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An Insight into the Global Decrement of Honey Bee Population: Causes and Its Imposing Effects

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Abstract

During the past few decades, world have seen a record breaking increase in the number of human population. The huge burst of the population size and the consequent implications of anthropogenic activities have aroused number of unprecedented phenomena. Climate change, severe air pollution, land degradation, deforestation, shortage of drinking water and significant loss of bio diversity are some of the crucial outcomes of it. One such detrimental effect of these amalgamated factors has been expressed in the sheer loss of honeybee population in today's world. The decrease in their habitat, lifespan or species diversity have been observed globally during the last few decades. The gradual decline in number of bee is affecting the natural flow of ecosystem and severely impact the production of important crops all over the world. As a principal facilitator of pollination, the loss of bee population will cause worldwide decline of food production which can lead to global catastrophe. In this situation the present article has tried to understand the present scenario of honeybee population dynamics, their principal cause of decline, implications and possible measures that can save bee diversity.

Introduction:

With the advent of the last century, human race have achieved never-seen-before advancement in the field of technological, scientific and economic growth. With the tremendous progress in the medical science, the risks of life–threatening diseases have been mitigated significantly. A stable socio-political environment with the thrust of economic growth has pushed the life–span of humans significantly in past few decades. With the bursting population size, today's Earth is facing a grave danger in terms of food production which can cater to the present 8 billion people. Industrial development and many other anthropogenic factors have already cut down the extent of agricultural land. Therefore, the modern society's growing concern is to produce crop in a way to cater the need of the people worldwide.

Green revolution has solved this problem to a greater extent where the use of chemical fertilizers and crop rotation has enormously boosted crop production but again there are few natural factors that science and technical advances have not yet been able to replace. Pollination is such a fundamental process on which the reproduction of angiosperms depends significantly. The process which ensures the transport of pollen from the anthers to the stigma is facilitated by various biological or non-biological ones. Though anemophily is favoured by most cereals and the advanced techniques of plant breeding has been able to by-pass the conventional fertilization or pollination process through parthenogenesis, still a large number of crops depend on zoophily or specifically entomophily. Entomophily or insect-mediated pollination is crucial for almost 87% of wild crops, essential for maintaining bio-diversity (Ollerton et al., 2011, Potts et al. 2023) of both the plants and the animals that interact with them. A mutualistic relation between plants and their pollinators has been well observed in many wild varieties (Heithaus

1974, Del Moral and Standley 1979). Other than wild varieties, plenty of economically important crops especially high–quality production of fruits have also been found to be dependent on insect pollinators (Hung et al. 2018, Lindao-Cordova et al. 2020, Durazzo et al. 2021, Klein et al. 2007, Khalifa et al. 2021). Not only crops, 98% trees in lowland tropical rain forests are dependent on insects for pollination (Bawa et al., 1990, Klein, et al, 2006). As the direct correlation between entemophily and production of crops has been well established in last few decades (Aizen et al. 2008, Potts et al. 2010, 2016, Goulson et al. 2015, Koh et al. 2016), it is utmost economically important to conserve the pollinators and their habitats to ensure the food supply and food safety worldwide (Murphy et al. 2022).

Socioeconomic values of honeybee:-

Insects, in general, are a large fraction of the animal world that contributes to the group is the most abundant and ubiquitous in natural world. Insects are also the most robust group who has withstand and survived many calamitous incidences, also many evolutionary selections. In recent years, a number of reports have surfaced to notify the gradual decline in the number of insect biota all over the world. The latest report has stated only USA has seen a record 75% loss of insect species in last 10 years. Being a crucial part of natural ecosystem, this mass extinction will no wonder create a devastating consequence to our natural environment (Bar-On, et al, 2018, Hallmann, et al, 2017, Leather, 2017, Sa´ nchez-Bayo, et al 2019, Klink et al, 2020).

Honeybees are globally considered to be the most significant pollinators of both wild and cultivated plants (Klein et al. 2007, Brittain et al. 2013a, 2013b, Satyshur et al. 2023). Bees (Hymenoptera: Apoidea: Anthophila), which constitutes mostly 20,000 species are the most efficient group of insect pollinators keeping in mind that not all of them are fully described yet (Orr et al. 2021). As they solely depend on floral nectars for their survival, bees are the group of insects that comes into closest contact with flowers (Potts et al. 2016). Hence, there can be no doubt that bee population is one of the principal contributors of pollination activity (Hoehn et al. 2008). Apid bees in the Western Ghats in Southern part of India, alone are responsible for 18% pollination of total 86 species of trees, and 22% of the shrubs (Devy, 2003, 2006).

Not only they are significant contributor to crop pollination but also play a key role improving socio-economic status as they produce a number of essential products for many communities and industries. Scientists have also valued their role in sustainable development (Patel et al, 2021). Honey, beeswax, propolis, pollen, royal jelly and bee venom are some vital products that have tremendous economic value (Aylanc et al, 2021, Kieliszek, M. et al., 2018). For breeding and rearing, live bees are also regarded of high value which are bought and sold in form of queens or a large number of working bees. Honeybees are sometimes used as protein sources in human and animal diets (Ghosh et al, 2016, Ulmer et al, 2020).Honey is regarded as a critical ingredient or adulterant in Ayurveda, widely used as medicine, economically important crop and vital ingredient in some cultural traditions. Beeswax has tremendous use in industrial processes other than just beekeeping practices. Beeswax are essential commodity in the manufacture of cosmetics, pharmaceuticals, candles, electronic components, polishes and specialized industrial lubricants (FAO, 1996, 2004).

It will be unwise to only discuss about pollinating capacity or products obtained from bees. Beekeeping is considered globally as a stable source for income in rural areas as these culturing or rearing needs no big investment. Across the world, the practice of beekeeping has great influence over the social, cultural

and economic viewpoint as it can be run by simple infrastructure whilst providing a significant source of income (Halvorson, et al, 2021).

As mentioned earlier, in recent years, there have been unfortunate reports of population loss of insects as well as bees which will be definitely a huge cause of global food outage (Osterman, et al., 2021, Dukas, 2008, Ellis, 2010). Not only this prospect of food-crisis but the decline in honey bee population will also bring wide-spread socioeconomic impacts.

Present status and threats of bee population:-

As there are thousands of bee species in the wild of which many are unidentified, beekeeping is generally practiced, using two species of managed honeybees, *Apis mellifera* Linnaeus (1758) and *Apis cerana* Fabricius (1793) throughout the world. There are also many stingless bees such as Trigona spp. and Melipona spp [15]. Honey bees, i.e., the *Apis* genus of the Apidea family (Hymenoptera), include 11 species of which 10 are generally found in South-eastern Asia (of which five managed ones), and one native to Africa, Middle-East, Central Asia and Europe (*Apis mellifera*) (Panziera et al.2022).

Though bee population loss is common in almost every part of the continents, most studies have been conducted particularly on one special bee taxa (e.g., *Bombus*). Reports are also confined to local, regional, or country-level datasets where most of them have taken place in the Northern Hemisphere, particularly North America and Europe. Comprehensive and elaborate surveys expanding uncharted regions regarding the decreased population on bees are still lacking.

Recent reports of alarming decrease in general insect diversity are serious matter of concern. A global meta-analysis revealed a 45% decline in insect abundance (Wagner 2020). Bees are also facing same existential crisis in today's human-dominated landscapes.

There are not one but numerous biotic and abiotic factors responsible for the gradual decrease in bee population. Climate change, habitat destruction, massive urbanization, diseases, insecticides, environmental stresses, and change in lifestyle pattern or a combination of all these may be attributed as causes for the decline and demise of honeybees. Intensive agriculture is again another serious or main contributor of pollinator decline and loss of their ecosystem dynamics (Kremen et al. 2002, Attwood et al. 2008, Kremen and Miles 2012, Goulson et al. 2015, Grab et al. 2019, Nottebrok et al. 2022). As discussed above, to cater the demand of ever-increasing human population, the threats on the natural ecosystem is continuously growing. The transition from natural to agricultural lands is a primary driver of biodiversity loss worldwide. Among the biotic causes, reports of pathogen attacks, uncontrolled use of pesticides and introduction of invasive species are usually common world-wide (Vilá et al. 2011, Vanbergen et al. 2013, Goulson et al. 2015, Wagner 2020). However, no one or two principal factors can be singled out to blame behind this phenomenon and more detailed studies are required to ascertain the exact scenario [8-10].

Occasionally some reports have shown that one or two single factors are responsible for regional or local loss of bee colonies. For example, varroa (Varroa destructor Anderson and Trueman) mites (Le Conte, Ellis & Ritter 2010; Rosenkranz, Aumeier & Ziegelmann 2010), pathogens (i.e. bee viruses and *Nosema* spp.; Higes et al. 2009; Cox-Foster et al. 2007; Genersch & Aubert 2010) etc. play crucial role in decreasing population. On the other hand, excessive use of pesticides also negatively affected beekeeping practices (Thompson 2003; Alaux et al. 2010; Johnson et al. 2010; Henry et al. 2012) (Oldroyd 2007). Again, these small scale datasets do not portray the reasons for increasing mortality in

general. The different stressors or their combination which is affecting the gradual decline should be addressed properly (e.g. van Engelsdorp et al. 2009; Ratnieks & Careck 2010).

A very interesting report from Chandrasekaran et al. (2011) stated that as a result of awareness on sustainable practices, there is a growing use of disposable paper cups, in a particular southern state of India. In Tamilnadu, people have started using environment friendly paper cups instead of glass cups and other metal cups from tea and coffee stalls. These left over paper cups containing sugary drink, or abandoned juice or beverages attracts the honey bees on a large scale. The bees do not want to exert their energy to find wild flowers and using these more sugary substances as a replacement of natural flowers. Unfortunately, it has been observed that bees who feast upon sugary products do not end up in beehives rather getting trapped into it. They fall into the sugary cups and get entangled in the syrupy residues. The cups which act like a death trap is a perfect example of how different variables are at play to maintain the natural ecosystem of bee population.

The situation with managed honeybees is occasionally better as they are monitored closely. Though there are some hopeful reports that the numbers of managed honeybee colonies are increasing globally (Aizen & Harder 2009), but considerable decline have been documented regionally (Stokstad 2007; Pettis & Delaplane 2010; Potts et al. 2010). Changing human diet also has a distant effect on wild-pollinated flowers and their pollinators. Though arrays of publications come out regularly but it still remains a mystery to pin-point the causes of colony loss (Ratnieks & Careck 2010). To comprehend the underlying factors and to predict consequences of different hive and landscape management practices on colony survival, currently scientists and experts on this field have felt demand for proper modelling systems (Ratnieks & Careck 2010; EFSA 2012; Osborne 2012).

To understand the multiple factors that are responsible for higher mortality of bee colonies, mammoth size data sampling should be done from smaller places as well as from larger and more complex ecosystems. However, this kind of extensive approaches is likely to be immensely time and resource-consuming and the results difficult to deduce. To overcome this setback, experts are in search of other approaches that can supplement experimental approaches (EFSA Panel on Plant Protection Products & their Residues (PPR) 2012; Osborne 2012). Cross-level 'systems ecology', based on mechanistic modelling (Evans, Norris & Benton 2012; Grimm & Railsback 2012), is one such method that includes individual as well as colony level data. The system incorporates the 'top down' and 'bottom up' regulating approaches which also measures the interactions between related organisms (e.g. parasites and pathogens) that regulate bee behaviour and health. This kind of system have made it possible to combine multiple processes and factors which consider different levels and scales thus render a detailed prediction on overall colony strength, survival and behaviour in diverse landscapes.

Though it has been generally considered that massive urban development is a principal cause of pollinator decay, surprising reports occasionally states that urban areas can also be recognized as a probable sanctuary for wild bee species (Hall et al., 2017). Excessive demolition of free landscape has definitely affected bee survival but (LeBuhn & Luna, 2021); cities sometime can provide refuge to a surprising diversity of pollinators. This targeted practice sometimes outnumber nearby agricultural or rural systems (Kaluza et al., 2016; Hall et al., 2017; Banaszak-Cibicka et al., 2018). The diverse urban landscapes, maintained greeneries and the implementation of pesticide-free environment in many cities have encouraged species richness in urban bee communities. Gardens, parks and residential yards in many urban areas provide an significant opportunity of feeding and nesting to wild bees (Ayers & Rehan, 2021; Matteson, Ascher & Langellotto, 2008; Baldock et al., 2019; Dylewski, Ma'ckowiak &

Banaszak-Cibicka, 2020). Urban bee community also contain diverse groups of which is helpful for maintaining bee diversity. Solitary and social species, cavity and ground nesters or many pollen generalists and occasionally pollen specialists: diverse groups when present they provide resilience and stronger adaptability in the ecosystem (Hernandez, Frankie & Thorp, 2009; Normandin et al., 2017). The presence of such diversity in urban bee community is also crucial for survival from pathogen attacks or balanced host-prey interaction of other species (Kleijn et al., 2015). Another positive side of urban bee rearing is the growing concern and proper awareness among public about the importance of wild bees. Mass knowledge and understanding of the situation is profoundly helpful for biodiversity conservation in cities.

Though awareness in general people is always beneficial for conservation but uncontrolled or unscientific methods of rearing will produce an adverse effect (Lorenz & Stark, 2015). Sudden increase of bee community is often reported as introduced by commercial and personal efforts in a small area. Various amateurs and commercial beekeepers have been capable of increasing bee colonies in high densities in many cities, sometimes on the order of six or more colonies per km2 (Ropars et al., 2019; Casanelles-Abella & Moretti, 2022). As healthy colonies can contain maximum of 50,000 bees by midsummer (Sagili & Burgett, 2011), this uncensored efforts has produced a higher than optimal density and results in competitive pressure on native bees for a limited amount of resource of pollen and nectar in a particular urban area. This saturated beekeeping operations may also have a negative influence on wild bees and other honey bees through amplified parasite and pathogen transmission to healthier ecosystem (Geldmann & González-Varo, 2018; Geslin et al., 2017).

Therefore, to revive and restore bee population, competition between communities should be considered. It may peaked where niche overlap among taxa is maximum resulting in generalist bees to directly contest for resources with other honey bees. This would cause as serious distress for specialist bees that may not be able to replace host plants (Wasser & Ollerton, 2006). In the face of sheer competition, small sized bees face great difficulties in foraging as they only can traverse shorter distances (Greenleaf et al., 2007). With opponents like larger generalist bees, smaller ones will have lesser resource (Herbertsson et al., 2016). Rearing bees in a confined and homogenous area will also create negative effects on larger bees as they need more floral resources as their energetic costs of foraging are higher, and they may tend to migrate to a less competitive place (Goulson, Stout & Kells, 2002). As the larger bee community have diverse requirement of nectar resource, sometimes in urban set-up, it is difficult to provide them. Urban environment generally consists of cultivated plants, though diverse but often paltry and patchy. They are generally meant for ornamental floral displays or other aesthetic properties rather than for pollen or nectar content (Lowenstein & Minor, 2016). Thus this critical factor of floral diversity in city areas is drastically different in rural areas and other influences of plant-pollinator relationships are also to be measured separately in non-urban cases than in urban bee community studies (Dylewski, Ma'ckowiak & Banaszak-Cibicka, 2020; Prendergast & Ollerton, 2021). Therefore a thorough and all-inclusive study should be taken into account to understand the interspecies interactions between managed and wild bees and the influence of other useful traits to increase the bee-biodiversity in cities and other areas.

Conclusion:-

The world-wide phenomena of honey bee colony decline have often been reported globally but they are mostly fragmented and not fully inclusive. Though it is well apprehended that bee-population decline

will definitely bring the world into the path of mass-starvation and alarming loss of bio-diversity, the fact remain mostly confined to a particular area or region with observations over a relatively short period of time. Very few reports have appeared from other continents, except Europe and North America which do not properly convey the actual condition. Furthermore, the study reports mainly centred about managed honey bees, *Apis mellifera* in particular, with little or no information on non-managed bees. Hence, interpretation based on biased findings cannot provide the real-time scenario.

It is of no doubt that different threats are at play in different parts of the world which diminishes honey bee community every day. The impact of loss of principal pollinators will be severe for smallholder farmers in low-income countries (Timberlake, 2022, Garibaldi, 2016). Lack of knowledge or data from under-developed regions where small farmers are mostly involved with bee-keeping is a crucial drawback (Steward, et al, 2014]). To overcome this challenge, extensive survey, spanning longer period of time or different seasons are required to assess the various risk factors and also to plan for mitigation strategies. Therefore, various factors, influences and dynamics, which have been discussed in the article, must be incorporated to get a fully inclusive and detailed idea about the proper insight about the bee population fluctuations.

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