**THE WARMING THREAT: CLIMATE CHANGE IS DEVASTATING HONEYBEE POPULATIONS**

**ABSTRACT:**

Climate change, fueled by industrialization and deforestation, has far-reaching consequences, including ozone layer depletion and rising carbon dioxide levels. This has compromised ecosystem health and biodiversity, ultimately impacting bee colonies and threatening their survival. Honeybees represent the most essential pollinators for agricultural crops worldwide, significantly contributing to biodiversity through the pollination of numerous plant species. Their adaptability has enabled them to thrive in diverse climates worldwide. Climate change may impact honeybee development, but their genetic variability and plasticity could facilitate adaptation to new environmental conditions. However, the exact effects of climate change on honeybees remain uncertain. This article explores the potential consequences of climate change on honeybee behavior, physiology, distribution, and disease interactions. To preserve the genetic diversity and valuable ecotypes of honeybees, conservation efforts are essential for maintaining global biodiversity.

**KEYWORDS:**

Climate change, Beekeeping, Pollination, Habitat Loss, Forage

**INTRODUCTION:**

Every bite of food we take is owed to the hard work of pollinators like bees, birds, insects, and mammals. In fact, 35% of global food production relies on these vital creatures. Globally, more than 1,300 plant varieties are cultivated to meet diverse needs, ranging from food and beverages to medicines, condiments, spices, and even fabric. Among these, about 75% are reliant on animal pollination. A substantial proportion—more than one-third—of the food and beverages we consume are directly associated with the efforts of pollinators. Notably, it is observed that a role is played by pollinators, such as bees, birds, and bats, in 35% of the crop production of world, with improvements in yields for 87 primary food crops globally and the exertion of influence on the production of diverse plant-derived medicines (Klein et al.,2007).

Honeybees are struggling due to climate change, which alters flower patterns, reduces nectar, and disrupts their habitats, ultimately threatening pollination and food production. Honeybees play a vital role in the pollination of crops on a global scale (Klein et al., 2007) as it is assumed to contribute 80% of insect pollination (Robinson et al.,1989). Out of 115 crops, 90 are entirely dependent on bee pollination, highlighting the crucial role of honeybees (Apis genus) in food security. In addition to bees, other insects, including beetles, wasps, butterflies, and moths, contribute significantly to pollination.

Honeybees are found worldwide, with *Apis mellifera* species inhabiting Sub-Saharan Africa, northern Europe, and central Asia, while other Apis species thrive in tropical south-east Asia. Climate change poses a significant threat to honeybee survival, as they are closely tied to their environment. However, these resilient creatures may adapt by migrating, altering their life cycles, or changing their behavior to survive in new environments. Moreover, honeybees must contend with predators, parasites, and pathogens. While climate change may create new opportunities for honeybees in certain regions, it also risks accelerating extinction rates. Climate change will inevitably affect the survival of honeybee species and ecotypes that are deeply connected to their environment. However, by migrating, adapting their life cycle, and altering their behavior, they may be able to thrive in new habitats. (Klein et al., 2007)

**SPECIES DIVERSITY**

The Apoidea superfamily is divided into two main groups: Spheciformes (wasps) and Apiformes (bees). Bees are distinct from wasps due to Branched, plumose hairs and Broader hind basitarsi compared to other tarsal segments. Generally longer proboscis than sphecoid wasps. In Worldwide, there are 17,533 bee species across 443 genera and seven families. In India, 633 species from 60 genera and six families have been documented. (Michener’s 2007). Honeybee species found in North – Eastern hill region are *Apis laboriosa* (rock bee), *Apis dorsata* (giant honeybee), *Apis florea* (little honeybee), *Apis cerana* (Asian honeybee), *Apis mellifera* (European honeybee), *Trigona iridepennis* (stingless bee).

Notably, the Asian honeybee, *Apis cerana,* has subspecies variations. They are *Apis cerana* Himalaya (northeastern region), *Apis cerana cerana* (Northwest Himalayas), *Apis cerana indica* (South India). Ecotypes of *Apis cerana* Himalaya exhibit variations in biological and economic characteristics across local populations in Naga and M4izo hills, Brahmaputra vall]ey, Khasi hills and Northeast Himalayan foothills (Singh & Verma 1992)

**Giant Honeybee,** *Apis laboriosa.; subgenus Megapis Ashmead*

The Giant Honeybee (*Apis laboriosa*) has been extensively documented by researchers, including Sakagami et al. (1980), in the high-altitude mountainous regions of the Himalayas, specifically in North-eastern India, Nepal, Bhutan, China (Tibet and Yunnan) (Trung et al., 1996). *Apis laboriosa*, the giant honeybee, typically inhabits elevations between 1000-3000 meters above sea level. the distinctive features of *Apis laboriosa* is completely dark abdomen and long, golden thoracic hairs. In contrast, *Apis dorsata* has orange or yellow anterior abdominal segments and dark thoracic hairs (Kitnya et al., 2020).

**Rock honeybee,** *Apis dorsata*

*Apis dorsata*, commonly known as the “Rock bee,” is a large-bodied species that plays a vital role in maintaining forest ecosystems. It is larger in body size and combs measuring 1.5-2.1m wide and 0.6-1.2m tall. Hives located on cliff faces, tall trees, and undersides of branches. Ecologically, It is Keystone species in forest ecosystems and crucial for sustaining forest flora and fauna. Hives are often inaccessible due to their location (Dyer & Seeley, 1994). *Apis dorsata*, the Rock Honeybee, is known for its aggressive behavior and extremely painful stings, making it unsuitable for domestication.

**Italian honeybee,** *Apis mellifera ligustica*

*Apis mellifera*, originally native to Africa, Europe, and the Middle East, was introduced to India in the late 1970s or early 1980s. In European countries and, of course, in the world beekeeping community, Italian bee became known thanks to the activities of J. Dzierżon, who brought Italian bees from Mira (Liguria) to Poland (Karlowice) in 1853. *Apis mellifera* is larger in size compared to *Apis cerana* and exhibits several distinct characteristics such as builds larger and multiple combs, greater honey storage capacity, higher fecundity (reproductive rate) and faster brood rearing and colony growth. These traits give *Apis mellifera* a competitive advantage over its Indian counterpart, *Apis cerana* (Atwal & Sharma, 1968; Rana & Goyal, 1994). Apis mellifera exhibits the following characteristics such as high honey production about 25-40 kg per colony and Optimal altitude about 1500 meters above mean sea level (AMSL) . For commercial beekeeping, these exotic bees migrate through floral mapping to ensure optimal foraging and honey production (Tej et al., 2017)

**Indian honeybee*,*** *Apis cerana*

The Asian honeybee, *Apis cerana*, is a native and well-established species in India. It was first described by Danish entomologist Johann Christian Fabricius (1793). Before the introduction of *Apis mellifera*, *Apis cerana* was the primary species used for commercial beekeeping in India. It was domesticated for its valuable products, including honey and other bee byproducts, making it a crucial part of India’s apiculture industry.

Apis cerana, the Asian honeybee, is moderately sized, falling between other Apis species , Smaller than Rock bees and Italian bees and larger than Dwarf bees (*Apis andreniformis*) or Little bees (*Apis florae).* It is a versatile species that constructs parallel combs in various cavities, including clay pots, logs, walls and tree openings. The genetic diversity and adaptability of A. cerana led to its classification into several subspecies by Ruttner (1988), including A. c. *cerana*, A. c. indica (Indian subspecies), A. c. *japonica* (Japanese subspecies), A. c. himalaya (Himalayan subspecies).

**POLLINATION:**

Pollination plays a vital role as a regulating ecosystem service in nature. Among the insect pollinators, solitary and social bees provide most pollination in both managed and natural ecosystems. Most of the world’s staple foods, including wheat, corn, and rice reproduce without insect pollination. These crops account for 65% of global food production, still leaving as much as 35% depending on pollinating animals (Klein et al. 2007). In part due to the massive scale and homogeneity of modern agriculture, the majority of crops requiring pollination are dependent on managed pollinators, and especially on managed honeybees (Aizenet al. 2008). Pollination is an ecosystem service that is key to food security. Pollinators are essential for many fruit and vegetable crops. In agriculture, especially among pollen-limited crops, promoting pollination services is a means of increasing productivity without resorting to expensive agricultural inputs of pesticides or herbicides.

Indeed, pollination services are most likely underpinning productivity in many crops without farmers even recognising it, so long as habitat and alternative pollinator forage are readily available as they often are in small holder farming systems. Increasing dependence on pesticides for pest control is also highly detrimental to beneficial insects such as pollinators, unless planned and undertaken with extreme care. According to estimates, the yearly economic value of bee pollination services in India is around ₹1,12,615.7 crores (USD 22.52 billion), or 8.7% of the country's overall agricultural value. In addition to the rise in quality traits, seed output, and breeding efficiency, this value is the result of insect pollination's direct contribution to Indian agriculture (Chaudhary & Chand, 2017). As demand for insect-pollinated crops increases, crop production is threatened by shortfalls in pollination services.

To ensure adequate pollen transport and ideal crop yield, both wild and managed pollinators might be required (Garibaldi et al. 2014, Isaacs et al. 2017). Coordinated action at the field, farm, and landscape sizes is required for farmers, land managers, and policy makers to manage insect pollination services in a cost-effective manner (Garibaldi et al. 2019; Garratt et al.2021). Therefore, a variety of insect pollinators, their functions in crop pollination, the circumstances that could lead to their extinction, and methods for halting that decline are covered in this chapter.

**THE ROLE OF POLLINATORS:**

No other group of insects is of more benefit to humans than bees. More than one-third of the world’s crops require pollination to set seeds and fruits, and most meat and dairy industries rely on bees for pollination of fodder (clover and Lucerne) (Diaset al. 1999). Crops relying on bee pollination include apple, citrus, tomato, melon, strawberry, apricot, peach, mango, grape, carrot, potato, onion, pumpkin, bean, cucumber, sunflower, various nuts, alfalfa, etc.

The annual value of this service is estimated at US$112 billion worldwide (Southwick and Southwick 1992). Even crops that do not require pollination for harvesting, such as those producing fibre or timber, still require pollination to produce further generations, and crops such as cotton that do not require pollination to produce seeds, provide greater yields when pollinators are available (Allen-Wardellet al. 1998). Two studies demonstrate the significant impact of honey bee pollination on crop yields. A study on Niger seed by Gebremedhn et al. (2014) found that honey bee pollination significantly increased seed yield, with caged crops yielding 16.7 quintals/ha compared to 9.6 quintals/ha without insects.

Research by Tura (2018) on wild apple [Malus sylvestris (L.) mill.] in Ethiopia’s central highlands showed similar results: Caged with honeybees: 3,560 kg/ha,Open pollination: 2,440 kg/ha, Caged without insects: 2,000 kg/ha. Notably, caging with honeybees resulted in higher marketable fruit yields. These findings highlight the crucial role of honey bee pollination in enhancing crop yields and quality. Apart from direct benefits derived from honeybees in the form of honey and beeswax, indirect benefits realized by way of increased yields of certain farm crops and forest products due to their pollination services are immense.

**INSECT POLLINATOR:**

Of all the insects in the world, only 1% of insects are pests (Triple horn & Johnson 2005) but they are responsible for the loss of 13% of crops and 9% of forest production (Pimental *et al.* 2000). Most insects are beneficial to humans either directly or indirectly (Peters 1993). Directly beneficial insects include pollinators and insect predators and parasites of pests. Other insects provide humans with material goods such as honey (honey bees), silk (silk moths), dyes and shellac (scale insects), and tannic acid and inks (insect galls) (Ostiguy, 2011). Notably, world 90 percent of flowering species and 75percent of the major crops are depend on animals for pollination (Burger 1982, Gullan & Cranston 2010).

Some plants have very light weight, smooth pollen that is easily blown by the wind from one plant to another. Many other plants, however, have heavy, sticky pollen that must be physically picked up from one plant and moved to a different plant. Whereas insects play a major role as pollinators. In invertebrates, Insect pollinators are coming under the order of Hymenoptera, Lepidoptera, Diptera, and Coleoptera. Insect pollinators; includes Bees, Flies, Butterflies, Moths, Wasps, Beetles, and Thrips (Jessia R.K. Forrest, 2017). Globally 80 percent of pollination is done by insect pollinators. In this, over 80 percent of pollination is done by bees in insect pollinators. According to estimates from the Food and Agricultural Organization (FAO) of the United Nations, 90% of the food supplies for 146 countries come from 71 crop varieties, the majority of which are pollinated by wild bees.

Table. 1. Pollination by various insects.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.NO** | **Pollinators** | **Syndrome** | **Major Pollinating crops** | **Reference** |
| 1 | Beetles | Cantharophily | Bitter guard, Chrysanthemum, Jackfruit | (R.B. Thapa,2006  &  Leslie Real,2012) |
| 2 | Carrion & Dung flies | Sapromyophily | Tea, Pepper mint, Okra, Cinnamon, celery |
| 3 | Syrphids & Bee flies | Myophily | Safflower |
| 4 | Bees | Melittophily | Pumpkin, Jute, Potato, Castor, Cluster bean |
| 5 | Hawk moths | Sphingophily | Papaya |
| 6 | Butterflies | Psychophily | Cashew, Cinchona |
| 7 | Birds | Ornithophily | Vanilla, Scarlet bean, Pineapple |
| 8 | Bats | Chiropterophily | Banana, Silk cotton |

**EFFICIENTN FORAGERS;**

***Domesticated species:*** There are two most important hive species. European honeybee, *Apis mellifera L*. is a native of old world except tropical Asia and introduced to most parts of the new world. It has a foraging range of 3 km. The Indian hive bee, *A. cerana indica*F., a native of tropical Asia is prevalent in a wide region with a flight range of 1.5 km. It is even a better pollinator than *A. mellifera* because of their longer foraging period and many other characters (Sihag and Mishra 1995).

**Wild species:** Two other species, *A. dorsata* (rock/giant bee) and *A. florea* (little bee) are also native of tropical Asia and efficient pollinators. But these cannot be managed for long time, as they do not live in artificial hives. Their  foraging range is 2.5–4.0 and 1 km, respectively.  Honeybee species can effectively be utilized for pollination of crops because Honeybees are dependent on flowers for pollen and nectar as their food. The bees possess some morphological adaptations favourable for pollen carry over and transfer.

The honeybees can be kept in the hives and are very easy to be managed. Due to their polylactic nature, honeybees visit large number of plants, therefore, they can pollinate a wide variety of crops. Their abundance on the crop can easily be manipulated. Honeybees have better communication system for food searching and gathering. When a honeybee forager begins foraging on a plant species, continues to do so until the resource gets exhausted. This behaviour of individual foragers has been termed as floral fidelity or constancy (Wells and Wells 1983; Waser 1986).

This is very important for the plant species they visit for the effectivity of pollination. Behaviour of honeybees can be manipulated by modifying the reward system of the plant/or nectar and pollen storage in the hive or colony’s unsealed brood. Colonies of honeybees can be moved to a place of short pollinators supply Due to their habits of making nest in the cavities, these bees can be domesticated in the wooden hives.

The population of both wild and managed pollinators is declining at alarming rates owing to alteration in their food and nesting habitats, shrinkage in natural ecosystems, i.e. forests and grassland ecosystems, pesticide poisoning, diseases and pests, over-collecting, smuggling and trading in certain rare and endangered species. The focus of beekeeping needs to change from conventional honey production to crop pollination.

Table: 2. The effect of pollination by bees on crop productivity and quality

|  |  |  |
| --- | --- | --- |
| Crop (Species) | Bee pollinator | Impact on crop yield |
| Apple  (*Malus domestica* L.) | Honey bees  (*Apis mellifera* L.)  Stinglessbees (*Melipona quadrifasciata anthidioides* L.) Africanised honeybee  (*A. mellifera)*  Bumble bees (*B. impatiens*) | Improving fruit quality (fruit size, seed count and content of fruit sugar) and increased fruit production. |
| Coconut  (*Cocos nucifera* L.) | Honey bees (*A. mellifera*) | Increased fruit set |
| Watermelon (*Citrullus lanatus* Thunb.) | Honey bees (*A. mellifera*) | With an increase in the frequency of honey bee visits, fruit set, fruit counts, and fruit weights per plot rose linearly. |
| Tartcherry (*Prunus cerasus* L.) | Solitary bee *(Osmia lignaria*) | The weight of the cherries improved 2.8% in comparison to the control. |
| Capegooseberry (*Physalis peruviana* L.) | Honey bees (*A. mellifera*) | 30.3% increase in fruit mass, 13.3% increase in equatorial diameter, 7% increase in seed variety, and 8.4% increase in seed mass. |
| Almond (*Prunus dulcis* (Mill.) | Honey bees (*A. mellifera*)  Solitary Bee (*O. cornuta*) | 20% more kernel yield and 60% more fruit set than with self-pollination. |
| Avocado (*Persea americana* Mill.) | Honey bees (*A. mellifera*) | High pollination efficiency raised fruit weight, boosted production, and promoted fruit set. |
| Citrus (*Citrus sinensis* L.) | Honey bees (*A. mellifera*) | Result in fewer seeds per flourish and heavier fruit with lower acidity levels. |
| Mango (*Mangifera indica* L.) | Honey bees (*A. cerana*) | Fruit setting reached 42.29%, compared to 33.36% with open pollination. |
| Guava (*Psidium guajava* L.) | Honey bees (*A. mellifera*) | Fruit set increased, and the girth and length of the fruit improved. |
| |  | | --- | | Strawberry  (*Fragaria × ananassa DUCH)* | | | Orchard bee (*Osmia bicornis* L.  *Osmia cornuta* L.) | Economic value increased by 38.6% compared to wind pollination, and by 54.3% compared to self-pollination. Furthermore, there were more fertilized achenes and improved post-harvest quality, characterised by lower sugar-acid ratios and a more intense red coloration. |
| Tomatoes *(Solanum lycopersicum* L.) | Bumble bee (*Anthophora urbana* Cresson and *Bombus vosnesenskii* Radoszkowski)  Bees (*Exomalopsis analis Spinola*, *Centris tarsata Smith*, *Bombus morio Swederus*, *Eulaema nigrita Lepeletier* and *Epicharis* sp.) | Lead to enhanced fruit production and improved fruit quality. |
| Cumin (*Cuminum cyminum* L.) | *Apis florea* F., *A. mellifera* and *A. dorsata* | Enhanced yield by 40.03% compared to 41.37% for open pollination. |
| |  | | --- | | Sunflowers (*Helianthus annuus* L.) | | | Honey bees (*A. mellifera*) | The average yield of seeds was 43% higher compared to the control. |
| Coriander (*Coriandrum sativum* Linnaeus.) | *Apis cerana* Fabricius | The seed set increased by 69.51% compared to the control group's 54.89%. The yield was 14.57 q/hectare, while the control group's was 11.66 q/hectare. |
| Cotton *Gossypium hirsutum* L.) | Honey bees (*A. mellifera*) | A fibre weight increase of more than 12% and an additional 17% seed production were observed. |
| Pumpkins (*Cucurbita maxima* L.) | Honey bees (*A. mellifera*) | The number of visits was correlated with a linear increase in fruit set, fruit size, weight, and seed quantity. |
| Sesame (*Sesamum indicum* L.) | Honeybees (*A. mellifera*) |  |
| Mustard (*Brassica juncea* L.) | Honey bees (*A. mellifera*)  Honey bees (*A. cerana*) | Increased siliqua/panicle by 20.8%, seeds/silique by 9.4%, and seed yield by 17.1% compared to open pollination. |
| Coffee (*Coffea arabica* L.) | Solitary bees and social bees | Fruit set was much enhanced. |
| Oilseed rape (*Brassica napus* L.) | Solitary mason bee (*Osmia rufa* L.)  Honey bees (*A. mellifera*) | Bee density increased fruit set, yield, and seed number per pod. |

(Khalifa, *et al.,* 2021)

**CLIMATE CHANGE:**

Generally, Climate change refers to persistent change in the Earth’s average temperature and atmospheric conditions. Human activities, particularly the burning of fossil fuels and unsustainable practices, have resulted in a 1.1°C rise in global temperatures compared to pre-industrial levels. This warming has triggered more frequent and severe extreme weather events, posing significant threats to ecosystems, human health, and global well-being. Government of India is aware about the impact of climate change on agriculture and farmers’ lives. Extensive field and simulation studies were carried out in agriculture by the network centers located in different parts of the country.

The climate change impact assessment was carried out using the crop simulation models by incorporating the projected climates of 2050 & 2080. In absence of adoption of adaptation measures, rainfed rice yields in India are projected to reduce by 20% in 2050 and 47% in 2080 scenarios while, irrigated rice yields are projected to reduce by 3.5% in 2050 and 5% in 2080 scenarios. Climate change is projected to reduce wheat yield by 19.3% in 2050 and 40% in 2080 scenarios towards the end of the century with significant spatial and temporal variations. Climate change is projected to reduce the kharif maize yields by 18 and 23% in 2050 and 2080 scenarios, respectively. Climate change reduces crop yields and lower nutrition quality of produce. Extreme events like droughts affect the food and nutrient consumption, and its impact on farmers. (Ministry of Agriculture & Farmers Welfare)

**CLIMATE CHANGE EFFECTS IN APIARY POPULATIONS**

**Altering The Scents Of Plants**

Bees rely on a combination of visual signals, such as the colour and number of flowers, and olfactory cues, including the unique floral scents of each plant, to search for nectar-rich food sources. Remarkably, bees have the ability to store these cues in their memory, utilizing them to guide their quest for pollen. However, climate change has recently disrupted this process, causing plants to alter their scents. This alteration occurs when plants experience stress due to changes in environmental conditions, such as water scarcity or extreme heat, leading them to release defensive compounds that modify their scent. As a result, bees struggle to locate their food sources, ultimately leading to a lack of nutrition and the loss of bee colonies. (Burger 1982, Gullan & Cranston 2010)

**Mismatch In Seasonal Timing**

The delicate timing of pollination is being disrupted by climate change, posing significant threats to ecosystems. Normally, bees emerge from winter hibernation in perfect synchrony with the blooming of flowers, allowing for successful pollination. However, climate change has caused a mismatch between the timing of pollen production and bee emergence. As a result, bees are unable to hatch earlier to coincide with the changed flowering schedule, leading to dire consequences. This loss of synchronicity impairs plant reproduction, reducing seed production, and causing food shortages for both animals and humans. Moreover, the mismatch has devastating effects on bee populations, as they struggle to find food, ultimately leading to their decline. (Visser et all, 2004)

**Habitat Loss**

Habitat loss poses a significant threat to bee populations, with studies revealing a staggering 200-mile contraction of bee territories in North America and Europe. As a result, honey bees are facing a crisis in finding suitable locations to establish their hives. Unlike adaptable insects like butterflies, certain bee species, such as bumblebees, exhibit limited flexibility in shifting their habitats in response to climate change. Consequently, the loss of habitat may ultimately lead to the extinction of some bee species, underscoring the urgent need for conservation efforts to protect these vital pollinators. (Rosenkranz, P.(2010).

**Bee Health - An Increase In Susceptibility To Diseases**

Changes in temperature can significantly impact the prevalence and spread of bee pathogens, including Nosema and certain viruses. Higher temperatures can increase the survival rate of disease-carrying spores and viruses, allowing them to persist longer in the environment. Warmer temperatures can accelerate the reproduction rate of certain pathogens, leading to a rapid increase in their populations. As a result, bee populations are more likely to become infected, which can lead to devastating consequences, including weakened immune systems, reduced colony growth, increased mortality rates , colony collapse.( Paxton, R. J., & Brown, M. J. F. (2014) Some of the most concerning bee diseases impacted by climate change are Nosema: A fungal disease that affects adult bees and can lead to malnutrition and death. Deformed Wing Virus (DWV): A viral disease that causes wing deformities and can lead to bee mortality. American Foulbrood (AFB): A bacterial disease that affects bee larvae and can lead to colony collapse.

To mitigate these impacts, beekeepers and researchers are exploring strategies such as climate-informed beekeeping practices, disease monitoring and surveillance, development of disease-resistant bee stocks, integrated pest management techniques. The Varroa destructor mite is considered one of the most significant threats to honeybee colonies worldwide. Beekeepers and researchers are working to develop effective management strategies to combat the spread of Varroa mites, including integrated Pest Management (IPM) techniques, mite-resistant bee stocks, Targeted treatments and monitoring, best management practices for beekeeping. , A., Otten, C., Buchler, R., … & Rosenkranz, P. (2010).

Climate change poses significant threats to bee health by altering the dynamics of diseases and pests that affect bee populations. To address these challenges, continued research and proactive strategies are essential. Climate change has led to a significant increase in temperatures, resulting in warmer winters and hotter summers. This shift in temperature patterns has made bees more susceptible to diseases and parasites, particularly gut and mite parasites that thrive in warm conditions.

As a result, bees are now at a greater risk of falling victim to these diseases and parasites than they were before, posing a substantial threat to their populations and overall health. Changes in temperature can significantly impact the prevalence and spread of bee pathogens, including Nosema and certain viruses. Higher temperatures can increase the survival rate of disease-carrying spores and viruses, allowing them to persist longer in the environment.

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**Increased Threat To Native Bee Species**

Native bees are facing an unprecedented threat of extinction due to widespread habitat loss, primarily driven by alarming global warming levels. The destruction of their natural habitats has put numerous species at risk, including the yellow carpet solitary bee, sunflower leaf-cutting bee, wild sweet potato bee, and Gulf coast solitary bee, which are among the most threatened. As temperatures continue to rise, the survival of these vital pollinators hangs in the balance, highlighting the urgent need for conservation efforts to protect their habitats and prevent further decline.(Dev Gousell,2018)

**Changes in Nectar flow**

**Increase in Diseases and parasites**

**Loss of forage**

**Colony losses**

**CAUSES OF CLIMATE CHANGE IN HONEY BEE**

**Biodiversity loss**

**Loss of Pollination services**

**Fig 1 : Causes Of Climate Change In Honey Bee**

**MAKING A BEE- FRIENDLY WORLD:**

In UK, farmers can choose to adopt any range of schemes, which aim to reduce yields and increase farmland wildlife. The schemes includes new hedge-planting, repair of existing hedgerows, conservation headlands (field margins that are not treated with fertilizer and pesticides), beetle banks (strips of tussock-forming grasses planted across fields).Conservation headlands will increase abundance of farmland butterflies and hover-flies. These schemes increase the diversity of flowers that are available. Due to inadequate pollination, the yield of crops is limited and the opportunities for the growth of novel crops are reduced through a lack of suitable pollinators. Thus, Agri-environment schemes provide an opportunity to enhance pollinator populations (Dave Goulson, 2003).

Creating green infrastructure such as green roofs to decrease fragmentation and promote pollinator livelihood in urban areas. This facilitates the correlation between pollinator shift and pollinator resource availability(Braaker, 2017). The type of vegetation and the green cover density can influence habitat heating and local microclimate. The surrounding vegetation will decrease the habitat temperature. So, maintain green spaces to support pollinators and preserve biodiversity. As per UN estimates, 55 percent of the world’s population resides in cities as of 2018, and that number could rise to 68 percent by 2050(Amarjit S Tanda, 2023).

In order to bring pollinators from the surrounding landscapes to the farms and ideally have them overflow to provide pollination services wild flower planting is done. To reduce the amount of insecticides used to manage pests, choose less toxic pesticides or employ alternative methods. Establish nesting sites by offering appropriate nesting material, tunnel-filled lumber and favourable ground conditions. Of all bee species, 30 percent use of tunnels drilled in to wood and about 70 percent nest in the ground. Small cavities are necessary for bumblebees, a tiny but crucial group of bees for crop pollination to build their nests (Showket A Dar *et al***,** 2017).

To avert a crisis, creating a pollinator-friendly world is crucial. This requires collaborative efforts from the agriculture science community, private and public organizations, and non-profits. Investing in technology, promoting beekeeping, and raising community awareness are essential strategies. The World Bee Project is a pioneering initiative that utilizes cloud technology, AI, and IoT to research and analyze bee health. By listening to bees, they develop localized solutions to protect their health.

The "Sweet Revolution" initiative, launched by the National Bee Keeping and Honey Mission of the Government of India, aims to promote beekeeping, generate employment, ensure food security, and conserve bee populations. This program is expected to boost apiculture growth by 4.43% between 2020-25. Further research is necessary to identify climate-resilient plant varieties that enhance bee nutrition in different regions. Educating farmers to create bee-friendly habitats, such as undisturbed soil and regional plants that bloom throughout the year, can help mitigate extreme weather events. Ultimately, raising awareness about the importance of bees to our food system is vital for creating a more pollinator-friendly world. (National Bee Board,2023)

Hon’ble Prime Minister had given a clarion call “SWEET KRANTI” after which [Honey](https://www.pepperhub.in/product/wild-honey-400g-pack/)Mission was launched by KVIC. The Sweet Kranti scheme, also known as the Honey Mission, is a government initiative in India launched by the Khadi and Village Industries Commission (KVIC) in 2017. It aims to promote beekeeping, also called apiculture, across the country. Agriculture Finance Bee Keeping Madhu Makshika Palan (Apiculture) is a term loan program offered by IDBI Bank in India to support individuals and organizations interested in starting beekeeping ventures. (NBB,2023)

The loan is specifically designed to finance the setting up of beekeeping units for honey production. The Mukhyamantri Madhu Vikas Yojana is a scheme launched by the Himachal Pradesh government in India specifically to promote beekeeping and honey production within the state. The goal of the scheme is to Encourage farmers, especially unemployed youth, to take up beekeeping as a source of livelihood, Boost honey production and overall income of farmers in rural areas and promote beekeeping as a sustainable agricultural practice. (Minstry of Agriculture and farmers welfare)

In TamilNadu, Supply of BeeHives ,Under This scheme,10 Beehives are provided free of cost to the tribal people living in hilly and wild areas to increase their income through beekeeping.(Tribal Welfare Programmes, Tenkasi District Portal). Conserving bee colonies is crucial to mitigate the devastating effects of climate change on these vital pollinators. To achieve this, protecting and managing bee-friendly habitats such as coastal areas, grasslands, and farmlands is essential. This can be accomplished by implementing environmental legislation that preserves areas where bees live, leading to increased bee populations and higher levels of pollination, ultimately minimizing food shortages. In addition to habitat preservation, reforestation efforts can significantly contribute to bee conservation. Bees rely on trees for building their hives, and deforestation has severely impacted their populations.

Individuals, governments, and non-governmental organizations can make a difference by planting trees and promoting sustainable forestry practices. Sustainable farming practices are also vital for bee conservation. Farmers can play a crucial role by avoiding harmful pesticides, herbicides, and fertilizers, such as those in the neonicotinoid family, which are toxic to bees. Instead, they can adopt organic farming methods, utilizing beneficial insects like ladybugs and praying mantises to maintain ecosystem balance. By shifting from conventional to sustainable agriculture, farmers can significantly contribute to bee conservation and promote ecosystem health. (Showket A Dar *et al***,** 2017)

**CONCLUSION:**Climate change poses a significant threat to beekeeping and the vital pollination services provided by honeybees. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events all impact bee colonies, compromising their health, productivity, and very survival. The consequences of climate change on beekeeping are far-reaching, with implications for food security, ecosystem health, and the livelihoods of beekeepers and farmers worldwide. It is imperative that we take immediate action to mitigate the effects of climate change on bee populations and the beekeeping industry. Rapid changes in the biodiversity of insect pollinators could have an impact on the availability of crop pollination services. Pollinator diversity and abundance declined as a result of pressure from the artificial agro-ecosystem, endangering biodiversity once more through lower agricultural productivity. Increased land use changes, alterations in the climate, pollution, urbanization, and the use of pesticides are some of the factors that led to threads becoming pollinators. Plant pollination failure rates rise as a result of this. In order to preserve, this declining Agri-environment scheme offers a chance to increase the population of Pollinators and to improve pollinator habitat by building green infrastructure, such as green roofs, to lessen fragmentation and encourage pollinators in urban areas.

**REFERENCES:**

Alaux, C., Ducloz, F., Crauser, D., & Le Conte, Y. (2010). Diet effects on honeybee immunocompetence. Biology Letters, 6(4), 562–565. https://doi.org/10.1098/rsbl.2009. 0986

Arias, M. C. & Sheppard, W. S. (2006). Corrigendum to: Phylogenetic relationships of honey bees (Hymenoptera: Apinae: Apini) inferred from nuclear and mitochondrial DNA sequence data. (Molecular Phylogenetics and Evolution, 2005, 37(1), 25–35. Molecular Phylogenetics and Evolution, 40(1), 315–315.

Barbet-Massin, M., Rome, Q., Muller, F., Perrard, A., Villemant, C., & Jiguet, F. (2013). Climate change increases the risk of invasion by the yellow-legged hor-net. Biological Conservation, 157, 4–10. https://doi.org/10. 016/j.biocon.2012.09.015

Blacquiere, T., Boot, W., Calis, J., Moro, A., Neumann, P., & Panziera, D. (2019). Darwinian Black Box selection for resistance to settled invasive parasites Varroa destructor in honey bees. Biological Invasions, 21(8), 2519–2528

Brodschneider, R., Ellis, J. D., & Neumann, P. (2022). A Special Issue on COLOSS. Bee World, 99(1), 1–4. https:// doi.org/10.1080/0005772X.2022.2019377

Brown, A. F., Rodriguez, V., Brzoska, C., Pfister, J., Neumann, P., & Retschnig, G. (2022a). Dream team for honey bee health: Pollen and unmanipulated gut microbiota pro-

mote worker longevity and body weight. Frontiers in Sustainable Food Systems, 6. 864741. https://doi.org/10.3389/fsufs.2022.864741

Brown, A. F., Rodriguez, V., Pfister, J., Perreten, V., Neumann, P., & Retschnig, G. (2022b). The dose makes the poison: Feeding of antibiotic-treated winter honey bees, Apis mellifera, with probiotics and b-vitamins. Apidologie, 53(2), 19. https://doi.org/10.1007/s13592-022- 00927-4

Castle, D., Alkassab, A. T., Bischoff, G., Steffan-Dewenter, I., & Pistorius, J. (2022). High nutritional status promotes vitality of honey bees and mitigates negative effects of pesticides

Chaudhary, O. P., & Chand, R. (2017). Economic benefits of animal pollination to Indian agriculture. *Indian Journal of Agricultural Sciences*, *87*(9), 1117-1138.

Flores, J. M., Gil-Lebrero, S., Gamiz, V., Rodrıguez, M. I., Ortiz, M. A., & Quiles, F. J. (2019). Effect of the climate change on honey bee colonies in a temperate Mediterranean zone assessed through remote hive weight monitoring system in conjunction with exhaust-ive colonies assessment. The Science of the Total Environment, 653, 1111–1119.

Pecl G.T., Araújo M.B., Bell J.D., Blanchard J., Bonebrake T.C., Chen I.-C., Clark T.D., Colwell R.K., Danielsen F., Evengård B., et al. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science. 2017;355:eaai9214. doi: 10.1126/science.aai9214.

Hautier Y., Tilman D., Isbell F., Seabloom E.W., Borer E.T., Reich P.B. Anthropogenic environmental changes affect ecosystem stability via biodiversity. Science. 2015;348:336–340. doi: 10.1126/science.aaa1788.

Leemans R., Eickhout B. Another reason for concern: Regional and global impacts on ecosystems for different levels of climate change. Glob. Environ. Change. 2004;14:219–228. doi: 10.1016/j.gloenvcha.2004.04.009.

Bowler D.E., Hof C., Haase P., Kröncke I., Schweiger O., Adrian R., Baert L., Bauer H.-G., Blick T., Brooker R.W., et al. Cross-realm assessment of climate change impacts on species’ abundance trends. Nat. Ecol. Evol. 2017;1:0067. doi: 10.1038/s41559-016-0067.

Weiskopf S.R., Rubenstein M.A., Crozier L.G., Gaichas S., Griffis R., Halofsky J.E., Hyde K.J.W., Morelli T.L., Morisette J.T., Muñoz R.C., et al. Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. Sci. Total Environ. 2020;733:137782. doi: 10.1016/j.scitotenv.2020.137782.

Hodgson J.A., Thomas C.D., Cinderby S., Cambridge H., Evans P., Hill J.K. Habitat re-creation strategies for promoting adaptation of species to climate change. Conserv. Lett. 2011;4:289–297. doi: 10.1111/j.1755-263X.2011.00177.x.

Forrest J.R.K. Insect pollinators and climate change. In: Johnson S.N., Jones T.H., editors. Global Climate Change and Terrestrial Invertebrates. John Wiley & Sons, Ltd; Chichester, UK: 2016. pp. 69–91.

Patel V., Pauli N., Biggs E., Barbour L., Boruff B. Why bees are critical for achieving sustainable development. Ambio. 2021;50:49–59. doi: 10.1007/s13280-020-01333-9.

Bartomeus I., Potts S.G., Steffan-Dewenter I., Vaissière B.E., Woyciechowski M., Krewenka K.M., Tscheulin T., Roberts S.P.M., Szentgyörgyi H., Westphal C., et al. Contribution of insect pollinators to crop yield and quality varies with agricultural intensification. PeerJ. 2014;2:e328. doi: 10.7717/peerj.328.

Wei N., Kaczorowski R.L., Arceo-Gómez G., O’Neill E.M., Hayes R.A., Ashman T.-L. Pollinators contribute to the maintenance of flowering plant diversity. Nature. 2021;597:688–692. doi: 10.1038/s41586-021-03890-9.

Winfree R. The conservation and restoration of wild bees: Wild bee conservation. Ann. N. Y. Acad. Sci. 2010;1195:169–197. doi: 10.1111/j.1749-6632.2010.05449.x.

Conrad K.M., Peters V.E., Rehan S.M. Tropical bee species abundance differs within a narrow elevational gradient. Sci. Rep. 2021;11:23368. doi: 10.1038/s41598-021-02727-9.

Orr M.C., Hughes A.C., Chesters D., Pickering J., Zhu C.-D., Ascher J.S. Global patterns and drivers of bee distribution. Curr. Biol. 2021;31:451–458. doi: 10.1016/j.cub.2020.10.053.

Garantonakis N., Varikou K., Birouraki A., Edwards M., Kalliakaki V., Andrinopoulos F. Comparing the pollination services of honey bees and wild bees in a watermelon field. Sci. Hortic. 2016;204:138–144. doi: 10.1016/j.scienta.2016.04.006.

Durant J.L. Climate Change is Ratcheting up the Pressure on Bees. [(accessed on 25 March 2023)]. Available online: <https://www.ucdavis.edu/climate/blog/bees-face-many-challenges-and-climate-change-ratcheting-pressure>.

Spivak M., Mader E., Vaughan M., Euliss N.H. The plight of the bees. Environ. Sci. Technol. 2011;45:34–38. doi: 10.1021/es101468w. [[DOI](https://doi.org/10.1021/es101468w)]

Khalifa S.A.M., Elshafiey E.H., Shetaia A.A., El-Wahed A.A.A., Algethami A.F., Musharraf S.G., AlAjmi M.F., Zhao C., Masry S.H.D., Abdel-Daim M.M., et al. Overview of bee pollination and its economic value for crop production. Insects. 2021;12:688. doi: 10.3390/insects12080688.

18.Van Dijk M., Morley T., Rau M.L., Saghai Y. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. Nat. Food. 2021;2:494–501. doi: 10.1038/s43016-021-00322-9.

19.Dubois T., Pasquaretta C., Barron A.B., Gautrais J., Lihoreau M. A model of resource partitioning between foraging bees based on learning. PLoS Comput. Biol. 2021;17:e1009260. doi: 10.1371/journal.pcbi.1009260.

20.Wignall V.R., Brolly M., Uthoff C., Norton K.E., Chipperfield H.M., Balfour N.J., Ratnieks F.L.W. Exploitative competition and displacement mediated by eusocial bees: Experimental evidence in a wild pollinator community. Behav. Ecol. Sociobiol. 2020;74:152. doi: 10.1007/s00265-020-02924-y.

Balfour N.J., Gandy S., Ratnieks F.L.W. Exploitative competition alters bee foraging and flower choice. Behav. Ecol. Sociobiol. 2015;69:1731–1738. doi: 10.1007/s00265-015-1985-y.

Alger S.A., Burnham P.A., Boncristiani H.F., Brody A.K. RNA virus spillover from managed honey bees (Apis mellifera) to wild bumblebees (Bombus spp.) PLoS ONE. 2019;14:e0217822. doi: 10.1371/journal.pone.0217822.

Novelli S., Vercelli M., Ferracini C. An easy mixed-method analysis tool to support rural development strategy decision-making for beekeeping. Land. 2021;10:675. doi: 10.3390/land10070675.

Vercelli M., Novelli S., Ferrazzi P., Lentini G., Ferracini C. A qualitative analysis of beekeepers’ perceptions and farm management adaptations to the impact of climate change on honey bees. Insects. 2021;12:228. doi: 10.3390/insects12030228.

Gajardo-Rojas M., Muñoz A.A., Barichivich J., Klock-Barría K., Gayo E.M., Fontúrbel F.E., Olea M., Lucas C.M., Veas C. Declining honey production and beekeeper adaptation to climate change in Chile. Prog. Phys. Geogr. 2022;46:737–756. doi: 10.1177/03091333221093757.

https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1909206#:~:text=Climate%20change%20is%20projected%20to%20reduce%20the%20kharif%20maize%20yields,and%20its%20impact%20on%20farmers.