Bee decline: an ecological concern

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Abstract: The necessity for maintaining the ecological balance in equilibrium is a critical and pressing issue *vis-a-vis* the biodiversity of organisms including beneficial insects like honey bees and pollinators. Pollination is one of the greatest ecological services provided by insects with bees playing a significant role. Bee decline over the years has affected nature's equilibrium and has resulted in biodiversity loss, the consequence of which will be impaired food and nutritional security around the globe. The majority of the causes, which are man-made, may be checked if strict policies and guidelines are in place. Habitat loss, parasites and viruses, pesticides, monotonous diets, shipping fever, and climate change are some of the key causes leading to ‘Bee decline’. Although not completely, concerted efforts toward an environmentally benign and conscious human activity could help to resurrect the vanishing bees and pollinators.

Key words: Bee decline, diseases, diversity, pollination, stressors

The diversity of wild bees and other pollinators has decreased over the last five decades, with a few species on the verge of extinction globally. In North America and Canada, as well as several European countries, managed honey bee numbers have collapsed (NRC, 2007). Apart from abiotic factors, almost 200,000 species of animal pollinators assist more than two-third of the world's angiosperms in meeting their reproductive needs to varying degrees. According to statistics, pollinator-plant interactions affect almost 4 lakh species. Pollination service is estimated to be worth 235-577 billion US dollars each year globally (Noriega *et al*., 2018). Pollination is a mutually beneficial interaction in which pollinating animals receive some form of nutritional ‘reward’ in exchange for transporting and visiting pollen. Pollen is a nutritive reward for some of the flies, butterflies, bees, and birds that do cross-pollination (Roulston *et al*., 2000).

Pollinator decline has reached such alarming levels that ecologists are warning that the world is on the cusp of a "pollination crisis," resulting in significant crop yield loss in the years ahead. Under future land use and climate change scenarios, an estimated five billion people could lose grain production due to insufficient pollination, notably in Africa and South Asia (Chaplin-Kramer *et al*., 2019). Reduced floral supply and nesting opportunities appear to be caused mostly by habitat loss, which was a key driver in the twentieth century and remains so now (Goulson *et al*., 2015). A series of parasites and diseases infect both wild and managed bees, mostly due to anthropogenic influences. Due to an over-reliance on chemical pesticides targeting the huge agricultural production to feed the burgeoning human population, pollinators are inevitably exposed to a cocktail of agrochemicals. Global climate change is also a major stressor, and it is expected to exacerbate such problems in the future. A nexus of stressors is involved and these do not act alone, making it impossible to anticipate how they will interact; for example, a few herbicides work synergistically rather than additively. Honey bee colony losses and wild pollinator decrease appear to be caused by chronic exposure to a nexus of stressors, while the specific combination appears to differ from place to place.

A study of apple orchards in China's Maoxian county highlighted the consequences of bee decline, where natural insect pollinators are inadequate or non-existent as a result of indiscriminate insecticide usage. Climate change has worsened the loss by causing changes in the weather, such as more frequent showers, cooler temperatures, and gloomy weather during the apple blossom season. This causes asynchrony in flowering, which inhibits pollination by natural pollinators when they are present (Partap and Partap, 2002). Pollination, which was once a free service provided by nature, is no longer available. They have resorted to employing human pollinators for 12-19 USD per person every day, with each pollinating a maximum of 12 plants (Partap *et al*., 2012). To ensure appropriate pollination, it is necessary to boost pollinator intensity in fields and orchards before the alarm bells ring in our neighborhood. Furthermore, roboticists in many labs across the world are building robotic bees to pollinate crops, based on the assumption that natural bees are dwindling and that, humans will soon require a replacement. No matter how far technology advances, we will never be able to replace honey bees with robotic arms to carry out the complex pollination process, which would be costly both economically and environmentally. It is wiser if we begin saving them today to avoid having to regret it later, as the saying goes, ‘Prevention is better than cure’.

Causes of Bee decline:

1. Habitat loss:

Long-tongued bumblebees' ranges have shrunk dramatically as a result of the loss of roughly 97 percent of the floral-rich grass ecology in the United Kingdom throughout the twentieth century (Howard *et al*., 2003; Goulson *et al*., 2008). The loss of bees has been linked to a variety of stresses, some of which are more plausible than others. The loss of habitat is one example. It has directly contributed to bee decline and colony loss, as bees require sufficient floral resources during the adult flight season, which might be short for solitary species or year-round for eusocial species in tropical climates. They also require unaffected nesting grounds, with different species occupying different locations (*e.g*., cavities underground, hollow-stemmed twigs, burrows in the soil, even abandoned snail shells). The conversion of flower-rich natural and semi-natural habitats into agricultural fields, as well as urbanization, has resulted in significant habitat loss. In gardens, bumblebees and numerous solitary bee species can survive in high numbers, however, in urbanized areas (where roads divide the habitat and traffic cause direct collisions with active colonies), bees are scarce (Bates *et al*., 2011).

2. Pathogens:

Pathogens that cause disease in bees include viruses, bacteria, fungus, protozoans, and other parasites and pathogens. Honey bees, rather than bumblebees or other solitary bees, are the focus of the study, and there is little information on other wild bees. Some disease infects both honeybees and bumblebees, such as deformed wing virus (DWV) and *Nosema ceranae* Fries (Microsporidia: Nosematidae); however, *Paenibacillus* larvae appear to be more host-specific (Graystock *et al*., 2013). The transportation of honey bees across long distance is one of the main causes, which is referred to as "shipping fever." Since the 1960s, *Varroa* mite has spread from Asia to Europe, the Americas, and, most recently to New Zealand (*Varroa* vectors DWV). The mite and the DWV spreads have a synergistic effect, contributing significantly to honey bee colony losses in North America and Europe (Nazzi *et al*., 2012).

In Europe and North America, commercial trafficking of bumblebee colonies for pollination of greenhouse crops like tomatoes is common, and this has resulted in a major loss of bee variety. Tragically, this trade has turned out to be a complete failure. Over one million European bumblebee, *Bombus terrestris* (Linnaeus) (Hymenoptera: Apidae), nests were bred in Europe and shipped to several countries during the 1980s. In North America, the eastern American species *Bombus impatiens* Cresson is raised for this purpose. Unfortunately, it does not appear to be able to raise disease-free colonies, not least because the bees are fed with pollen collected by honeybees, which provides a path for many bee viruses to enter the colony. Parasites like *Nosema bombi* Fantham and Porter, *N. ceranae*, *Apicystis bombi* (Liu, Macfarlane & Pengelly), and DWV are all common parasites identified in commercial *B. terrestris* colonies (Graystock *et al*., 2013).

3. Introduction of exotic honey bee species for managed pollination:

Wild bumblebee populations have been demonstrated to be severely impacted by non-native infections or pathogen strains associated with these colonies. Species can become extinct merely as a result of ignorance. Despite the presence of native *Bombus* species, the Chilean government deliberately introduced *B. terrestris*, which soon expanded across southern South America. The introduction of *B. terrestris* in the area appears to have resulted in the rapid extinction of the native *Bombus dahlbomii* Guerin-Meneville, at a rate that can only be explained by pathogen spillover. Although the parasite responsible for the invasion has yet to be identified with certainty, both *Apicystis bombi* (Liu, Macfarlane & Pengelly) and *Crithidia bombi* Leger have been discovered to be common among invading species (Schmid-Hempel *et al*., 2013). It is gratifying to note that the large-scale introduction of bumblebees from other countries has not been on hold in India owing to its perceived impact on native bumblebee diversity in the country (Uma Shankar, 2014).

4. Injudicious use of pesticides:

Herbicides, on the other hand, allow farmers to plant near-pure monocultures, but their use diminishes the availability of flowers for pollinators, making farmland uninhabitable for bees (Goulson *et al*., 2008). Sanchez-Bayo and Goka (2014) anticipated that three neonicotinoids (thiamethoxam, imidacloprid, and clothianidin) and two

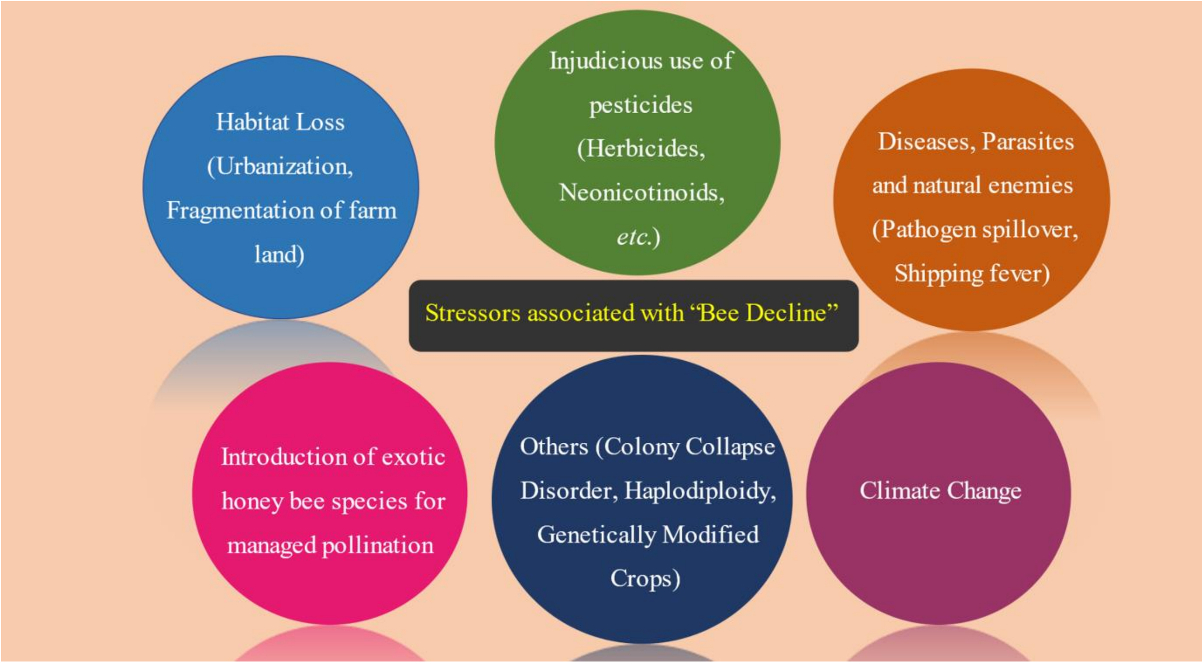

Plate 1: Causes of Bee decline

organophosphates (phosmet and chlorpyrifos) pose the greatest harm to honey bees on a worldwide scale out of 161 pesticides used. Chemical insecticides continue to remain a major threat to domesticated and wild bees ever since the introduction of high-yielding varieties of crops in the 1960s. Many regulations are in place to check the indiscriminate use of insecticides which would potentially endanger the bee pollinators. A lot of concern has been raised about the possible impact of neonicotinoids on bee health. Several reports allude to the colony collapse to the widespread use of neonicotinoids in crops (Krupke *et al.*, 2012; Han *et al.*, 2010).

Neonicotinoids are widely used for seed treatments because they are systemic within plants, spreading through plant tissues and into pollen and nectar of blooming crops like canola (Cutler and Scott-Dupree, 2007); sunflower (Higes *et al.*, 2010); corn (Genersch *et al.*, 2010). They're also water-soluble yet exceedingly persistent in soil and soil water, therefore they've been found in biologically significant concentrations in pollen and nectar from wildflowers near crops (Krupke *et al.*, 2012). Both honey bees and bumblebees have shown sublethal symptoms of neonicotinoid exposure, including reduced learning, foraging, and homing abilities, all of which are critical for bee survival (Han *et al.*, 2010). In bumblebees, however, exposure to field-realistic levels of imidacloprid significantly slowed colony growth and reduced queen production by 85 per cent (Whitehorn *et al.*, 2012).

Bee decline may be caused by a complex interplay of stresses; embryonic exposure to neonicotinoid insecticides makes honey bees more vulnerable to the invading disease, *N. ceranae* (Wu *et al.*, 2012). Colony Collapse Disorder (CCD) is also a result of the stresses combined. Neonicotinoids are highly potent neurotoxic insecticides, and the finding that they are present in 75% of the honey samples collected from around the world (Mitchell *et al*., 2017) demonstrates that bees (and by implication many other insects) are routinely exposed to them.

5. Climate change:

The most prevalent man-made pollution, of course, is greenhouse gas emissions, which cause climate change. Some insects' ranges have begun to move as a result of climate change, with European and North American bumblebees disappearing from the southern borders of their range and adopting higher elevations in mountainous areas (Pyke *et al*., 2016). There is also evidence that the phenology of some herbivorous and pollinating insects are becoming decoupled from their host plants. For example, in Colorado, some highland plants are now blooming before bumblebees have emerged from hibernation when they did not previously (Pyke *et al*., 2016). Low electromagnetic fields, such as those formed by high voltage cables, have been found to impair the cognitive capacities of honey bees, and it has been claimed that this may have led to bee colony losses and, more broadly, could disrupt insect navigation and dispersal (Shepherd *et al*., 2018).

Adoption and mitigation measures:

Conservation is an anthropocentric pursuit; it requires integrating social and ecological understandings and greater coordination to advance insect pollination conservation practices and policies fit for Anthropocene. Humans are the major beneficiaries of the ecological services rendered by bees. Ironically, bees have been viewed as a conditional danger – annoying if provoked- and education about bees vanishes fear, and increases interest and willingness to protect them. There is no silver bullet in determining bee-friendly practice adaption. A key strategy to support native and managed bees is through diversified practices such as planting and maintaining permanent pollinator habitats. Diversification also serves as an adaptive capacity by enhancing the foraging range of the wild and non-domesticated bees which comprises ecological engineering and habitat management. Strips of cover crops, hedgerows, or wildflower strips can increase wild pollinator diversity and visitation. Moreover, the availability of such floral resources regularly ensures the honey bee's health. Incentivizing the beekeepers and their neighbors to adopt diversified bee-friendly management practices such as forage planting, artificial nesting sites, and reduced pesticide use directly increase food security and pollinator health. Progressive beekeepers are encouraged through initiatives such as USDA's EQIP (Environmental Quality Incentive Program) and the non-profit Project Apis m's "Seeds for Bees" cost-free program for cover crop planting in the United States. Urban populace around the world is leaning toward sustainable living, and it can be contemplated by the construction of buildings using hollow bricks, and 'bee hotels' are more sought after to encourage solitary bees for nesting.

In the absence of sweeping international agreements aimed at pollinator conservation, national, sub-national, and municipal governments are developing policy approaches to address insect pollinator conservation. Many policies from legislative bodies include- officially designating

"Pollinator Day" or "Pollinator Week", in many others "Bee Day" to raise awareness; tightened beekeeping standards to manage pathogens; creating a task force to update pest management approaches (pesticide use); funded research and monitoring for managed bees and native insect pollinators. In India, there are Centers for Excellence for beekeeping especially, AICRPs, and IBDCs throughout the country to carry out region-specific research and disease management. There are nascent efforts to goad in international policy. Emergent from the United Nations Convention on Biological Diversity Conferences, in 2018, nations began coordinating national strategies for pollinator protection through a coalition of willing pollinators called "Promote Pollinators" (~ 25 members). Coalition members share methods for conservation and tactics for instigating policy.

Apart from biotic and abiotic factors, bees' decline needs to be addressed based on their genetics, with special emphasis on haplodiploidy, as the haplodiploidy and complementary sex determination affect genetic parameters which are pertinent to the viability of bees. Hymenopteran shows the genetic effect of population fragmentation over other insect orders and the reduced population size due to haplodiploidy. Because in one generation there are only ¾ gene copies in haplodiploid organisms compared to diplo-diploid ones, haplodiploid hymenopterans will generally have less effective population size which reduces the heterozygosity and calculation of population size is highly complex due to unusual sex ratio (Packer and Owen, 2001). The production of inviable or sterile diploid males, a necessary by-product of complementary sex determination, is a large threat to the short-term viability of small bee populations. Although, happening of inbreeding depression by dominance and overdominance is lower in haplodiploids compared to diploids, it still reduced the fitness and viability of small bee populations which shows adversity in conservation (Zayed, 2009).

Conclusion:

In general, the loss of nectarivorous bees would result in the significant plummeting of forest and agro-biodiversity, resulting in skyrocketing food prices. Moreover, many floral species are dependent on honey bees for pollination and many local communities also depend on honey and wax as a source of their livelihood security. Bees, which are critical to the survival of the human race, are on the decline majorly due to the use of pesticides and habitat loss. Conservation prescriptions appear attainable; they emphasize managing rural and urban lands to maximize forage for insect pollinators and curb agrochemical-pollinator interactions.

Abbreviations:

AICRP-All India Coordinated Research Project

CCD: Colony collapse disorder

DWV: deformed wing virus

EQIP- Environmental Quality Incentive Program

IBDC-Integrated Bee Development Centers

NRC: National Research Council

USDA: United States Department of Agriculture

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