Royal Society B, 2023, 290(2001), 20230967. DOI: 10.1098/rspb.2023.0967

[2] Papa, G., Maier, R., Durazzo, A., et al. The honey bee Apis mellifera: An insect at the interface between human and ecosystem health. Biology, 2022, 11(2), 233. DOI: 10.3390/biology11020233

[3] Hung, K.L.J., Kingston, J.M., Albrecht, M., et al. The worldwide importance of honey bees as pollinators in natural habitats. Proceedings of the Royal Society B: Biological Sciences, 2018, 285(1870), 20172140. DOI: 10.1098/rspb.2017.2140

[4] Kontogiannis, T., Dimitriou, T.G., Didaras, N.A., et al. Antiviral Activity of Bee Products. Current Pharmaceutical Design, 2022, 28(35), 2867-2878. DOI: 10.2174/1381612828666220929153844

[5] Démares, F.J., Schmehl, D., Bloomquist, J.R., et al. Honey bee (Apis mellifera) exposure to pesticide residues in nectar and pollen in urban and suburban environments from four regions of the United States. Environmental Toxicology and Chemistry, 2022, 41(4), 991-1003. DOI: 10.1002/etc.5266

[6] Ayers, A.C., Rehan, S.M. Supporting honey bees in cities: how honey bees are influenced by local and landscape features. Insects, 2021, 12(2), 128. DOI: 10.3390/insects12020128

[7] Pecenka, J. IPM in Midwestern Agriculture: Implications to Pests, Pollinators, and Yield. Purdue University, 2021.

[8] Sobieraj-Betlińska, A., Twerd, L. Are parks as favourable habitats for wild honey bees as wastelands in watercourse valleys of a large city? Urban Forestry & Urban Greening, 2024, 99, 128450. DOI: 10.1016/j.ufug.2024.128450

[9] Edo, C., Fernández-Alba, A.R., Vejsnæs, F., et al. Honey Bees as active samplers for microplastics. Science of The Total Environment, 2021, 767, 144481. DOI: 10.1016/j.scitotenv.2021.144481

[10] Griffin, S.R., Bruninga-Socolar, B., Gibbs, J. Bee communities in restored prairies are structured by landscape and management, not local floral resources. Basic and Applied Ecology, 2021, 50, 144-154. DOI: 10.1016/j.baae.2020.12.004