



# Strategies and Outcomes in Bee Conservation: Evaluating Impact on Pollination Ecosystems

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## Authors' contributions

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Pollination stands as a crucial process vital for ecosystem maintenance, with pollinators serving as pivotal vectors. Approximately 80% of pollination relies on insects, with bees emerging as primary contributors. Their significant role in ecosystem services and economic value cannot be overstated, given that approximately 30% of food sources directly or indirectly rely on honeybee pollination. Additionally, honeybees provide essential products such as honey, propolis, beeswax, and venom. However, the alarming decline in honeybee populations due to various threats, including habitat loss from land use intensification, pesticides, climate change, pathogens, parasites, diseases, invasive species, and nutritional deficiencies, poses a grave concern. To ensure the conservation of honeybees and sustain pollination for future generations, a multifaceted approach is imperative. Key strategies include promoting beekeeping in urban areas to provide alternative habitats, implementing pesticide bans to mitigate harmful effects, fostering genetic resistance to combat diseases, establishing wildflower strips to enhance foraging resources, employing biocontrol agents

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for pest management, ensuring proper nutrition through diverse floral resources, and implementing effective sterilization techniques. Evaluating the impact of these conservation efforts on pollination ecosystems is paramount for assessing their efficacy and guiding future conservation initiatives.

*Keywords: Pollinator; honeybees; Urban beekeeping.*

## 1. INTRODUCTION

The survival of ecosystems, human agriculture, and various plant species relies heavily on the indispensable ecosystem service of pollination, where pollinators facilitate the transfer of pollen from the male stamen to the female stigma of plants. This intricate process not only sustains wild plant networks but also enhances farming efficiency [1]. Approximately 80% of wild plant species and 75% of crop types crucial for human consumption depend on insect pollination [2]. Among the diverse pollinators, bees contribute significantly to this vital ecological function. Bees, encompassing a reported 17,553 species globally, with 633 species in India alone, play a pivotal role in ensuring effective pollination of both native and cultivated crops [3], [4]. Honey bees, constituting a substantial portion of the bee population, are not only economically valuable for honey and wax production but are also essential pollinators for a myriad of crops, including almonds, apples, cherries, and more [5]. Studies indicate that bee pollination can boost crop production by up to 50% [6].

Despite their crucial role, there is a concerning decline in pollinator populations globally. Factors such as habitat loss, agricultural intensification, pesticide use, and the introduction of alien species contribute to this decline, posing a threat to both pollinators and the plants reliant on them [7], [8]. Rapid urbanization and deforestation further exacerbate the challenges faced by pollinators [9].

Conservation efforts are imperative to address this decline in pollinator populations. Strategies include habitat creation, urban beekeeping, protection of non-floral resources, and banning harmful pesticides [10], [11], [7]. The importance of conserving bees extends beyond their role in pollination – it also influences floral growth, providing shelter and sustenance for various animals, insects, and birds. The origin and global distribution of honey bees, recognizing their significance as pollinators, identifying major crops dependent on bee pollination, and implementing conservation measures are crucial

steps in safeguarding these essential contributors to our ecosystems. Failure to address the decline in honey bee populations could result in a significant impact on global crop production and nutrition. Therefore, urgent and concerted efforts are needed to ensure the conservation of bees for the well-being of both ecosystems and humanity [12].

## 2. WHAT ARE POLLINATORS?

A pollinator refers to biotic agents, creatures, or vectors that transfer pollen from the anthers to the stigma of a flower. Insects and various other animal pollinators play a crucial role in ensuring the development of robust crops for food, fibres, edible oils, medicines, and other essential products. The contribution of pollinators is immense in the production of a wide range of fruits, vegetables, and field crops. Numerous reports highlight insect pollination as a pivotal ecosystem service supporting agricultural food production at both local and global levels [13].

Honey bees are particularly significant for crop pollination, but other insects such as wasps and butterflies also play a vital role in pollinating numerous economically and ecologically important plant species. Additionally, pollinating birds, including humming birds and roosting birds, as well as flies, rodents, monkeys, snails, and slugs, are effective contributors to the pollination process. Achieving enhanced pollination in crops is essential for sustainable food production as it reduces the time between flowering and fruit setting, resulting in better-shaped fruits. A majority of these pollinators belong to the dipteran and Hymenoptera categories [14].

### **Crops benefitted by honey bee pollination:**

Honeybees are important pollinators to many horticultural crops and also, they are important for the sustainability of many of the cultivated and wild plants [15]. Approximately 30% of the food crops around the world are directly or indirectly pollinated by honey bees [16]. The following table 1 shows the various crops that are benefitted by honey bee pollination.

**List 1. Contributions of the pollinators**

S. No	Crops	Pollinator/Visitors
1.	Tomato, Watermelon, cole crop, pumpkin and squash, lettuce, okra, onion.	Honey bees
2.	Lima beans, beans, beet, bitter gourd	Thrips
3.	Field been, Carrot, Scarlet runner bean	Bumble bees
4.	Parsnip, peppers, brinjal	Beetles
5.	Fig	Female fig wasps
6.	Carrot, Chilli	Solitary bees
7.	Okra, Radish	Flies
8.	Banana, Guava	Bats
9.	Papaya	Moths
10.	Vanilla	Birds

[5], [14]

**Table 1. Crops benefitted from honey bee pollination**

S. No	crop	Scientific name	Family	Mode of pollination	Benefit
1.	Kiwi	<i>Actinidia deliciosa</i>	Actinidiaceae	Cross pollination	Fruit set and yield of the fruit increase
2.	Pear	<i>Pyrus</i>	Rosaceae	Cross pollination	Increase in the yield by 10to 15%and fruit size by 7%
3.	Citrus	<i>Citrus</i>	Rutaceae	Self-pollination or cross pollination	Increase in fruit set and weight by 24% and 35% resp.
4.	Apple	<i>Malus domestica</i>	Rosaceae	Cross pollination	Fruit set increase by 10%. Also increase in fruit sugar and seed set.
5.	Water melon	<i>Citrullus lanatus</i>	Cucurbitaceae	Cross pollination	As no. of honey bee visits increase the fruit No., fruit set and weight increase linearly
6.	Avocado	<i>Persea americana</i>	Lauraceae	Cross pollination	Increase the production and improves fruit weight.
<b>Vegetables</b>					
7.	Pumpkin	<i>Cucurbita maxima</i>	Cucurbitaceae	Cross pollination	Linear increase in fruit size, set and weight and no. of seeds as the number of visits increase.
8.	Cucumber	<i>Cucumis sativus</i>	Cucurbitaceae	Self-pollination	Increase in production by 10%
<b>Other Plants</b>					
9.	Soya beam	<i>Glycine max</i>	Fabaceae	Self-pollination	Increase yield by 18.09% and seed no.
10.	Cotton	<i>Gossypium hirsutum</i>	Meliaceae	Self-pollination	Increased production for fiber weight and seed no. by 12%and 17% resp.

[17], [18]



**Fig 1. Threats to Honeybee population**

**Threats to Honeybees:** Honey bees are important pollinators in the ecosystem and agriculture; however, their numbers have significantly declined. Declines in insect population are thought to result in multiple factors together with habitat loss, temperature change, exaggerated vulnerability to diseases and parasites and chemical use.

**Climate change:** The impacts of climate change on honey bees and pollination are not completely obvious for some time. Climate changes the nature of flowers and can increment or lessen colony harvesting limit and advancement and impact the life cycle of honeybees [19].

Climate change can have a variety of effects on honey bees and other pollinators. It can change the quality of the environment of flora. Also climate change can have a direct impact on the behaviour of pollinators and their physiology. Any type of change in climate and migration of pollinators, especially honey bees race from one region to another is likely to have noticeable impacts. It can result in the emergence of new pathogens and parasites which are harmful to the pollinators [20].

**Pathogen and parasites:** Honey bees face a myriad of challenges from a diverse array of pathogens and parasites [21,22]. Several pathogens including viruses (ABPV, DWV, IAPV), bacteria (*Melissococcus plutonius*), fungi (*Nosema cerenae*), and the parasitic mite *Varroa destructor*, all implicated in colony losses across various regions globally. The impact of the phorid fly *Apocephalus borealis* on honey bees, noting its association with hive abandonment behaviour and subsequent death of parasitized bees, with phorid larvae emerging from the deceased bees. Microarray analysis revealed the presence of twisted wing virus and *Nosema cerenae* in infected hives [22]. The role of *Varroa* and other microorganisms in honey bee health, particularly in *A. miberiensis* subspecies used in Spanish apiculture. Their findings underscored the critical link between *Varroa* infestation and viral diseases such as deformed wing virus and acute paralysis virus, emphasizing the urgent need for effective *Varroa* control to mitigate colony losses [23].

**Pesticide:** The risk posed by pesticides to honeybees encompasses both toxicity and exposure levels, influenced by various factors such as chemical composition, land management practices, interaction with other stressors, and

landscape features [24]. Herbicides, employed for weed control, indirectly threaten honeybees by reducing the abundance and diversity of flowering plants that provide essential pollen and nectar [25]. Studies have demonstrated the sublethal effects of pesticide exposure on honeybee behavior, Furthermore, investigated the effects of neonicotinoids on honeybee circadian rhythms and critical behaviors, finding that exposure disrupted circadian clocks and led to alterations in time memory, sleep patterns, and social communication. These disruptions in clock neurons suggest potential impairments in navigation and learning processes critical for honeybee survival [26].

**Nutrition deficit:** Honeybees rely on floral resources for essential nutrition, with nectar providing honey, warmth, and energy, while pollen supplies protein, vitamins, fatty substances, and other nutrients. Insufficient quality or quantity of nutrition renders honeybees vulnerable to certain diseases [27]. The importance of diverse floral resources, encompassing varied sugar content, nectar, and pollen species, for successful brood rearing in honeybee colonies. A balanced intake of carbohydrates, proteins, lipids, vitamins, minerals, and water from multiple floral sources is crucial for bee nutrition. Dependence on a single floral source can lead to nutritional deficiencies, resulting in undernourishment and population decline, particularly during reproduction and overwintering periods, especially under stress conditions [28].

**Land use intensification:** Land use changes, including habitat destruction and agricultural intensification, have led to a decline in pollination services and honeybee populations [29,30]. Pollinator species, particularly bees, are heavily impacted by habitat loss and degradation due to urbanization and intensified agriculture, resulting in local and regional declines. The extensive use of pesticides in intensive crop management further exacerbates this decline by damaging pollinator populations [7]. Urbanization poses a significant threat to honeybee health, affecting food store quality and colony strength, with urban areas showing positive effects on colony strength but rural areas exhibiting lower performance.

**Electromagnetic radiations:** The impact of cell phone tower electromagnetic radiation on honey bee foraging behaviour from December to May over two years. Five treatments at varying distances from the tower showed that worker

bees' foraging behaviour was highest at 500m, followed by 1000m, 300m, and 200m, with the minimum at 100m. The study suggests that honey bees near the tower experienced adverse effects, leading to a decline in their population [31].

**Alien species:** The presence of invasive species like *Vespa velutina* poses significant environmental threats to honeybees and pollination ecosystems, as invasive predators can disrupt native honeybee populations, leading to changes in pollination frameworks. [32]. *Vespa velutina* presence correlates with increased oxidative stress in honeybee workers, emphasizing the negative impact on honeybee health. These findings underscore the urgent need for conservation efforts amidst multiple threats like climate change, pesticides, pathogens, electromagnetic radiation, and land intensification [33].

**Need to conserve:** In conservation efforts, understanding the tangible benefits of species is crucial for prioritization and funding allocation. While the significant value of crops pollinated by western honey bees (*Apis mellifera*) is well-documented, assessments for Asian regions are lacking. Deforestation contributes to honeybee decline, impacting ecosystems reliant on pollination. Hence, halting deforestation is imperative. Conservation strategies must align with both philosophy and sound science, focusing on achievable goals with tangible benefits [34].

**Importance in the environment:** Honey bees are cornerstone species, if honey bees vanish it will end most life. In nature different creatures depend on honey bees for endurance because their food sources-nuts, berries, seed and organic products on insect pollination. Pollination, likewise permits botanical development, which gives living spaces for creatures, including different bugs and birds. Finally honey bees themselves and the honey they produce are well. Spring of nourishment for some creatures [35].

**Environment Services:** While the honey bee populace proceeds to decline, the development of food harvests will diminish also, as honeybee pollination is essential for a very long-time crop. Honey bees are answerable for pollinating 35% of rural creation and very nearly 90 different monetarily developed food crops [36].

**Economic Contribution:** The worth of honey bee pollination to overall horticulture has been assessed to be around 215 billion dollars. Other than their job as pollinators of numerous plant, vegetable and field crop as well as wild blossoms, honey bees are the wellspring of honey and different honey hives items, for example, propolis, royal jam, toxin and beeswax. The overall creation of honey sums north of 1,000,000 tons, yielding a trade market worth over 1 billion [37].

**Plant Pollination:** Pollinators unequivocally impact the environmental connections, biological system protection and solidness of the hereditary variety in plant networks. More than 35% of harvests and significant 60 to 80% of wild plant species depend on the movement of pollinators, honey bees are among the major pollinating insects that assume a significant part in ensuring yield and quality for various plant, field and vegetable harvests. They are likewise the most financially significant pollinators of yield monocultures around the world. Without the movement of these insects, the yield of few natural products, seed and nuts harvests would diminish, by more than 90%. Undoubtedly, clear any decrease in the pollinator populace will think twice about creation and thusly the economy [38].

**Conservation of Honeybees:** Honeybees are significant pollinators of many natural products, nuts, vegetables and field crops. Honeybees additionally pollinate different wild-blooming plants and assist with keeping up with the biological systems. Right now, these honeybees are confronting various dangers including pesticides, habitat loss and many other. As a result of the decrease in their number, there is an extraordinary loss of environmental administrations which impacts the world economy [39].

So, in order to decrease the decline in the honeybee population various conservation methods are used.

**Beekeeping in urban area:** Urban beekeeping offers advantages due to reduced exposure to pesticides, but public concerns for health necessitate the implementation of barriers [40,41]. Honeybee flight patterns with barriers at varying distances and heights, finding that barriers were effective in increasing flight height, especially when placed closer to the hives.

Urban beekeeping contributes to biodiversity and community building [42].

**Bio control Agents:** Breeding biocontrol agents present a promising and environmentally friendly approach for managing honeybee parasitic and harmful pests by leveraging beneficial microorganisms and natural products [43]. An eco-friendly biocontrol method by conserving honeybees through their own microbiota, showcasing the potential of supporting honeybee health against infections. Various bacteria found in healthy honeybees and their products exhibit significant inhibitory activity against the American foulbrood agent *P. larvae* [44]. Additionally, the use of antibiotic treatment, specifically oxytetracycline hydrochloride, as a means to control American foulbrood disease in honeybees, providing a method to mask infection signs in hives for an extended period [45].

**Chemical:** The use of antibacterial sodium sulfathiazole to reduce bacterial diseases in honeybee hives rapidly. Fumagillin antibiotics at 25 mg/1L of sugar syrup can decrease Nosema disease during extended precipitation seasons. To control *Varroa destructor* and its damage, various substances such as essential oils, organic acids, amitraz, oxalic acid, lactic acid, flumethrin, and formic acid are employed [46]. The global use of various products for mite management, noting the adverse environmental effects of chemical pesticides. Formic acid and Mite-Away quick strips were found to be commercially available products that effectively reduce mite populations within about 2 months, with no observed negative impact on honeybees. Sulfur-containing compounds, like sulfur and Hopguard, were also used to reduce mite populations but had effects on adult bees in developing colonies [47].

**Genetic resistance:** Honeybees exhibit genetic resistance to certain pathogens and parasites. waxes and unsaturated fatty acids in honeybee cuticles possess antifungal properties, breaking down primary physical barriers in invading organisms [48]. Invasive organisms trigger various physiological immune responses, including cell and humoral immune reactions, with phagocytosis and encapsulation being common defense mechanisms against entomopathogenic

organisms [49] [50]. The midgut's biochemical environment provides protection against food-borne parasites, while septic injuries prompt the activation of clotting cascades and melanin production, which release reactive oxygen species with cytotoxic antimicrobial properties, preventing further infection [51].

**Proper Sterilization techniques:** The gamma irradiation with a cobalt-60 source used to disinfect polluted beekeeping instrumentation. It is accomplished after the honey bee wax and honey are irradiated. At the ideal degree of irradiation, it had no adverse consequences on the wax constitution, aside from chemical science adjustments of honey like diminishing of its enzymatic exercises and changing of shading [52].

**Proper nutrition:** The availability of assorted floral resources and its species regarding nectar, sugar content and pollen square measure important for brood rearing. Honeybee should be accessing the adequate sources of carbohydrates, proteins, lipids, vitamins Minerals and water that collect from the nectar pollen, honey reserves and different water supplements [53]. Nectar could be a supply of honey, heat and energy for honeybees whereas pollen provide macromolecule, vitamins, fatty substances and alternative nutrients [54].

### 3. CONCLUSION

In summary, diverse pollinators contribute to the vital process of pollination, with bees playing a predominant role at 73%. Honey bee pollination positively impacts various crops, including those in the Cucurbitaceae family. Global variations in winter honey bee population losses were observed in 2018-19. The decline in pollinator populations has led to significant crop losses, particularly in stimulant crops. The Brassicaceae family stands out as a major source of pollen and nectar for a variety of plants.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

### REFERENCES

1. Garibaldi LA, Steffan-Dewenter I, Winfree R, Aizen MA, Bommarco R, Cunningham

- SA, Klein AM. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science*. 2013; 339(6127):1608-1611.
2. Klein AM, Vaissiere BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, Tscharntke T. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*. 2007;274(1608):303-313. Available: <https://doi.org/10.1098/rspb.2006.3721>
  3. Lerman SB, Milam J. Bee fauna and floral abundance within lawn-dominated suburban yards in Springfield, MA. *Annals of the Entomological Society of America*. 2016;109(5):713-723.
  4. Chandra K, Saini J, Gupta D. Insecta: Hymenoptera: Apoidea (Bees). *Fauna of Punjab, State Fauna Series*. 2019;23:1-486.
  5. Pannure A. Bee pollinators decline: perspectives from India. *International Research Journal of Natural and Applied Sciences*. 2016;3(5):1-10.
  6. Krishnan S, Kushalappa CG, Shaanker RU, Ghazoul J. Status of pollinators and their efficiency in coffee fruit set in a fragmented landscape mosaic in South India. *Basic and Applied Ecology*. 2012;13(3):277-285. Available: <https://doi.org/10.1016/j.baae.2012.03.007>
  7. Vanbergen AJ, Initiative TIP. Threats to an ecosystem service: Pressures on pollinators. *Frontiers in Ecology and the Environment*. 2013;11(5):251-259. Available: <https://doi.org/10.1890/120126>
  8. Gill RJ, Baldock KC, Brown MJ, Cresswell JE, Dicks LV, Fountain MT, Potts SG. Protecting an ecosystem service: Approaches to understanding and mitigating threats to wild insect pollinators. In *Advances in Ecological Research*. 2016;54:135-206. Available: <https://doi.org/10.1016/bs.aecr.2015.10.007>
  9. Sodhi NS, Koh LP, Brook BW, Ng PK. Southeast Asian biodiversity: An impending disaster. *Trends in Ecology & Evolution*. 2004;19(12):654-660. Available: <https://doi.org/10.1016/j.tree.2004.09.006>
  10. Egerer M, Kowarik I. Confronting the modern gordian knot of urban beekeeping. *Trends in Ecology & Evolution*. 2020; 35(11):956-959. Available: <https://doi.org/10.1016/j.tree.2020.07.012>
  11. Requier F, Leonhardt SD. Beyond flowers: including non-floral resources in bee conservation schemes. *Journal of Insect Conservation*. 2020;24(1):5-16. Available: <https://doi.org/10.1007/s10841-019-00206-1>
  12. Kamala IM, Devanand II. Pollination and ecological intensification: A way towards green revolution. In *Ecological Intensification of Natural Resources for Sustainable Agriculture*. 2021;381-427. Available: [https://doi.org/10.1007/978-981-33-4203-3\\_11](https://doi.org/10.1007/978-981-33-4203-3_11)
  13. Das A, Sau S, Pandit MK, Saha K. A review on: Importance of pollinators in fruit and vegetable production and their collateral jeopardy from agro-chemicals. *Journal of Entomology and Zoology Studies*. 2018;6(4):1586-1591.
  14. Sharma A, Banerjee J. Pollinator management-A realistic way to improve yield of vegetables and Spices. 2021; 1(10):1-8.
  15. Guzman-Novoa E, Cork S, Hall DC, Liljebjelke K. Colony collapse disorder and other threats to honey bees. One health case studies: addressing complex problems in a changing world. 2016;204-216.
  16. Greenleaf SS, Kremen C. Wild bees enhance honey bees' pollination of hybrid sunflower. *Proceedings of the National Academy of Sciences*. 2006;103(37):13890-13895. Available: <https://doi.org/10.1073/pnas.060929103>
  17. Joshi U, Kothiyal K, Kumar Y, Bhatt R. Role of honeybees in horticultural crop productivity enhancement. *International Journal Agricultural Science*. 2021;17:314-320. DOI: 10.15740/HAS/IJAS/17-AAEBSSD/314-320
  18. Khalifa SA, Elshafiey EH, Shetaia AA, El-Wahed AAA, Algethami AF, Musharraf SG, El-Seedi HR. Overview of bee pollination and its economic value for crop production. *Insects*. 2021;12(8):688.

- Available:<https://doi.org/10.3390/insects12080688>
19. Field CB, Barros VR. (Eds.). Climate change 2014–Impacts, adaptation and vulnerability: Regional aspects. Cambridge University Press; 2014.
  20. Le Conte Y, Navajas M. Climate change: impact on honey bee populations and diseases. *Revue Scientifique et Technique-Office International des Epizooties*. 2008;27(2):499-510.
  21. Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE. Global pollinator declines: Trends, impacts and drivers. *Trends in Ecology & Evolution*. 2010;25(6):345-353.  
Available:<https://doi.org/10.1016/j.tree.2010.01.007>
  22. Genersch E. Honey bee pathology: Current threats to honey bees and beekeeping. *Applied Microbiology and Biotechnology*. 2010;87(1):87-97.  
Available:<https://doi.org/10.1007/s00253-010-2573-8>
  23. Flores JM, Gámiz V, Jiménez-Marín Á, Flores-Cortés A, Gil-Lebrero S, Garrido JJ, Hernando MD. Impact of varroa destructor and associated pathologies on the colony collapse disorder affecting honey bees. *Research in Veterinary Science*. 2021; 135:85-95.  
Available:<https://doi.org/10.1016/j.rvsc.2021.01.001>
  24. Park MG, Blitzer EJ, Gibbs J, Losey JE, Danforth BN. Negative effects of pesticides on wild bee communities can be buffered by landscape context. *Proceedings of the Royal Society B: Biological Sciences*. 2015;282(1809):20150299.  
Available:<https://doi.org/10.1098/rspb.2015.0299>
  25. Gabriel D, Tschardt T. Insect pollinated plants benefit from organic farming. *Agriculture, Ecosystems & Environment*. 2007;118(1-4):43-48.  
Available:<https://doi.org/10.1016/j.agee.2006.04.005>
  26. Tackenberg MC, Giannoni-Guzmán MA, Sanchez-Perez E, Doll CA, Agosto-Rivera JL, Broadie K, McMahon DG. Neonicotinoids disrupt circadian rhythms and sleep in honey bees. *Scientific Reports*. 2020;10(1):1-10.  
Available:<https://doi.org/10.1038/s41598-020-72041-3>
  27. Dolezal AG, Toth AL. Feedbacks between nutrition and disease in honey bee health. *Current Opinion in Insect Science*. 2018;26:114-119.  
Available:<https://doi.org/10.1016/j.cois.2018.02.006>
  28. Hendriksma HP, Shafir S. Honey bee foragers balance colony nutritional deficiencies. *Behavioral Ecology and Sociobiology*. 2016;70(4):509-517.  
Available:<https://doi.org/10.1007/s00265-016-2067-5>
  29. Baude M, Kunin WE, Boatman ND, Conyers S, Davies N, Gillespie MA, Morton RD, Smart SM, Memmott J. Historical nectar assessment reveals the fall and rise of floral resources in Britain. *Nature*. 2016;530(7588):85-88.  
Available:<https://doi.org/10.1038/nature16532>
  30. Kennedy CM, Lonsdorf E, Neel MC, Williams NM, Ricketts TH, Winfree R, Kremen C. A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems. *Ecology Letters*. 2013;16(5):584-599.  
Available:<https://doi.org/10.1111/ele.12082>
  31. Taye RR, Deka MK, Rahman A, Bathari M. Effect of electromagnetic radiation of cell phone tower on foraging behaviour of Asiatic honey bee, *Apis cerana*F. (*Hymenoptera: Apidae*). *J Entomol Zool Stud*. 2017;5:1527-1529.  
Available:[www.entomoljournal.com](http://www.entomoljournal.com)
  32. Traveset A, Richardson DM. Mutualistic interactions and biological invasions. *Annual review of ecology, Evolution, and Systematics*. 2014;45:89-113.  
Available:<https://doi.org/10.1146/annurev-ecolsys-120213-091857>
  33. Leza M, Herrera C, Marques A, Roca P, Sastre-Serra J, et al. The impact of the invasive species *Vespa velutina* on honeybees: A new approach based on oxidative stress. *Science of The Total Environment*. 2019;689:709-715.  
Available:<https://doi.org/10.1016/j.scitotenv.2019.06.511>
  34. Oldroyd BP, Nanork P. Conservation of Asian honey bees. *Apidologie*. 2009;40(3):296-312.  
Available:<https://doi.org/10.1051/apido/2009021>
  35. Dietemann V, Pirk CWW, Crewe R. Is there a need for conservation of



- honeybees in Africa? *Apidologie*. 2009;40(3):285-295.  
Available:<https://doi.org/10.1051/apido/2009013>
36. Aslan CE, Liang CT, Galindo B, Kimberly H, Topete W. The role of honey bees as pollinators in natural areas. *Natural Areas Journal*. 2016;36(4):478-488.  
Available:<https://doi.org/10.3375/043.036.0413>
37. Haregewoin T, Belay B, Bezabeh E, Kelemu K, Hailu D, Daniel F. Impact of improved wheat variety on productivity in Oromia Regional State, Ethiopia. *Greener Journal of Agricultural Sciences*. 2018;8(4):074-081.
38. Breeze T, Bailey A, Balcombe K, Potts S. Pollination services in the UK: How important are honeybees? *Agriculture, Ecosystems & Environment*. 2011;142(3-4):137-143.  
Available:<https://doi.org/10.1016/j.agee.2011.03.020>
39. Paudel YP, Mackereth R, Hanley R, Qin W. Honey bees (*Apis mellifera* L.) and pollination issues: Current status, impacts, and potential drivers of decline. *Journal of Agricultural Science*. 2015;7(6):93.  
Available:<http://dx.doi.org/10.5539/jas.v7n6p93>
40. Fitch G, Wilson CJ, Glaum P, Vaidya C, Simao MC, Jamieson MA. Does urbanization favour exotic bee species? Implications for the conservation of native bees in cities. *Biology Letters*. 2019;15(12):20190574.  
Available:<https://doi.org/10.1098/rsbl.2019.0574>
41. Ropars L, Dajoz I, Fontaine C, Muratet A, Geslin B. Wild pollinator activity negatively related to honey bee colony densities in urban context. *PloS One*. 2019;14(9):e0222316.  
Available:<https://doi.org/10.1371/journal.pone.0222316>
42. Matsuzawa T, Kohsaka R. Preliminary experimental trial of effects of lattice fence installation on honey bee flight height as implications for urban beekeeping regulations. *Land*. 2021;11(1):19.  
Available:<https://doi.org/10.3390/land11010019>
43. Arbia A, Babbay B. Management strategies of honey bee diseases. *Journal of Entomology*. 2011;8(1):1-15.  
Available:<https://doi.org/10.3923/je.2011.1.15>
44. Ugras S, Dursun H, Dulger G, Kekecoglu M. Potential use of firstly isolated bacteria from yigilca honeybees (*Apis mellifera* L.) and products against the pathogens. *Fresenius Environmental Bulletin*. 2017; 26(11):6825-6834.
45. Allipi AM, Reynaldi FJ, Lopez AC, De Giusti MR, Aguilar OM. Molecular epidemiology of *Paenibacillus larvae* larvae and incidence of American foulbrood in Argentinean honeys from Buenos Aires province. *Journal of Apicultural Research*. 2004;43:135-143.
46. Ritter W, Akwatanakul P. Honey bee diseases and pests: a practical guide; 2006.
47. Pettis JS, Rose R, Chaimanee V. Chemical and cultural control of *Tropilaelaps mercedesae* mites in honeybee (*Apis mellifera*) colonies in Northern Thailand. *PloS One*. 2017; 12(11):e0188063.  
Available:<https://doi.org/10.1371/journal.pone.0188063>
48. Gliński Z, Jarosz J. Infection and immunity in the honey bee *Apis mellifera*. *Apiacta*. 2001;36(1):12-24.
49. Gliński Z, Buczek K. Response of the Apoidea to fungal infections. *Apiacta*. 2003;38:183-189.
50. Govind S. Innate immunity in *Drosophila*: Pathogens and pathways. *Insect Science*. 2008;15(1):29-43.  
Available:<https://doi.org/10.1111/j.1744-7917.2008.00185.x>
51. Davis RB, Baldauf SL, Mayhew PJ. The origins of species richness in the Hymenoptera: Insights from a family-level supertree. *BMC Evolutionary Biology*. 2010;10(1):1-16.  
Available:<https://doi.org/10.1186/1471-2148-10-109>
52. Baggio A, Gallina A, Benetti C, Mutinelli F. Residues of antibacterial drugs in honey from the Italian market. *Food Additives and Contaminants: Part B*. 2009; 2(1):52-58.
53. Hendriksma HP, Pachow CD, Nieh JC. Effects of essential amino acid supplementation to promote honey bee gland and muscle development in cages and colonies. *Journal of Insect Physiology*. 2019;117:103906.

54. Pasquale GD, Salignon M, Conte YL, Belzunces LP, Decourtye A, Kretzschmar A, Suchail S, Brunet L, Alaux C. Influence of pollen nutrition on honey bee health: Do pollen quality and diversity matter? PloS One. 2013;8(8):e72016. Available:<https://doi.org/10.1371/journal.pone.0072016>

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