

Pollinators decline: struggle for existence and conservation

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ABSTRACT

The process of transferring pollen from an anther of a plant to the stigma of a plant, which enables fertilisation and production of seeds, is known as *pollination*. The role of pollination is played by the pollinators. Pollinators, including bees, butterflies, and birds, play a crucial role in maintaining biodiversity and ensuring food security. However, their existence is increasingly threatened by both climatic and manmade hazards. Climate change disrupts pollinators' natural habitats through rising temperatures, erratic weather patterns, and altered flowering cycles, leading to mismatches between pollinators and their food sources. Additionally, human activities such as habitat destruction, pesticide use, and intensive agriculture further exacerbate their decline. The loss of pollinators pose significant risks to global ecosystems and agricultural productivity, making conservation efforts essential. Strategies such as habitat restoration, sustainable farming practices, and climate adaptation measures are necessary to safeguard pollinator populations and ensure ecological balance.

Keywords: Pollinator decline, Struggle, Pollination, Conservation, Decline.

INTRODUCTION

Pollinators, including bees, butterflies, birds and bats, contribute to the environment by helping plants produce food. They aid plant propagation, promoting biodiversity and food supply. Sexual reproduction in many crops and most wild plants relies on animal pollination, including insects, birds, bats, and others, with insects as a principal actor (Renner, 1998). How, Charles Darwin observed, flowers evolved to attract pollinators with particular characteristics and, in turn, have acquired ways to extract the nectar or pollen from those flowers. Mutualism between plants and their floral visitors maintains not only plant diversity but also the estimated 350000 animal species (mainly insects, birds and mammals) that depend on flowers (Adugna & Sadre, 2020). Around 90% of all the world's angiosperms are dependent on insect pollination (Klein *et al.*, 2007), and 85% of crops show enhanced productivity with insect pollination (Winfrey *et al.*, 2011). About 73% of the world's crops are

grown with the help of any species of bees (e.g., cashews, squash, mangoes, cocoa, cranberries, and blueberries), 19% by flies, 6.5% by bats, 5% by wasps, 5% by beetles, 4% by birds, and 4% by butterflies and moths (Freitas *et al.*, 2004). Of the hundred primary crops that provide 90 per cent of the world's food, 71 are pollinated by bees, little buzz bombs of winged flight that zoom from blossom to blossom of crops that form the foundation of the planet's diet, everything from apples to zucchini, the alfalfa that's fed to dairy cows to the cotton in our shirts and the meat on our plates, and the sweet corn, oranges and other edibles we pile up on our tables. By comparison, at least 80% are pollinated by wild bees and other fauna (and since there are 25000 species of bees in total, the total number of pollinators likely exceeds 40000 species). According to recent studies, whether it is climate change and habitat loss, as is happening with bees (insects) around the world, or this environmental agriculture, which affects most aspects of the biology of insects pollinating plants in the natural and agricultural composition, near-future uses of fertilisers and the fate of insecticides in addition to agricultural use, body structure and metabolism decades crossing any sectors are on a downward trend. Fig.1 showing types found on Earth.

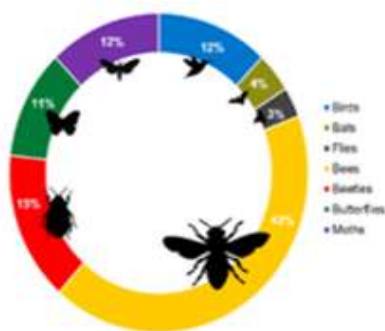


Fig. 1 Types of pollinators on Earth

MATERIALS AND METHODS

This review is based on a systematic literature review approach, focusing on existing studies, reports, and databases that explore the challenges faced by pollinators and their role in biodiversity and agriculture. We conducted the literature review through searching bibliographic databases, peer-reviewed journals, and reports from international organisations (FAO, IPBES, IUCN, and UNEP), books, scientific reviews, SCOPUS, and the open-access website, an authoritative, free information resource to

help protect the world's biodiversity. Our review identifies the positive/negative impact of pollinators on different crop production systems, such as field, fruit, vegetable, and plantation crops.

Nature's ecosystem services are at increasing risk from pressures imposed by an ever-increasing population and growing per capita consumption. As such, despite their proven importance, biodiversity and ecosystem services are under tremendous threats across the world. Investigations reveal that nearly 60% of ecosystem services are being degraded or not regenerated quickly enough to meet human demand (MEA, 2005). All this has severe negative impacts on the quality of human life. Among various types of ecosystem services, pollination is regarded as a regulating ES, which exemplifies an ES whose capacity is currently being degraded at a fast pace owing to a global decline in pollinator abundance (MEA, 2005). Studies have shown that pollinators struggling for existence against climatic and manmade hazards is a pressing issue that has sparked extensive discussions among scientists, environmentalists, and policymakers. The change in climatic conditions disrupts pollinators' natural behaviours, life cycles, food sources, and habitats. Furthermore, human activities such as deforestation, pesticide use, and urbanisation exacerbate these challenges, leading to reduced pollination efficiency and biodiversity loss. Research highlights the importance of understanding pollinator behaviour and floral interactions to develop effective solutions.

Climatic Hazards

The alteration of the climate increases the risk of mismatches in the phenology of plants and pollinators. Traits to help flowers attract and reward pollinators, including size, colour, scent and nectar or pollen production, are among those known to be changed by climate change. Environmental, social and economic impacts of climate change are among the most important problems the world has to cope with. Land use change, pesticide application, agricultural monocultures and the introduction of alien species and disease agents are all threats, likely to be enhanced with climate change as well (Ulfat & Joopaka, 2025). The plants have a variety of reactions to climate change and constrain the communities as they rearrange into new communities (Alexander *et al.*, 2018). Quote Insect taxon Weather change Temporal pattern of buckwheat flower visitorships. Beetles,

butterflies, and wasps were most active under sunny and/or high-temperature conditions, whereas ants and other flies did so under the reverse. Climate change can also have an impact on the dynamics of pollination services by reducing not only the abundance and richness of pollinators but also the activity of these agents and the integration between them and the flowering of crop plants (Gonzalez, 2013). Fig.2 Showing safeguarding pollinators and their values to human well-being.



Fig. 2 Safeguarding pollinators & their values to human well-being – Nature

a) Temperature Changes

Variations in air temperature profoundly impact the biology of all living forms, altering their form, cell function, physiology, ontogeny, ethology, and also their range. The change in climate may threaten the pollinators, and the pollinators themselves may be affected. Emerging temperature effects have also been found: Changes in temperature affect the activity of pollinators, causing them to reproduce less and move elsewhere. The most significant aspect of climate change is the rise of the average temperature worldwide. High temperatures have been shown to affect foraging and body size at maturity, as well as the lifespan of individual insects (Scavan & Rafferty, 2013). Hegland and Deutsch (2016) presented that species distribution was likely to be redistributed further north and toward higher altitudes in a warmer climate if the temperature rose above the thermal tolerance of the plants. Hence, various insects, mammals and other pollinators' activities might be disrupted due to an increase in the temperature along with other factors of the environment.

b) Erratic Weather Patterns

The unpredictable rainfall, storms, and droughts reduce nectar availability, making survival difficult and significantly affecting organisms across ecosystems. Organisms may miss key signals like breeding or

migration cues. Plants may flower too early or too late, disrupting pollination. Pollinators like bees may not sync with the flowering times of plants. Birds may migrate at the wrong time, etc. The erratic weather pattern creates stress and reduced immunity of organisms, which may become more vulnerable to infections or die from heat or cold shock. Warming temperatures led to earlier spring blooms in many floral species, a trend observed across various regions and ecosystems (Cleland *et al.*, 2007). This shift in plant phenology is particularly the earlier onset of flowering due to changes in atmospheric temperature and growing season length (Scheller *et al.*, 2014). Increases in mean temperature affect the diversity and abundance of wild bees in agricultural ecosystems.

c) Habitat Shifts

Climate change and changing precipitation levels force pollinators to adapt to new environments, leading to mismatches with native flora. Some of the species might be able to adapt and expand their range or establish populations in new areas, whereas many are at risk of population decline due to future threats such as habitat loss and competition for resources. Most insect-pollinating species were sensitive to the temperature and precipitation changes, according to some research. Warming and shifting climate can change the range of pollinator species, which is upshifted towards higher latitudes or elevations in search of favourable climatic conditions (Parmesan, 2006). Habitat loss and land use change caused a decrease in forested habitats, which resulted in a transition towards conservation-oriented pollination research in India (Aluri, 1990; Shaanker & Ganeshaiah, 1993). Worldwide, the global change drivers, especially climate change, exotic species introduction, and habitat modification, have multiple impacts on insect pollinators. Table.1 Showing pollinator diversity in India.

Table.1 Pollinator Diversity in India (India is a home of over 700 sp. of bees)

Species Richness	Vertebrate Pollinators
The insects, birds, bats, and mammals also contribute to pollination, especially in forested and tropical regions	Around 85 bird & mammal species identified as pollinators
	Indian flying fox, Malabar giant squirrel, & various nectar-feeding birds

Manmade Hazards

Human activities create hazards for the environment and the organisms that live in that environment. These hazards can be intentional/accidental and often lead to severe consequences for individuals, communities, and the environment. Human activities are making it difficult for species of pollinators to live and grow. Researchers learnt the populations of bees and pollinators, or the pollinating organisms, are decreasing due to many reasons caused by humans which are interrelated and interact with each other (Sabia Malik, 2014). Pollinators are in big trouble, thanks in part to chemical pesticides and herbicides. Some of the pivotal manmade threats are as –

1. Deforestation & Urbanisation

Habitat transformation on a larger scale result in the actual loss of natural habitat, and pollinators are forced to use fragmented habitats. Numerous pollinators are threatened by human activities, including climate change, loss of habitat and the use of insecticides (Memott *et al.*, 2007). Consequently, the dearth of wild pollinators is causing a huge gap in crop production and is having a negative impact on livelihoods in rural areas (Garibaldi *et al.*, 2016). Unplanned cutting of trees has reduced the forest cover by 3.16 per cent globally between 1990 and 2015.

Despite a rise in the overall forest cover in India, estimated to be ca. 1%, some parts of the country have undergone reduction in forest cover (Rima Kumari *et al.*, 2019). Urbanization worldwide is one of the most salient agents of anthropogenic environmental change, with substantial consequences for global biodiversity (Van Klink *et al.*, 2020). Urbanisation traits of various pollinators, hence the pollinators' seasonal rhythms are also disrupted, and migration is observed in them. At present, pollinators are decreasing globally (Olletron, 2017), and due to the possible function of cities as refuge for pollinators, urban pollinators have been becoming a focus of research (Baldock, 2020).

2. Pesticides & Chemical Pollution

Globally, pesticides and chemicals are used to control pests, which causes the problem of pollution. Harmful chemicals like neonicotinoids weaken pollinators, impacting their health and reproduction. It is well-documented that a majority of the pesticide application works as a plant protection product which normally preserves the plants from weeds, fungi, or insects. These insecticides, fungicides, herbicides, molluscicides, avicides, rodenticides, piscicides, and

nematicides are used to target pests, which can be anything from insects, plant pathogens, and weeds, birds and mammals, to fish and molluscs, to nematodes and microbes that can ruin property. The United Nations cautioned that 40% of all invertebrate pollinators, including certain species of bee and butterfly are now facing extinction across the world. While massive loss of honey bee population, approximately a 30% decrease, is stated in the United States (USA) and European countries due to the excessive application of pesticides (Sajed Ali *et al.*, 2021). Pesticides affect honeybees in a variety of ways, both individually and as a colony. Bees are extremely poisoned by insecticides such as carbamates, pyrethroids, neonicotinoids, and organophosphates (Sangita Sharma *et al.*, 2024). Bees and other pollinators face major problems and frequently die as a result of exposure to toxic chemicals. Fig.5 Showing worldwide decline rate in bee species richness.

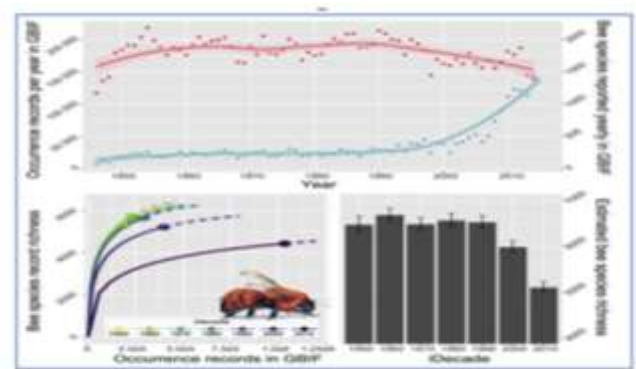


Fig. 5 Worldwide decline in bee species richness – ScienceDirect

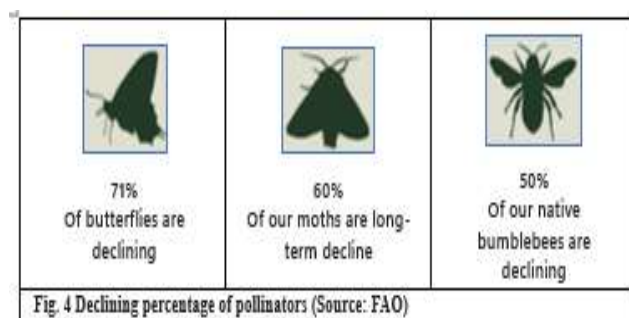
3. Industrial & Agricultural Practices

Industrial development and agricultural growth are crucial aspects of economic growth, characterised by the establishment and expansion of industries. It plays a vital role in creating jobs and improving living standards. The development and growth reduce the pollinators' population. Similarly, a new trend in the agricultural sector, i.e., monoculture farming practices, reduces plant diversity, limiting food sources for pollinators. In recent decades, human activities associated to industrialisation and agricultural intensification have posed an increasing threat to biodiversity and ecosystem service delivery in addition to exceptional historical scales and velocities (CBD, 1992; Curran *et al.*, 2011). The recurrent use of conventional pesticides may reduce the abundance and species diversity of insect pollinators in agricultural systems (Paras Kumar *et al.*, 2020). Overuse of pesticides leads to a reduction in the number of pollinators in the field

and then indirectly decreases crop yield and product quality. In India, the pesticide application rates increased more than a hundred fold, with significant environmental and human health implications (Alavanja, 2009). Globally, about 3.39 million tonnes of pesticides were used for agriculture in 2020, with India using 61,702 tonnes (FAO, 2024). Data suggests that the density of pollinators is decreasing; some species are specific to crops and bee species, and some butterflies, bats and hummingbirds fly towards non-polluted and protected areas.

4. Invasive alien species

Native pollinators suffer problems with invasive alien species, which provide both risks and opportunities for pollinator forage. Species can also interact to influence native community stability and the spread and selection of virulent diseases. Invasive alien plant species are mostly not appreciated because of their high pressure on native communities. Yet their ecological impacts on pollinators are mixed (Aniko *et al.*, 2022). Adam (2018) discovered that the aliens alter the pollinator species richness as well as the services of the pollinators which support the ecosystem functioning and human well-being. Instead, invasive plants may outcompete native plants for pollinators, since meta-analyses indicate that the visitation rates of native plants decline, showing that competition dominated. Intense interspecific competition from invasive honeybees has changed the behaviour and reproductive success of native pollinators (Thomson, 2004). One possibility is that alien visitors may deter native visitors, and this may increase the efficiency of native pollinators if it leaves them with fewer less-profitable flowers to choose from and encourages them to move between flowers more frequently (Lach 2007; Greenleaf & Kremen, 2006). Alien invaders as disrupters of plant-pollinator interactions: effects of invasive alien flora on pollination networks. Fig.4 Showing declining percentage of pollinators as reported by FAO.



Consequences of Pollinator Decline

a) Threat to Food Security

Diminished pollination has a negative impact on crop yields, thereby influencing worldwide agriculture management and food supply. In many parts of the world the dependence of agricultural producers on pollinating species, faced with the threats of habitat loss, pesticide use, climate change, invasive species and disease, is putting increasing pressure on this iconic group. This being has led to the scientific observation that a degradation of pollinator species has disastrous consequences that cannot solely be attributed to reduced crop and animal production but also a weakened system resistance. Insect pollinators are essential for the health of ecosystems and agriculture. Without them, many plants would not be able to reproduce, and we would have a much smaller variety of fruits, vegetables, and seeds to eat (Maggi *et al.*, 2023). Worldwide, 87 of the major food crops rely on animal pollination. Together, they account for 35 per cent of food produced in the world by volume. Pollinator-dependent crops are significant for major micronutrients in humans (Jeroen *et al.*, 2016). According to the literature on terrestrial ecosystems, many cultivated crops and wild plants require pollinators to set fruit and seeds. In pollination, pollen is moved in any one of the various ways between flowers. Nearly all – 94% – flowering plants on earth reproduce and evolve thanks to animal pollination (Ollerton *et al.*, 2011). So, in other words, if you have fewer and fewer pollinators, that affects agricultural productivity rate, but it also has an effect on the world economy. Agriculture is destined to change over time, and so will its pollination needs. In these ways, conservation of pollinators and agriculture cross paths.

b) Biodiversity Loss

As pollinators play a critical role in supporting ecosystems, plant species and wildlife, and without them, ecosystems are starving. Biodiversity is a concept that tries to measure how much variety of life exists in a particular place or on the entire planet. Loss of biodiversity occurs when a given species goes extinct and/or when species decline/disappear from a given place. Globally, the most common driver of biodiversity loss is anthropogenic activity by humans, involving habitat destruction and the expansion and intensification of land use. Selected pollinators became the focus of attention worldwide due to their serious impact on biodiversity and agricultural productivity

(Eileen & Bronson, 2024). The current situation demonstrates that the variety, diversity and health of pollinators are abundant, and the supplies are put at risk by direct threats such as habitat fragmentation and modification, intensive agricultural management, insecticides, pesticides, parasites, alien species, diseases, and climate change.

c) Economic Impacts

Losses of pollinators have implications for industries that depend on the crops they pollinate, such as those producing fruits, vegetables and nuts. Around the world, now, it's common knowledge: farmers would have fewer crop yields, smaller fruit and (in some cases) no crop at all. The healthy pollinator sp. Quality and quantity of production lost is a direct function of population. Not enough pollinators are able to decrease crop production and commodity markets (Peter & Truman, 2001). They caution that global loss of pollinators has geopolitical implications for the production and trade of cultivated crop species, on the robustness of global food systems, and on issues of global inequality and poverty (Dicks *et al.*, 2021). The current pollination systems implemented in most agricultural ecosystems are threatened by the unsustainability or lack of managed, exotic or native pollinators. One of every three bites of human food has direct responsibility of pollinators for 180,000 plant species which are counted and 1200 crops (Hall, 2020; Wagner, 2020). The value of pollinator services to the world's economy has been estimated to be around US \$217 billion in agricultural production (Wagner, 2020). Can't find a counterexample in animals, but let's try bees for a minute: bees are affected by everything from climate change and industrial farming to pesticides, loss of biodiversity and pollution (FAO).

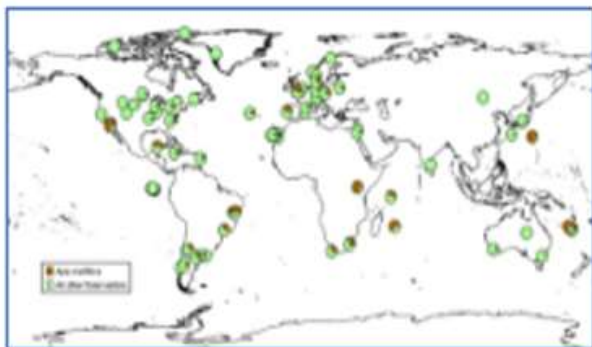


Fig. 3 Worldwide importance of Honey bees for natural habitats captured in New Report Source: BIO SCI

Declining numbers of bees, butterflies and other pollinators threaten the food security and nutrition of human beings throughout the world. FAO is warning countries that depend on pollinators to take urgent action and invest in their habitats and conservation.

d) Ecological Imbalance

A reduction in the population of pollinators disturbs natural food chains and causes instability of the ecosystem. Plants and pollinators form a mutually beneficial relationship. And contribute heavily toward preserving biodiversity and stable ecosystems. Global reduction in insect pollinators due to change and use of land caused by the climate, early-emerging species, and lack of synchronicity between the existence of flowers and phenological (Whipple & Bowser, 2023). Its lack in any ecosystem may unbalance the entire system of life on Earth (Silva *et al.*, 2021). Reduction of pollinators may lead to a decline in pollination services, which has dangerous ecological implications that may even seriously affect the persistence of plant diversity. Fig.6 Showing decline population of pollinators as reported by FAO.

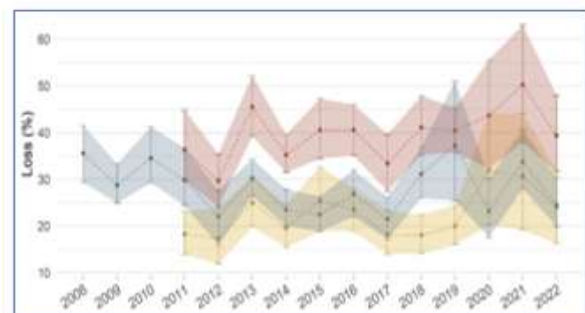


Fig. 6 Graph showing decline of pollinators Source: FAO

Challenges Facing Pollinators

It has been observed from various research studies that most of the pollinator species are facing multiple threats that impact their ability to thrive and survive. Analyses of global biodiversity records indicate that between 2006 and 2015, the number of recorded bee species dropped by about 25 per cent compared to pre-1990s levels. The problem of habitat loss, climate challenge, misuse of pesticides, invasive species, parasites and pathogens. Some species are facing the problem of extinction (UNESCO). The United Nations Environmental Programme listed 12 specific hurdles that pollinators face. Bees, butterflies, wasps, flies, birds, and mammals of pollinators were in crisis worldwide. Table.2 Showing extinction rate of pollinators as reported by FAO.

Table.2 Extinction rate of pollinators

Metric	Estimate	Source
Pollinator extinction rate	100-1000 x higher than background	FAO
Pollinator species at risk	~40% threatened	FAO
Crop yield decline without pollination	Up to ~90% for certain crops	FAO
Annual production loss from poor pollination	3-5% of fruits, vegetables, nuts	Modelling study (FAO)
Annual excess deaths linked to pollination loss	~427,000 deaths/year	Study (FAO)
Decline in bee species richness	~25% drop (2006-2015) vs pre-1990	Data analysis

(Source: FAO)

Conservation Efforts for Pollinator Species -

The Food and Agriculture Organisation (FAO), among others, has initiated regional programmes, projects and actions aimed at providing a more integrated approach to achieve the same objective of conservation and sustainable utilisation of pollinator diversity in ecosystems. The status of pollinators in India and the report on the same are prepared by The Nature Conservancy (TNC). In terms of economic impact, citizen science programmes have been deployed to track changes in pollinator populations of traditional honey businesses in Himachal Pradesh (India).

i) Sustainable Agriculture

Encouraging organic farming and reducing pesticide use to protect pollinators. For promoting environmental sustainability, improving human health, and supporting economic viability in the agricultural sector. Studies have demonstrated that organic farms support more pollinators than conventional farms (Andersson *et al.*, 2014). It was also discovered that services to pollinated crops on organic farms increased with increasing habitat heterogeneity. The organic farming area enlarged quickly from 0.58 thousand ha in 2003-04 to 26.6 thousand ha in 2020-21, and several government schemes came into existence (Natesan *et al.*, 2021). So, to keep the pollinators in the ecosystem.

ii) Habitat Restoration

As pollinators are showing their importance in food production, ecosystem health, and our biodiversity, they are also supporting the global economy. Creating pollinator-friendly spaces through native plants and protected zones. About 75 per cent of flowering plants in the world, while 35 per cent of the world's food crops rely on different types of pollinators. A decline in the population of pollinators could threaten food

security and the health of ecosystems. The recovery of forests in human-modified landscapes generates new habitats which may be colonised (Fuller *et al.*, 2018). The Nature Conservancy (TNC) funded Working Group 1 on the status of pollinators in India. The European Union Biodiversity Strategy (2030) and the European Pollinators Initiative set up the commitment to reverse the decline in pollinators by 2030. Throughout the world, scientists are aware of the consequences, which we will face in the future in the absence of pollinator species.

iii) Climate Adaptation Strategies

Climatic issues, i.e., changes in climate conditions, disturbances in rainfall and other environmental conditions, are recorded in the form of alterations in seasonal patterns. Supporting environmental policies that safeguard pollinator populations affects the behaviour of pollinators. We have to implement adaptive strategies such as habitat conservation, sustainable farming practices and research initiatives (Ultat & Ramu, 2025). Another important measure for the protection of pollinators is advancing sustainable farming methods, including organic agriculture and fewer pesticides. For instance, enhanced floral diversity in farmed areas could offer more diverse food sources for pollinators (Klein *et al.*, 2007). Community engagement, a key factor for the success of pollinator conservation projects, has been studying community participation that is crucial for pollinator conservation projects to succeed. For saving pollinator populations, strategies and promoting research, education, and sustainable practices may play a crucial role in conservation. Genomic tools also hold significant promise in understanding the adaptive potential of both plants and pollinators. Advances in genomics can help identify genetic traits that enhance climate resilience, providing valuable information for conservation strategies (Chetan & Sushmita, 2025).

iv) Public Awareness & Education

For promoting pollinator conservation as a social and educational imperative involves fostering widespread public awareness and embedding ecological literacy within formal and informal learning systems. Educational initiatives such as the *Prompt Pollinators* campaign demonstrate that informed communities are more likely to support conservation policies and practices. Policymakers must therefore prioritise public engagement by enacting and promoting legislation that safeguards pollinator habitats and funds scientific research. The National Geographic Society (NGS, Washington, DC) exemplifies this approach by integrating students and under-represented communities into pollinator research and storytelling, thereby democratising environmental knowledge and advocacy. Community-based interventions such as school programmes, awareness workshops, and the establishment of pollinator-friendly gardens serve as effective platforms for experiential learning and civic participation (Bronwen, 2025). Social media campaigns further amplify these efforts, fostering a culture of conservation across diverse demographics. Importantly, early educational exposure to pollinator ecology cultivates a generation of environmentally conscious citizens and future leaders equipped to champion sustainability. Embedding such experiences within curricula and community initiatives ensures that pollinator protection becomes a shared responsibility, rooted in knowledge, empathy, and action.

CONCLUSION

Pollinators are vital for maintaining biodiversity, ensuring food security, and sustaining healthy ecosystems. Yet, they face serious threats from habitat loss, climate change, pesticide use, pollution, and disease. Their decline directly affects not only wild plant reproduction but also agricultural productivity and human survival. Therefore, protecting pollinators is not just an environmental concern but a necessity for the balance of life on Earth. Sustainable farming practices, conservation of natural habitats, reduced use of harmful chemicals, and awareness among people are essential steps to safeguard their existence. In conclusion, the struggle of pollinators is a reminder that our own survival is intricately linked with theirs, and their protection is ultimately the protection of our future. By creating pollinator-friendly gardens, publicity on social media, education, offering

experiences and policies that protect their habitats, and scientific research activities may help them thrive for future generations. The aim of this website of the Food and Agriculture Organisation (FAO) is to provide an overview of a selection of regional initiatives, programs and projects with the goal to conserve and sustainably use pollinator diversity in agriculture and related ecosystems.

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REFERENCES

- Adam J. Vanbergen, Anahí Espíndola & Marcelo A. Aizen (2018) Risks to pollinators and pollination from invasive alien species, *Nature Eco. & Evol.*, Springer Nature, 2:16-25.
- Adrian C. Newton, Danilo Boscolo, Patrícia A. Ferreira, Luciano E. Lopes, Paul Evans (2018) Impacts of deforestation on plant-pollinator networks assessed using an agent-based model, *journal pone* [0209406](https://doi.org/10.1371/journal.pone.0209406).
- Adujna Gindaba & M. Sadre Alam Fakhri (2020) Insect Pollinators and Their Challenges: A Review, *WJPLS*, 6(11): 45-50.
- Alavanja, M.C. (2009) Introduction: Pesticides use and exposure, extensive worldwide. *Rev. Environ. Health*, 24, 303–310.
- Alexander JM, Chalmandrier L, Lenoir J, Burgess TI, Essl F, Haider S (2018) Lags in the response of mountain plant communities to climate change. *Glob Change Biol* 24(2):563–579.
- Aluri, R.J.S. (1990) Studies on pollination ecology in India: a review. *Proceedings of the Indian National Science Academy B*, 56, 375–388.
- An Approach to Assessing the Consequences, *Conservation Ecology* 5(1): 8. [online] URL: <http://www.consecol.org/vol5/iss1/art8/>
- Andersson, G.K.S., *et al.*, (2014) Effects of farming intensity, crop rotation and landscape heterogeneity on field bean pollination. *Agriculture, Ecosystems & Environment*, 184(0): p. 145 – 148.
- Aniko Kovacs, Hostyanszki, Viktor Szigeti, Zsombor Miholesa, Dorottya Sandor, Zoltan Soltesz Annamaria

- Fenesi (2022) Threats & benefits of invasive alien plant species of pollinators, Basic & Applied Ecology, ELSVIER, 64: 89-102.
- Baldock, K.C. (2020) Opportunities and threats for pollinator conservation in global towns and cities. *Current Opinion in Insect Science*, 38, 63– 71.
- Bronwen Cowie & Paula Mildenhall (2025) Chapter. The important role of pollinators in sustainability education, In book: *The Routledge Handbook of Global Sustainability Edu. & Thinking for the 21st Century*, Edi. 1st, Pub. Routledge India.
- Buchmann, S. L. and Nabhan G. P. (1996) *The Forgotten Pollinators*. Washington, DC: *Island Press*.
- Burkle L.A., & Runyon J.B. (2016) Drought and leaf herbivory influence floral volatiles and pollinator attraction. *Glob Change Biol*, 22: 1644-1654.
- CBD (1992). Convention on Biological Diversity (CBD). CBD Convention Text. Available at: <http://www.cbd.int/convention/text/>.
- Chetan Kumar Jani 1*, Sushmita Rajpurohit (2025) Adaptive Responses of Pollinators and Host Plants to Climate Change: A Study of Plant-Animal Interactions in Evolving Ecosystems, *Int. Jr. of Contemp. Res. in Multi.*, 4(2):248-253.
- Cleland, Elizabeth E., et al. (2007) Shifting Plant Phenology in Response to Global Change, Response to Global Change, *Trends in Ecology & Evolution*, 22: 357-365.
- Curran M., L. de Baan, A.M. De Schryver, R. van Zelm, S. Hellweg, T. Koellner, G. Sonnemann, M.A.J. Huijbrgts (2007) Towards meaningful end points of biodiversity in life cycle assessment *Environ. Sci. Technol.*, 45:70-79.
- Deutsch A., J. J. Tewksbury, R. B. Huey, K. S. Sheldon, G. C. K. ha-Lambro, and D.C. Haak, (2008) Impacts of climate warming on terrestrial ectotherms across latitude, in *Proc. National Academy of Sciences, USA*, p. 6668.
- Dheerendra Vadiraj (2025) Climate change and its impact on plant pollinator dynamics': Shifting interactions consequences, *Jour. EPRA*, 11(2): 430-436.
- Dicks L.V., Breeze T.D., An J., Aizen M., Báldi A., Basu P., Buchori B., Galetto L., Garibaldi L., Gemmill- Herren B., Howlett B., Imperatriz- Fonseca V., Johnson S., Kovács-Hostyánszki A., Kwon Y.J., Lattorff M., Lungharwo T., Ngo H., Senapathi D., Seymour C., Vanbergen A., & Potts S.G. (2021) A global assessment of drivers and risks associated with pollinator decline. *Nature Ecology & Evolution*, 5, 1453– 1461. <https://doi.org/10.1038/s41559-021-01534-9>.
- FAO (2024) Availableonline: <https://www.fao.org/3/cc0918en/cc0918en.pdf> (accessed on 1 March 2024).
- Filgueiras et al. (2021) B.K.C. Filgueiras, C.A. Peres, F.P.L. Melo, I.R. Leal, M. Tabarelli
- Freitas B.M., Otávio J., Pereira P. (2004) Solitary bees' conservation, rearing and management for pollination. A contribution to the International Workshop on Solitary Bees and Their Role in Pollination, held in Beberibe, Ceará, Brazil, 282 p. Fortaleza CE (eds).
- Fuller et al., (2018) Determine the suitability of woodland creation sites for Diptera, *J. Appl. Ecology*, 55:1173-1184, 10.1111/1365-2664, 13035.
- Garibaldi LA, Carvalheiro LG, Vaissière BE, Gemmill-Herren B, Hipólito J, Freitas BM (2016) Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science*, 351(6271): 388-391. pmid:26798016
- Gonzalez-Varo, J.P. (2013) Combined effects of global change pressures on animal-mediated pollination, *Trends Ecol.*, 28:524-530.
- Hall, M. (2020) The great" bee-pression:" Declining bee populations amid an ever-growing human-centered world. *The Drake Journal of Agricultural Law*, 25, 453.
- Hegland S. J., A. Nielsen, A. Lázaro, A. L. Bjerknes, and O. Totland, How does climate warming affect plant-pollinator interactions? (2009) *Ecol Letters*, vol. 12, pp. 184-195.
- Jeroen P. van der Sluijs & Nora S. Vaage (2016). Pollinators and Global Food Security: the Need for Holistic Global Stewardship, *Food ethics, Crossmark, Springer*, 1:75– 91.
- Klein, A.M., et al. (2007) Importance of pollinators in changing landscapes for world crops, *Journal of Applied Ecology*, 45(1):205-213.
- Maggi, T.L. Pardo & R. Chreil (2023). Pollinator Diversity: A Key to Ecosystem, Resilience and Food Security, In book: *Pollinators*, 6:33-48.
- Memmott J, Craze P.G., Waser N.M., Price M.V. (2007) Global warming and the disruption of plant–pollinator interactions. *Ecology Letters*, 10: 710–717. pmid:17594426.
- Natesan Ravisankar, Meraj Alam Ansari, A.S. Panwar & Charanjit Singh Aulakh (2021) Organic farming research in India: Potential technologies and way forward, *Indian Journal of Agronomy* 66 (5th IAC Special issue): S142-S162.
- Ollerton, Jeff, Rachael Winfree, and Sam Tarrant (2011) How many flowering plants are pollinated by animals? *Oikos*. doi:10.1111/j.1600-0706.2010.18644.x.
- Paras Kumar, Gagandeep Singh & Harpinder Singh (2020) Impact of Insect Pollinators on Quantitative and Qualitative Improvement in Agricultural Crops: A Review, *Int. J. Curr. Microbiol. App. Sci.*, 9(9): 2359-2367.
- Peter G. Kevan and Truman P. Phillips (2001) *The Economic Impacts of Pollinator Declines*:
- Renner S.S. and Ricklefs R.E (1995) Dioecy and its correlates in the flowering plants. *Am J Bot*, 82: 596–606.
- Rima Kumar, Ayan Banerjee, Rahul Kumar, Amit Kumar (2019) Deforestation in India: Consequences & Sustainable Solutions, n book: *Deforestation around the World Publisher: Intech Open, UK*.

- Rosalind R. James & Theresa L. Pitts-Singer (2008) *Bee Pollination in Agricultural Ecosystems*, Oxford University Press.
- Sajjed Ali, [Muhammad Irfan Ullah](#), [Asif Sajjad](#), [Qaiser Shakeel](#) (2021) Environmental and Health Effects of Pesticide Residues, In Book: Sustainable Agriculture Reviews 48, Springer Pub.
- Sangita Sharma, Pankaj Sharma Istatu, Neelam Kumari, Dinesh Singh Thakur, Shorya Chauhan & Vinod Kumar Dubey (2024) Impact of Pesticides on Pollinators and Pollination, In book: Insect Pollinators Diversity: Distribution, Ecological Function and Conservation Status in Himalayan Region (pp.236-247) Edition: 1st Publisher: Bharti Pub., New Delhi.
- Scaven V.L. and Rafferty N.E. (2013) Physiological effects of climate warming on flowering plants and insect pollinators and potential consequences for their interactions, *Current Zoology*, 59(3):418-426.
- Shaanker, R.U. & Ganeshaiah, K.N. (1993). Pollination biology in India-surveying the past. *Current Science*, 10, 195-198.
- Silva, F.D.S., Carvalheiro, L. G., Aguirre-Gutierrez, J., Lucotte, M., Guidoni-Martins, K., & Mertens, F. (2021) Virtual pollination trade uncovers global dependence on biodiversity of developing countries, *Science Advances*, 7(11), eabe6636.
- Soltis P. S. and Soltis D.E. (2004) The origin and diversification of angiosperms. *Am J Bot*, 91: 1614-26.
- Tadashi Miyashita, Shouta Hayashi, Kae Natsume & Hisatomo Taki (2023) Diverse flower-visiting responses among pollinators to multiple weather variables in buckwheat pollination, *Nature, Scientific reports*, 13:3099.
- Thomson, D (2004) Competitive interactions between the invasive European honey bee and native bumble bees. *Ecology* 85, 458-470.
- Ulfat Jan & Joopaka Ramu (2025) Effect of Climate Change on Insect Pollinators: Challenges and Adaptation Strategies, *IJGSR*, 12(1):2538-2543.
- Van Klin k.R., Bowler, D.E., Gongalsky, K.B., Swengel, A.B., Genti le, A. & Chase, M. (2020) Meta- analysis reveals declines in terrestrial but increases in freshwater insect abundances. *Science*, 368, 417- 420.
- Wagner, D.L. (2020) Insect declines in the Anthropocene. *Annual Review of Entomology*, 65, 457-480.
- Winner-loser species replacements in human-modified landscapes *Trends Ecol. Evol.*, 36 (2021), pp. 545-555, [10.1016/j.tree.2021.02.006](#).

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