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GUIDELINES
RECONCILING BEEKEEPING AND THE CONSERVATION OF WILD POLLINATORS

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COORDINATING BENEFICIARY:
UNIVERSITÀ CA' FOSCARI VENEZIA
Dipartimento di Scienze Ambientali, Informatica e Statistica
Via Torino 155 - 38172 Mestre (Venice) - ITALY

www.lifepollinaction.eu
lifepollinaction@unive.it
LIFE_POLLINACTION lifepollinaction

Table of contents

LIFE PollinAction GUIDELINES

RECONCILING BEEKEEPING
AND THE CONSERVATION OF WILD POLLINATORS

Beekeeping plays a crucial role in supporting crop pollination and honey production, but its impact on wild pollinators and ecosystems needs to be addressed and managed. Wild pollinators are an essential component of biodiversity, and their decline poses a significant ecological and economic risk. This guide offers strategies to balance beekeeping practises with the conservation of wild pollinator populations.

1. GLOBAL POLLINATOR CRISIS

Pollination is a fundamental ecological function and a critical ecosystem service that is essential for maintaining ecosystem structure and resilience and agricultural productivity. It is the basis for fruit and seed production and contributes directly to supporting wild plant communities and agricultural crops, both of which are vital to human well-being (Aguilar et al., 2006; Ricketts et al., 2008). Insects, especially wild pollinators, play a central role in providing the pollination service (Kumar and Khan, 2023). Approximately 84% of European crop species and 90% of the world's flowering wild plant species depend on animal pollination, which contributes an estimated $153 billion annually to global food production (Gallai et al., 2009; IPBES, 2016; Tong et al., 2023). It is alarming that many wild plant species and their pollinators are experiencing rapid population declines (Ollerton, 2017).

The crucial role of pollinators was not widely recognised until the early 1990s, when the global decline in pollinator populations and diversity, largely due to anthropogenic environmental change, was highlighted as a significant threat. This led to the recognition of the 'global pollination crisis', a phenomenon associated with ecosystem disruption and reduced pollination service (Abrol, 2012). The decline in pollinator populations has already led to productivity losses in crops such as apples and other orchards (Aizen et al., 2009; Pérez-Méndez et al., 2020).

Although the number of managed honey bee (*Apis mellifera* Linnaeus, 1758) colonies has increased globally over the last 50 years, the demand for pollination has increased even faster as the number of crops requiring animal pollination has tripled. At the same time, populations of wild pollinators have declined significantly (Abrol, 2012; Aizen and Harder, 2009; Phiri et al., 2022). This imbalance emphasises the urgent need for conservation measures that focus on wild pollinators, as reliance on managed honey bees alone is not sufficient to meet the challenges posed by the decline in pollination services (Aizen and Harder, 2009).

2. CAUSES OF WILD POLLINATOR DECLINE

The global decline of wild pollinators is the result of a synergistic interplay of several factors that rarely act in isolation. In many cases, one factor exacerbates the effects of another and amplifies their consequences (González-Varo et al., 2013). These factors are often associated with urban expansion and agricultural intensification and include land use change and associated habitat loss, climate change, pesticide use, the spread of invasive alien species and pathogens and the intensification of beekeeping (Fig. 1; Le Buhn and Vargas Luna, 2021).

2.1 Land use change and habitat loss

The loss of natural and semi-natural habitats at the local and global level is one of the main causes of the decline in pollinator populations (Kosior et al., 2007). Major drivers of habitat loss are urban expansion and agricultural intensification.

Urbanisation contributes significantly to the loss of pollinator habitats (Lorenzato et al., 2024). The replacement of green spaces by buildings and roads reduces the availability of wildflowers and nesting sites, while the homogenisation of urban planting often favours ornamental species with limited value for pollinators (Sponsler et al., 2020). Such urban-induced habitat loss disrupts the continuity of floral and nesting resources, resulting in reduced abundance and diversity of pollinators (Bates et al., 2011). Furthermore, urban heat islands and increasing pollution pose additional stress factors for pollinator populations, affecting their physiology and foraging efficiency (Hamblin et al., 2017; Phillips et al., 2020). Although urban areas can be designed to support pollinators by incorporating pollinator-friendly green spaces (Hall et al., 2017), the current trajectory of urban expansion generally undermines the ecological integrity needed to sustain pollinator populations.

Beside urban expansion, agricultural intensification exacerbates pressure on pollinators by driving habitat loss and altering landscapes in ways that diminish their ecological value. Monocultural flower crops (MFCs), such as oilseed rape and sunflowers, have been proposed as a strategy to provide resources for pollinators in the agricultural land. However, while these crops provide abundant nectar and pollen during their short flowering period, their lack of floral diversity and the temporally limited availability of resources pose a major ecological challenge. In addition, in landscapes dominated by MFCs, pollinators may shift their foraging from native plants to MFCs, reducing the reproductive success of wild plants that rely on animal-mediated pollination. This shift disrupts pollination networks and exacerbates pollination deficits in native plant species, especially in areas with low diversity of wild pollinators (Holzschuh et al., 2016).

In addition, the rapid expansion of MFCs, which have been reported to have increased by almost 50 % between 2000 and 2010 (Holzschuh et al., 2013), highlights the need for strategies to contain the problem. The conservation of alternative floral and nesting resources in semi-natural habitats is crucial to compensate for the environmental deficiencies of MFCs. These habitats can provide year-round support for both wild and managed pollinators and increase their resilience to habitat loss and agricultural intensification. In addition, many MFCs, such as hybrid sunflowers, rely on male-sterile seeds to increase their yields. These seeds often provide inferior floral resources to pollinators, further stressing pollinator populations and emphasising the need to integrate pollinator-friendly practises into the agricultural landscapes. Approaches such as crop diversification, and restoring semi-natural habitats are essential to ensure the conservation of pollinators and the ecosystem services they provide in the face of ongoing environmental change.

2.2 Climate change

Climate is undergoing profound changes caused by the release of significant amounts of greenhouse gases such as carbon dioxide, methane and others into the atmosphere, mainly through the consumption of fossil fuels. These emissions are leading to progressive global warming and the intensification of extreme weather events, such as torrential rains, prolonged droughts and unseasonable temperature fluctuations. These climatic changes have serious consequences for the conservation of pollinators (Settele et al., 2016).

One major challenge is the "desynchronisation" between the life cycles of pollinators and the flowering times of plants. Rising temperatures can lead to pollinators, such as bees, waking up prematurely from hibernation so that they no longer have sufficient food resources due to the lack of flowers. Conversely, plants may flower earlier or later than expected, resulting in the absence of pollinators necessary for reproduction. Late frosts that follow warm periods further exacerbate the risk. They can destroy early flowers or jeopardise pollinators that have become active too early.

In addition, climate change alters the composition and structure of ecosystems, often leading to the decline of native species and the introduction or spread of invasive alien species. These new arrivals can displace native plants and animals, disrupt existing pollination networks and introduce new pests or diseases. For example, invasive plants can lure pollinators away from native species and thus reduce the reproductive success of native plants, while invasive predators and parasites can directly threaten pollinator populations.

2.3 Introduction of invasive alien species

The rapid expansion of world trade, driven by globalisation, has inadvertently facilitated the spread of exotic animal and plant species to new regions. While some species have been deliberately introduced for agricultural or ornamental purposes, others have been accidentally introduced in freight containers or on vehicles. Many of these species have successfully established themselves in new regions, and some have become invasive, displacing native species. These invasive alien species pose a significant threat to biodiversity, ecosystem stability and economic activities.

Pollinators are particularly vulnerable to the impacts of invasive species (Kovács-Hostyánszki et al., 2022). A notable example is the arrival of the Asian hornet (*Vespa velutina* Lepeletier, 1836), in Europe (Rojas-Nossa and Calviño-Cancela, 2020). Native to Southeast Asia, *Vespa velutina* reached France in 2005 and has spread throughout Europe. This hornet feeds of both wild bees and managed honey bees, which are essential for the pollination of crops and wild plants. By attacking and killing bees, it poses a serious threat to pollinator populations and disrupts the pollination service in the agricultural land and the structure and resilience of ecosystem. The spread of *Vespa velutina* highlights the broader challenges that invasive species pose to pollinator conservation. Invasive predators and competitors can severely impact native species, often leading to ecological cascade effects.

2.4 Pesticide and agrochemical exposition

Since the early 1990s, the use of pesticides has increased by about 70%, due to the intensification of agricultural practises (Aizen et al., 2022). This sharp escalation has led to widespread chronic exposure to pesticides at lethal and sublethal doses, with profound consequences for wild pollinators. Exposure to these chemicals increases direct mortality from poisoning and indirectly disrupts pollinator community dynamics by reducing species diversity and abundance (Guzman et al., 2024; Walker and Wu, 2017). Such losses threaten ecosystem services provided by pollinators, including pollination of wild plants and agricultural crops, which are critical to ecosystem health and human food security.

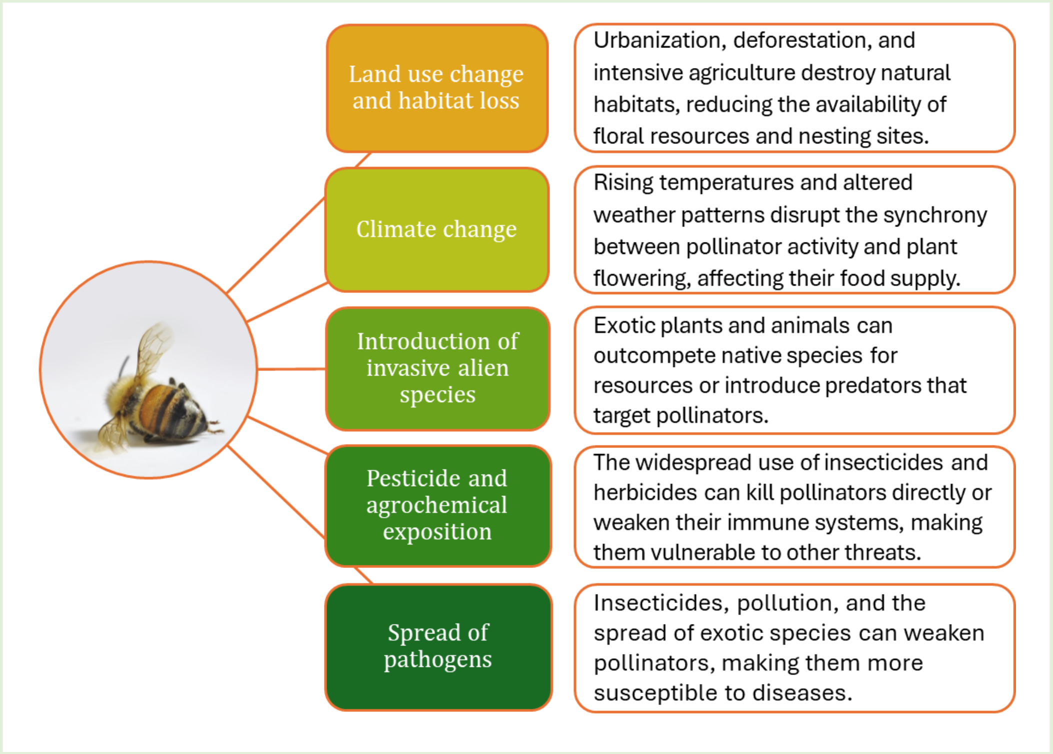
Among pesticides, neonicotinoids have been shown to be particularly harmful to pollinators. Neonicotinoids are often used as seed treatments and are highly water soluble and persistent in soil and water. This persistence allows them to accumulate in nearby wildflowers and contaminate their pollen and nectar. As neurotoxic compounds, neonicotinoids interfere with the nervous system of insects and impair critical behaviours such as memory, orientation and foraging efficiency. These impairments can lead to disorientation, paralysis or death and further exacerbate the decline in pollinator populations. Despite the wide-ranging ecological damage these substances cause, risk assessments for neonicotinoids focus primarily on sub-lethal effects in honey bees, often overlooking their broader and potentially more severe impacts on other wild pollinator species and the ecosystems they support.

The challenges for pollinators are exacerbated by the intensification of agriculture, which includes not only the use of pesticides but also fertilisers and herbicides. Heavy fertilisation alters soil chemistry and can indirectly affect pollinators by promoting species-poor nitrophilous communities that lack floral diversity. The use of herbicides exacerbates these problems by directly reducing the abundance and diversity of wild plants, further limiting the availability of important floral resources such as nectar and pollen. These combined practises disrupt the intricate relationships between pollinators and plants, threatening their survival and reproduction.

2.5 Spread of pathogens

Wild pollinators are threatened by a variety of pathogens and parasites, many of which are also found in managed honey bees. These pathogens, including viruses, bacteria, fungi and protozoa, can have a negative impact on the health, reproduction and survival of wild pollinator populations. The spread of pollinator pathogens and parasites is primarily driven by the transport of managed honey bee colonies over long distances, often for commercial pollination services, and by the presence of managed honey bees at high densities, which facilitates the probability of transmission of infectious agents (Ahn et al., 2012; Dynes et al., 2019; Gordon et al., 2014).

Managed honey bees can act as reservoirs or amplifiers of pathogens that spread to wild pollinator populations, a process that is exacerbated by the overlap of foraging areas between managed and wild bees. For example, pathogens such as Deformed Wing Virus (DWV) and *Nosema* spp. have been detected in both honey bees and wild bees, often with severe consequences for the latter due to differences in immunity and ecological resilience. This sharing of pathogens is exacerbated by environmental stressors such as habitat loss and exposure to pesticides, which weaken pollinators' immune systems and increase their susceptibility to infection.



Urbanization, deforestation, and intensive agriculture destroy natural habitats, reducing the availability of floral resources and nesting sites.

Rising temperatures and altered weather patterns disrupt the synchrony between pollinator activity and plant flowering, affecting their food supply.

Exotic plants and animals can outcompete native species for resources or introduce predators that target pollinators.

The widespread use of insecticides and herbicides can kill pollinators directly or weaken their immune systems, making them vulnerable to other threats.

Insecticides, pollution, and the spread of exotic species can weaken pollinators, making them more susceptible to diseases.

Figure 1: *The main causes of pollinator decline*

3. THE IMPACT OF INTENSIVE BEEKEEPING ON WILD POLLINATORS

3.1 Managed honeybee populations: misconceptions and trends

While pollinator populations are generally declining worldwide, managed honey bee colonies are a notable exception. Over the past two decades, localised losses of managed honey bee colonies in North America and Western Europe have been widely reported and often linked to phenomena such as Colony Collapse Disorder (CCD). However, these regional losses have led to misconceptions perpetuated by the public media suggesting a global decline in managed honey bee populations. This misrepresentation has increased public concern about honey bee conservation, despite the fact that managed honey bee populations have increased globally by approximately 85% over the last six decades. Managed honey bees are not considered globally threatened, which emphasises the importance of distinguishing their status from that of wild pollinators.

3.2 Ecological impacts of honey bee introductions

The introduction of honey bee colonies is often used as a management strategy to compensate for pollination deficits in agricultural systems, which are often caused by the decline of wild pollinator populations (Fig. 2; Breeze et al., 2014; Geslin et al., 2017). While this practice can provide a short-term solution to pollination problems, it also has significant ecological consequences for wild pollinators.

Figure 2: *Honey bees used to pollinate sunflowers (Helianthus annuus* L.*) in monocultures. Honey bees are used in large-scale sunflower cultivation to increase pollination efficiency and ensure high seed production and crop yields*

The introduction of honey bees increases competition for resources with wild pollinators, which negatively impacts wild pollinator populations. Such competition can lead to the local reduction of wild pollinator abundance and diversity, which has a cascading effect on ecosystem functionality. The decline in local wild pollinator populations, in turn, has been linked to lower seed production in wild plants and lower crop yields, emphasizing the critical role of wild pollinators in maintaining plant diversity and agricultural productivity (Angelella et al., 2021; Bommarco et al., 2021). Honey bee-mediated pollination is also associated with the spread of invasive plant species, which contributes to ecological imbalances (Geslin et al., 2017).

Honey bees show strong resource fidelity, with individual bees repeatedly visiting flowers of the same plant species when foraging (Fragoso and Brunet, 2023). While this behavior can initially have a positive effect on pollination through the spread of conspecific pollen, it also increases the likelihood of self-pollination, which can lead to inbreeding depression and lower plant fitness. In addition, a high density of honey bee colonies can lead to excessive flower visitation, which damages plants and depletes nectar resources. This pressure can affect the reproductive success of native plants and crops, further exacerbating honey bee impacts.

Taken together, this evidence underscores the ecological and evolutionary risks of introducing honey bee colonies into ecosystems that are not adapted to their presence. This practice can have detrimental effects on biodiversity, ecosystem functioning and services and crop production (Hung et al., 2019).

3.3 Forms of competition between honey bees and wild pollinators

Interactions between honey bees and wild pollinators occurs in various forms and can influence the structure and function of pollinator communities. These interactions are primarily competitive (either directly or indirectly) and affect wild pollinator communities to varying degrees.

- *Direct competition*

Direct competition involves direct interactions between honey bees and wild pollinators, such as aggressive foraging behaviour. Although aggressive encounters, such as flower abandonment or physical altercations, are frequently observed, their impact on wild pollinator populations is generally minimal (Geslin et al., 2017). However, localised instances of direct competition can exacerbate stress for endangered or rare pollinator species, especially in resource-poor environments.

- *Indirect competition through resource exploitation*

Indirect competition occurs when honey bees, as generalist foragers, deplete common floral resources and thereby disadvantage wild pollinators. This form of competition can disproportionately affect specialised pollinators, such as oligolectic species that rely on a narrow range of plants. Several factors contribute to the competitive advantage that honey bees have over wild pollinators:

- *Demographic advantage*

  Honey bee colonies are exceptionally large, consisting of tens of thousands of individuals that can harvest vast quantities of nectar and pollen. For example, a single honeybee colony can collect an amount of pollen equivalent to the requirements of the offspring of 100,000 individuals of the round-tailed carpenter bee (*Megachile rotundata* Fabricius, 1787) during a single foraging season (Geslin et al., 2017). This sheer numerical advantage allows honey bees to deplete floral resources, limiting their availability to wild pollinators.

- *Longer periods of activity*

  Honey bees forage for much longer periods of time compared to most wild pollinators. While many wild pollinator species are only active at certain times of the year or day, honey bees can forage all year round in suitable climates. In addition, thanks to their wide foraging range, which can be up to 10 km, they can utilise resources in different habitats (Beekman and Ratnieks, 2000). This prolonged and wide-ranging activity often leads to resource depletion and displaces wild pollinators, especially those with shorter lifespans or reduced mobility (Geslin et al., 2017).

- *Beekeeper management*
  Honey bees benefit from significant human interventions, including disease control, supplemental feeding and colony care, which ensure the stability and resilience of their populations. This artificial support enhances their competitive dominance over unmanaged wild pollinator species that struggle with natural environmental stress factors such as pathogens and resource scarcity.

While direct competition may have limited overall impact, indirect competition through resource exploitation poses a major challenge to wild pollinator populations. These dynamics can lead to a reduction in abundance, diversity and fitness of wild pollinators, especially for species with specific habitat or nutritional requirements. Consequently, understanding and mitigating the effects of competition from honey bee colonies is crucial to maintaining the ecological role of wild pollinators and ecosystem functioning and services.

BOX 1. THE MANAGED HONEY BEE

The honey bee is the most widely managed pollinator in the world, representing a significant economic value both through its pollination service and the production of honey, wax and propolis (Calderone, 2012; Kumar et al., 2022). Their ease of maintenance in artificial hives and their polylectic, generalist diet make them one of the most efficient and versatile pollinators (Delaplane, 2021). Honey bees are particularly effective at co-operative use of floral resources, which has led to their widespread use in the pollination of monocultures worldwide (Johnson, 2023).

Humans have managed honey bee colonies for millennia, initially for honey production and more recently for agricultural pollination (Aizen et al., 2022). As a result, honey bees have achieved a cosmopolitan distribution, largely due to their extensive use in beekeeping (Delaplane, 2021). It is estimated that around 90% of commercial pollination service is provided by this species (Klein et al., 2007).

Honey bees are social insects that live in colony. The honey bee colony is a highly efficient social structure in which each individual contributes to the collective welfare of the colony. A colony generally consists of thousands of bees comprising between 15,000 and 60,000 individuals (Southwick and Heldmaier, 1987). Through natural selection, honey bee colonies have evolved to maximise reproductive success, resulting in a strong hierarchical structure and a highly specialised division of labour between castes (Frisch, 1993; Huang and Robinson, 1995).

As in other Hymenoptera, sex determination in the honey bees is based on the haplodiploid system. Unfertilised eggs develop into haploid males (drones), while fertilised eggs develop into diploid females, which can develop into either new queens or worker bees, depending on the needs of the colony (Johnson, 2023).

Within the colony there are three main castes: the queen, the worker bees (which are divided into different sub-castes) and the male drones, which are only present during the mating season (Crailsheim et al., 1996). Female worker bees perform both internal tasks such as honey production, cell cleaning and storage as well as external tasks such as foraging and guarding the hive. These workers are essential for the health of the colony. They show remarkable plasticity in their circadian rhythms, which help to maintain colony homeostasis and prevent collapse (Beer and Bloch, 2020).

Honey bees generally forage from April to October. However, the intensity of foraging varies depending on the season and environmental factors (Bloch et al., 2006). In temperate regions, foraging ceases in winter, a time that is crucial for colony survival. During winter, honey consumption increases as a vital energy resource to feed the colony's offspring. Estimates indicate 20 kg of honey consumed per winter by a single colony (Seeley and Visscher, 1985). In contrast, honey bees collect more pollen in spring, with the amount collected correlating positively with the number of larvae and pupae to be supplied (Abou-Shaara et al., 2017). On average, a bee colony needs around 120 kg of nectar (equivalent to around 4 million trips), 15-30 kg of pollen and 25 kg of water each year to raise its offspring and regulate the temperature in the hive (Seeley, 1995).

Among the environmental parameters that influence honey bee foraging activity and colony well-being, temperature is the most important. The optimal foraging temperature range for honey bees is between 10°C and 40°C, with the highest activity at 20°C, which makes foraging highly dependent on the time of day and environmental conditions. As a polylectic generalist, the honeybee feeds on a wide range of floral resources, including both nectar and pollen, from various plant species (Requier et al., 2015). The specific foraging preferences of honey bees are influenced by the availability of species in bloom at a given time and the nutritional requirements of the colony (Lowe et al., 2022; Richardson et al., 2021). However, the abundance of certain species is not the only factor that determines foraging decisions. The nutritional quality of the available pollen and nectar, as well as the temporal availability of these resources, are key elements that influence colony health (Danner et al., 2017).

Nutrition is crucial to prevent physiological stress and ensure colony health. The nectar primarily provides carbohydrates, mainly in the form of fructose and glucose, while the pollen provides proteins, lipids, vitamins and minerals that are important for colony development and immunity (Brodschneider and Crailsheim, 2010). The balance of proteins and carbohydrates has a direct impact on colony health, as a high ratio of proteins to carbohydrates and high-quality pollen improve immune defences against pests and pathogens and improve performance on tasks such as learning and memory (Di Pasquale et al., 2013; Ghosh et al., 2020).

Once the foragers return the nectar to the hive, it is either passively dehydrated by evaporation or actively dehydrated, reducing its water content to around 18-25%. This transformation creates a hygroscopic, supersaturated sugar solution that inhibits the growth of pathogens in the hive (Berenbaum and Calla, 2021).

At the same time, the food storage box processes the nectar into honey, which undergoes a maturation process over a period of 1 to 11 days, culminating in the sealing of the cell to prevent fermentation (Eyer et al., 2016). The stored honey is crucial for the survival of the colony. Above all, it serves as a food source in winter and provides energy for the adult foragers. In addition to its nutritional value, honey also plays an important role in regulating the temperature and humidity in the hive and thus contributes to the overall vitality of the colony (Harano, 2020).

4. STRATEGIES TO RECONCILE BEEKEEPING AND THE CONSERVATION OF WILD POLLINATORS

There is growing empirical evidence of the negative effects of the large-scale introduction of honey bees on native wild pollinator communities, primarily due to competition. Competition arises when honey bees, often introduced at high densities, can displace native pollinators for limited floral resources and thus alter ecosystem dynamics. The extent of this impact is influenced by a number of factors, including local environmental conditions, the availability of floral resources and the behavioural and ecological characteristics of honey bee colonies.

Although targeted management strategies have the potential to mitigate such impacts, it is important to emphasise that formulating concrete and generally applicable recommendations remains a challenge due to the complexity of the topic and the need for further research. Current evidence suggests that regulating hive density and avoiding the placement of hives in ecologically sensitive or biodiversity-important natural areas are effective measures. In addition, managing floral resources at the landscape scale by considering spatial and temporal patterns can help reduce competitive pressure on native pollinators. These measures make it possible to support the pollination services of honey bees for agriculture while promoting the conservation of wild pollinators and thus maintaining the resilience of ecosystems.

4.1 Apiary placement and density

The ecological impacts of honey bee hive placement and density are increasingly recognised as important factors influencing biodiversity and ecosystem structure and resilience. Managed honey bees, as generalist pollinators, can disrupt ecosystem stability, especially in natural or protected areas where competition with wild pollinators can affect sensitive species. Appropriate management strategies that take into account the placement of honey bee hives and their density are crucial to minimise these impacts.

The placement of honey bee hives in ecologically sensitive areas such as nature reserves or biodiversity hotspots has been associated with negative impacts on both wild plants and pollinators. Honey bees can displace native pollinator species for floral resources, reducing the reproductive success of rare or endemic plants and threatening sensitive pollinators that are already under pressure from habitat loss and other stressors. Therefore, hives should be placed outside areas with sensitive or endangered wild pollinator and plant species. The same hold true in the urban environment, where the lack of pesticide use, and a relatively high landscape heterogeneity contribute to the conservation of wild pollinator populations (Hall et al., 2017).

In agricultural landscapes, competition between honey bees and wild pollinators intensifies under homogenous and intensively managed sites. Such landscapes often lack floral diversity and abundance, leading to an increasing overlap of niches and a decline in abundance and diversity of wild pollinator populations (Mallinger et al., 2017; Senapathi et al., 2015). In addition, a too high density of hives in homogeneous areas reduces honey bee foraging success, as demonstrated by the negative effects of hive proximity on foraging efficiency (Henry and Rodet, 2018). Maintaining an appropriate hive density is a critical component of sustainable honey bee management. Research has found that maintaining a density of approximately one hive per 3.8 km^2 strikes a balance between the need for crop pollination and biodiversity conservation (Henry and Rodet, 2020). This threshold minimises the displacement of wild pollinators while optimising the success of honey bees in foraging, which is a win-win situation for agriculture and pollinator conservation.

Transhumance, namely, the relocation of honeybee colonies over long distances to utilise seasonal floral resources, has long been a cornerstone of beekeeping (Crane, 1999; Mavrofridis et al., 2024). While this approach can improve foraging opportunities for honey bees, it also poses significant ecological and health risks. Frequent relocation leads to physiological stress in honey bee colonies and makes them more susceptible to pathogens and parasites such as *Varroa destructor* and *Nosema ceranae* (De La Rúa et al., 2009; Klee et al., 2007; Tehel et al., 2016; Zhu et al., 2014). In addition, stressed colonies are more likely to transmit diseases to wild pollinators via shared floral resources, further jeopardising already endangered wild pollinator populations (Martínez-López et al., 2022). These dynamics emphasise the need to reassess traditional transhumance practises in terms of their ecological impact. A more sustainable alternative to transhumance is to strategically place hives in agricultural landscapes that provide abundant and diverse flowering resources throughout the foraging season. Greater floral diversity has been shown to reduce both competition for resources and the risk of pathogen transmission between honey bees and wild pollinators. By maintaining diverse and resource-rich landscapes, managers can limit foraging overlap, reduce colony stress and promote the coexistence of honey bees and wild pollinators.

4.2 Habitat management

To reconcile beekeeping with wild pollinator conservation, a scientifically grounded strategy emphasizes the creation of distinct habitats tailored to the ecological needs of honey bees and wild pollinators. This approach, developed under the LIFE PollinAction project, centres on establishing two types of wildflower strips (Fig. 3): (1) monospecific stands composed of plant species highly attractive to honey bees and (2) diverse wildflower strips containing a high richness of flowering plants to provide floral resources to a wide array of wild pollinator species with varied floral preferences. This dual approach aims to provide targeted floral resources, thereby minimizing interspecies competition and promoting coexistence.

Monospecific wildflower strips designed for honey bees can include both annual and perennial species such as *Centaurea cyanus* L. (cornflower) and *Trifolium repens* L. (white clover), which are known to be highly favoured by honey bees. These strips can also be supplemented during the bees' active periods with mass-flowering crops like *Brassica napus* L. (oilseed rape) or *Sinapis alba* L. (white mustard), which provide an abundant source of nectar and pollen. Importantly, these crops must offer both pollen and nectar to meet the nutritional requirements of honey bee colonies during the entire activity season of honey bees and reduce the likelihood of honey bees straying to other plants, potentially alleviating competition with wild pollinators. On the other hand, wildflower strips for wild pollinators should prioritize species-rich assemblages, mimicking natural grasslands with diverse flowering plants. These strips should include species with staggered blooming periods to ensure a continuous availability of floral resources throughout the entire activity season of wild pollinators. This temporal resource provisioning is critical for supporting a wide variety of pollinator species, including those with specific or narrow floral preferences. Additionally, these wildflower habitats can be managed to align with local biodiversity goals, further enhancing their ecological benefits.

By strategically designing and managing these habitats, this approach not only supports the sustainable coexistence of honey bees and wild pollinators but also contributes to broader goals of ecosystem health and agricultural productivity.

Figure 3: *Species rich wildflower strip designed for wild pollinators (on the left) and monospecific wildflower strip for honey bees (on the right).*

5. REFERENCES

Abou-Shaara, H.F., Owayss, A.A., Ibrahim, Y.Y., Basuny, N.K., 2017. A review of impacts of temperature and relative humidity on various activities of honey bees. Insect. Soc. 64, 455–463. https://doi.org/10.1007/s00040-017-0573-8

Abrol, D.P., 2012. Pollination Biology. Springer Netherlands, Dordrecht. https://doi.org/10.1007/978-94-007-1942-2

Aguilar, R., Ashworth, L., Galetto, L., Aizen, M.A., 2006. Plant reproductive susceptibility to habitat fragmentation: review and synthesis through a meta-analysis. Ecology Letters 9, 968–980. https://doi.org/10.1111/j.1461-0248.2006.00927.x

Ahn, K., Xie, X., Riddle, J., Pettis, J., Huang, Z.Y., 2012. Effects of Long Distance Transportation on Honey Bee Physiology. Psyche: A Journal of Entomology 2012, 1–9. https://doi.org/10.1155/2012/193029

Aizen, M.A., Garibaldi, L.A., Cunningham, S.A., Klein, A.M., 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. Annals of Botany 103, 1579–1588. https://doi.org/10.1093/aob/mcp076

Aizen, M.A., Garibaldi, L.A., Harder, L.D., 2022. Myth and reality of a global crisis for agricultural pollination. Ecol. Austral 32, 698–715. https://doi.org/10.25260/EA.22.32.2.1.1875

Aizen, M.A., Harder, L.D., 2009. The Global Stock of Domesticated Honey Bees Is Growing Slower Than Agricultural Demand for Pollination. Current Biology 19, 915–918. https://doi.org/10.1016/j.cub.2009.03.071

Angelella, G.M., McCullough, C.T., O'Rourke, M.E., 2021. Honey bee hives decrease wild bee abundance, species richness, and fruit count on farms regardless of wildflower strips. Sci Rep 11, 3202. https://doi.org/10.1038/s41598-021-81967-1

Bates, A.J., Sadler, J.P., Fairbrass, A.J., Falk, S.J., Hale, J.D., Matthews, T.J., 2011. Changing Bee and Hoverfly Pollinator Assemblages along an Urban-Rural Gradient. PLoS ONE 6, e23459. https://doi.org/10.1371/journal.pone.0023459

Beekman, M., Ratnieks, F.L.W., 2000. Long-range foraging by the honey-bee, *Apis mellifera* L. Functional Ecology 14, 490–496. https://doi.org/10.1046/j.1365-2435.2000.00443.x

Beer, K., Bloch, G., 2020. Circadian plasticity in honey bees. The Biochemist 42, 22–26. https://doi.org/10.1042/BIO04202002

Berenbaum, M.R., Calla, B., 2021. Honey as a Functional Food for *Apis mellifera*. Annu. Rev. Entomol. 66, 185–208. https://doi.org/10.1146/annurev-ento-040320-074933

Bloch, G., Shemesh, Y., Robinson, G.E., 2006. Seasonal and task-related variation in free running activity rhythms in honey bees (Apis mellifera). Insect. Soc. 53, 115–118. https://doi.org/10.1007/s00040-005-0844-7

Bommarco, R., Lindström, S.A.M., Raderschall, C.A., Gagic, V., Lundin, O., 2021. Flower strips enhance abundance of bumble bee queens and males in landscapes with few honey bee hives. Biological Conservation 263, 109363. https://doi.org/10.1016/j.biocon.2021.109363

Breeze, T.D., Vaissière, B.E., Bommarco, R., Petanidou, T., Seraphides, N., Kozák, L., Scheper, J., Biesmeijer, J.C., Kleijn, D., Gyldenkærne, S., Moretti, M., Holzschuh, A., Steffan-Dewenter, I., Stout, J.C., Pärtel, M., Zobel, M., Potts, S.G., 2014. Agricultural Policies Exacerbate Honeybee Pollination Service Supply-Demand Mismatches Across Europe. PLoS ONE 9, e82996. https://doi.org/10.1371/journal.pone.0082996

Brodschneider, R., Crailsheim, K., 2010. Nutrition and health in honey bees. Apidologie 41, 278–294. https://doi.org/10.1051/apido/2010012

Calderone, N.W., 2012. Insect Pollinated Crops, Insect Pollinators and US Agriculture: Trend Analysis of Aggregate Data for the Period 1992–2009. PLoS ONE 7, e37235. https://doi.org/10.1371/journal.pone.0037235

Crailsheim, K., Hrassnigg, N., Stabentheiner, A., 1996. Diurnal behavioural differences in forager and nurse honey bees (Apis mellifera carnica Pollm). Apidologie 27, 235–244. https://doi.org/10.1051/apido:19960406

Crane, E., 1999. The world history of beekeeping and honey hunting. Routledge, Taylor & Francis Group, New York, NY London.

Danner, N., Keller, A., Härtel, S., Steffan-Dewenter, I., 2017. Honey bee foraging ecology: Season but not landscape diversity shapes the amount and diversity of collected pollen. PLoS ONE 12, e0183716. https://doi.org/10.1371/journal.pone.0183716

De La Rúa, P., Jaffé, R., Dall'Olio, R., Muñoz, I., Serrano, J., 2009. Biodiversity, conservation and current threats to European honeybees. Apidologie 40, 263–284. https://doi.org/10.1051/apido/2009027

Delaplane, K.S., 2021. Crop pollination by bees, Volume 1: Evolution, ecology, conservation, and management, 2nd ed. CABI, UK. https://doi.org/10.1079/9781786393494.0000

Di Pasquale, G., Salignon, M., Le Conte, Y., Belzunces, L.P., Decourtye, A., Kretzschmar, A., Suchail, S., Brunet, J.-L., Alaux, C., 2013. Influence of Pollen Nutrition on Honey Bee Health: Do Pollen Quality and Diversity Matter? PLoS ONE 8, e72016. https://doi.org/10.1371/journal.pone.0072016

Dynes, T.L., Berry, J.A., Delaplane, K.S., Brosi, B.J., De Roode, J.C., 2019. Reduced density and visually complex apiaries reduce parasite load and promote honey production and overwintering survival in honey bees. PLoS ONE 14, e0216286. https://doi.org/10.1371/journal.pone.0216286

Eyer, M., Neumann, P., Dietemann, V., 2016. A Look into the Cell: Honey Storage in Honey Bees, Apis mellifera. PLoS ONE 11, e0161059. https://doi.org/10.1371/journal.pone.0161059

Fragoso, F.P., Brunet, J., 2023. Honey bees exhibit greater patch fidelity than bumble bees when foraging in a common environment. Ecosphere 14, e4606. https://doi.org/10.1002/ecs2.4606

Frisch, K. von, 1993. The dance language and orientation of bees. Harvard university press, Cambridge (Mass.) London.

Gallai, N., Salles, J.-M., Settele, J., Vaissière, B.E., 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecological Economics 68, 810–821. https://doi.org/10.1016/j.ecolecon.2008.06.014

Geslin, B., Gauzens, B., Baude, M., Dajoz, I., Fontaine, C., Henry, M., Ropars, L., Rollin, O., Thébault, E., Vereecken, N.J., 2017. Massively Introduced Managed Species and Their Consequences for Plant–Pollinator Interactions, in: Advances in Ecological Research. Elsevier, pp. 147–199. https://doi.org/10.1016/bs.aecr.2016.10.007

Ghosh, S., Jeon, H., Jung, C., 2020. Foraging behaviour and preference of pollen sources by honey bee (Apis mellifera) relative to protein contents. j ecology environ 44, 4. https://doi.org/10.1186/s41610-020-0149-9

González-Varo, J.P., Biesmeijer, J.C., Bommarco, R., Potts, S.G., Schweiger, O., Smith, H.G., Steffan-Dewenter, I., Szentgyörgyi, H., Woyciechowski, M., Vilà, M., 2013. Combined effects of global change pressures on animal-mediated pollination. Trends in Ecology & Evolution 28, 524–530. https://doi.org/10.1016/j.tree.2013.05.008

Gordon, R., Bresolin-Schott, N., East, I., 2014. Nomadic beekeeper movements create the potential for widespread disease in the honeybee industry. Aust Veterinary J 92, 283–290. https://doi.org/10.1111/avj.12198

Guzman, L.M., Elle, E., Morandin, L.A., Cobb, N.S., Chesshire, P.R., McCabe, L.M., Hughes, A., Orr, M., M'Gonigle, L.K., 2024. Impact of pesticide use on wild bee distributions across the United States. Nat Sustain 7, 1324–1334. https://doi.org/10.1038/s41893-024-01413-8

Hall, D.M., Camilo, G.R., Tonietto, R.K., Ollerton, J., Ahrné, K., Arduser, M., Ascher, J.S., Baldock, K.C.R., Fowler, R., Frankie, G., Goulson, D., Gunnarsson, B., Hanley, M.E., Jackson, J.I., Langellotto, G., Lowenstein, D., Minor, E.S., Philpott, S.M., Potts, S.G., Sirohi, M.H., Spevak, E.M., Stone, G.N., Threlfall, C.G., 2017. The city as a refuge for insect pollinators. Conservation Biology 31, 24–29. https://doi.org/10.1111/cobi.12840

Hamblin, A.L., Youngsteadt, E., López-Uribe, M.M., Frank, S.D., 2017. Physiological thermal limits predict differential responses of bees to urban heat-island effects. Biol. Lett. 13, 20170125. https://doi.org/10.1098/rsbl.2017.0125

Harano, K., 2020. Honeybee colonies provide foragers with costly fuel to promote pollen collection. J Comp Physiol A 206, 587–595. https://doi.org/10.1007/s00359-020-01427-5

Henry, M., Rodet, G., 2020. The apiary influence range: A new paradigm for managing the cohabitation of honey bees and wild bee communities. Acta Oecologica 105, 103555. https://doi.org/10.1016/j.actao.2020.103555

Henry, M., Rodet, G., 2018. Controlling the impact of the managed honeybee on wild bees in protected areas. Scientific Reports 8, 9308. https://doi.org/10.1038/s41598-018-27591-y

Holzschuh, A., Dainese, M., González-Varo, J.P., Mudri-Stojnić, S., Riedinger, V., Rundlöf, M., Scheper, J., Wickens, J.B., Wickens, V.J., Bommarco, R., Kleijn, D., Potts, S.G., Roberts, S.P.M., Smith, H.G., Vilà, M., Vujić, A., Steffan-Dewenter, I., 2016. Mass-flowering crops dilute pollinator abundance in agricultural landscapes across Europe. Ecology Letters 19, 1228–1236. https://doi.org/10.1111/ele.12657

Holzschuh, A., Dormann, C.F., Tscharntke, T., Steffan-Dewenter, I., 2013. Mass-flowering crops enhance wild bee abundance. Oecologia 172, 477–484. https://doi.org/10.1007/s00442-012-2515-5

Huang, Z.-Y., Robinson, G.E., 1995. Seasonal changes in juvenile hormone titers and rates of biosynthesis in honey bees. J Comp Physiol B 165, 18–28. https://doi.org/10.1007/BF00264682

Hung, K.-L.J., Kingston, J.M., Lee, A., Holway, D.A., Kohn, J.R., 2019. Non-native honey bees disproportionately dominate the most abundant floral resources in a biodiversity hotspot. Proc. R. Soc. B. 286, 20182901. https://doi.org/10.1098/rspb.2018.2901

IPBES, 2016. The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. Zenodo. https://doi.org/10.5281/ZENODO.3402856

Johnson, B.R., 2023. Honey bee biology, First edition. ed. Princeton University Press, Princeton Oxford. https://doi.org/10.1515/9780691246093

Klee, J., Besana, A.M., Genersch, E., Gisder, S., Nanetti, A., Tam, D.Q., Chinh, T.X., Puerta, F., Ruz, J.M., Kryger, P., Message, D., Hatjina, F., Korpela, S., Fries, I., Paxton, R.J., 2007. Widespread dispersal of the microsporidian Nosema ceranae, an emergent pathogen of the western honey bee, Apis mellifera. Journal of Invertebrate Pathology 96, 1–10. https://doi.org/10.1016/j.jip.2007.02.014

Klein, A.-M., Vaissière, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. Proc. R. Soc. B. 274, 303–313. https://doi.org/10.1098/rspb.2006.3721

Kosior, A., Celary, W., Olejniczak, P., Fijał, J., Król, W., Solarz, W., Płonka, P., 2007. The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of Western and Central Europe. Oryx 41, 79–88. https://doi.org/10.1017/S0030605307001597

Kovács-Hostyánszki, A., Szigeti, V., Miholcsa, Z., Sándor, D., Soltész, Z., Török, E., Fenesi, A., 2022. Threats and benefits of invasive alien plant species on pollinators. Basic and Applied Ecology 64, 89–102. https://doi.org/10.1016/j.baae.2022.07.003

Kumar, G., Khan, M.S., 2023. Insects as Crop Pollinators, in: Omkar (Ed.), Insects as Service Providers. Springer Nature Singapore, Singapore, pp. 37–64. https://doi.org/10.1007/978-981-19-3406-3_3

Kumar, R., Agrawal, O.P., Hajam, Y.A. (Eds.), 2022. Honey: a miraculous product of nature. CRC Press, Boca Raton London New York.

LeBuhn, G., Vargas Luna, J., 2021. Pollinator decline: what do we know about the drivers of solitary bee declines? Current Opinion in Insect Science 46, 106–111. https://doi.org/10.1016/j.cois.2021.05.004

Lorenzato, L., Fantinato, E., Sommaggio, D., Favarin, S., Buffa, G., 2024. Pollinator abundance, not the richness, benefits from urban green spaces in intensive agricultural land. Urban Ecosyst 27, 1949–1959. https://doi.org/10.1007/s11252-024-01565-7

Lowe, A., Jones, L., Brennan, G., Creer, S., De Vere, N., 2022. Seasonal progression and differences in major floral resource use by bees and hoverflies in a diverse horticultural and agricultural landscape revealed by DNA metabarcoding. Journal of Applied Ecology 59, 1484–1495. https://doi.org/10.1111/1365-2664.14144

Mallinger, R.E., Gaines-Day, H.R., Gratton, C., 2017. Do managed bees have negative effects on wild bees?: A systematic review of the literature. PLoS ONE 12, e0189268. https://doi.org/10.1371/journal.pone.0189268

Martínez-López, V., Ruiz, C., De La Rúa, P., 2022. “Migratory beekeeping and its influence on the prevalence and dispersal of pathogens to managed and wild bees.” International Journal for Parasitology: Parasites and Wildlife 18, 184–193. https://doi.org/10.1016/j.ijppaw.2022.05.004

Mavrofridis, G., Tataris, G., Petanidou, T., 2024. Traditional migratory beekeeping in Greece, 18th – mid 20th century. Journal of Apicultural Research 63, 417–430. https://doi.org/10.1080/00218839.2023.2221564

Ollerton, J., 2017. Pollinator Diversity: Distribution, Ecological Function, and Conservation. Annu. Rev. Ecol. Evol. Syst. 48, 353–376. https://doi.org/10.1146/annurev-ecolsys-110316-022919

Pérez-Méndez, N., Andersson, G.K.S., Requier, F., Hipólito, J., Aizen, M.A., Morales, C.L., García, N., Gennari, G.P., Garibaldi, L.A., 2020. The economic cost of losing native pollinator species for orchard production. Journal of Applied Ecology 57, 599–608. https://doi.org/10.1111/1365-2664.13561

Phillips, B.B., Wallace, C., Roberts, B.R., Whitehouse, A.T., Gaston, K.J., Bullock, J.M., Dicks, L.V., Osborne, J.L., 2020. Enhancing road verges to aid pollinator conservation: A review. Biological Conservation 250, 108687. https://doi.org/10.1016/j.biocon.2020.108687

Phiri, B.J., Fèvre, D., Hidano, A., 2022. Uptrend in global managed honey bee colonies and production based on a six-decade viewpoint, 1961–2017. Sci Rep 12, 21298. https://doi.org/10.1038/s41598-022-25290-3

Requier, F., Odoux, J.-F., Tamic, T., Moreau, N., Henry, M., Decourtye, A., Bretagnolle, V., 2015. Honey bee diet in intensive farmland habitats reveals an unexpectedly high flower richness and a major role of weeds. Ecological Applications 25, 881–890. https://doi.org/10.1890/14-1011.1

Richardson, R.T., Eaton, T.D., Lin, C., Cherry, G., Johnson, R.M., Sponsler, D.B., 2021. Application of plant metabarcoding to identify diverse honeybee pollen forage along an urban–agricultural gradient. Molecular Ecology 30, 310–323. https://doi.org/10.1111/mec.15704

Ricketts, T.H., Regetz, J., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S.S., Klein, A.M., Mayfield, M.M., Morandin, L.A., Ochieng', A., Viana, B.F., 2008. Landscape effects on crop pollination services: are there general patterns? Ecology Letters 11, 499–515. https://doi.org/10.1111/j.1461-0248.2008.01157.x

Rojas-Nossa, S.V., Calviño-Cancela, M., 2020. The invasive hornet Vespa velutina affects pollination of a wild plant through changes in abundance and behaviour of floral visitors. Biol Invasions 22, 2609–2618. https://doi.org/10.1007/s10530-020-02275-9

Seeley, T.D., 1995. The wisdom of the hive: the social physiology of honey bee colonies. Harvard University Press, Cambridge, Mass.

Seeley, T.D., Visscher, P.K., 1985. Survival of honeybees in cold climates: the critical timing of colony growth and reproduction. Ecological Entomology 10, 81–88. https://doi.org/10.1111/j.1365-2311.1985.tb00537.x

Senapathi, D., Carvalheiro, L.G., Biesmeijer, J.C., Dodson, C.-A., Evans, R.L., McKerchar, M., Morton, R.D., Moss, E.D., Roberts, S.P.M., Kunin, W.E., Potts, S.G., 2015. The impact of over 80 years of land cover changes on bee and wasp pollinator communities in England. Proc. R. Soc. B. 282, 20150294. https://doi.org/10.1098/rspb.2015.0294

Settele, J., Bishop, J., Potts, S.G., 2016. Climate change impacts on pollination. Nature Plants 2, 16092. https://doi.org/10.1038/nplants.2016.92

Southwick, E.E., Heldmaier, G., 1987. Temperature Control in Honey Bee Colonies. BioScience 37, 395–399. https://doi.org/10.2307/1310562

Sponsler, D.B., Grozinger, C.M., Richardson, R.T., Nurse, A., Brough, D., Patch, H.M., Stoner, K.A., 2020. A screening-level assessment of the pollinator-attractiveness of ornamental nursery stock using a honey bee foraging assay. Sci Rep 10, 831. https://doi.org/10.1038/s41598-020-57858-2

Tehel, A., Brown, M.J., Paxton, R.J., 2016. Impact of managed honey bee viruses on wild bees. Current Opinion in Virology 19, 16–22. https://doi.org/10.1016/j.coviro.2016.06.006

Tong, Z.-Y., Wu, L.-Y., Feng, H.-H., Zhang, M., Armbruster, W.S., Renner, S.S., Huang, S.-Q., 2023. New calculations indicate that 90% of flowering plant species are animal-pollinated. National Science Review 10, nwad219. https://doi.org/10.1093/nsr/nwad219

Walker, L., Wu, S., 2017. Pollinators and Pesticides, in: Steier, G., Patel, K.K. (Eds.), International Farm Animal, Wildlife and Food Safety Law. Springer International Publishing, Cham, pp. 495–513. https://doi.org/10.1007/978-3-319-18002-1_17

Westphal, C., Steffan-Dewenter, I., Tscharntke, T., 2003. Mass flowering crops enhance pollinator densities at a landscape scale. Ecology Letters 6, 961–965. https://doi.org/10.1046/j.1461-0248.2003.00523.x

Zhu, X., Zhou, S., Huang, Z.Y., 2014. Transportation and pollination service increase abundance and prevalence of *Nosema ceranae* in honey bees (*Apis mellifera*). Journal of Apicultural Research 53, 469–471. https://doi.org/10.3896/IBRA.1.53.4.06