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Strategies to combat the decline in pollinator's population

Sapna Devi, Diksha Devi, Swaraj Jit Singh and Babita Kaushal

Abstract
Pollinators are preferred to be the key component of global biodiversity, providing vital ecosystem services to agricultural crops as well as wild plants. But during the recent years, there has been reported a huge global decline in both wild and domesticated pollinators. This decline has commercially threatened agriculturally economic crops due to the fact that 75% of the crop's production totally relies on insect pollination. Previous reports have shown that 71% of the pollinator species have decreased and 3.4% became extinct over the past 20 years. Declines in pollinator species is driven primarily by habitat loss and declines in floral abundance as well as diversity, resulting from agricultural intensification. There are some other reasons including GM crops, pesticides and climate change etc. that may also cause loss of pollinator's diversity. Pesticide use is also a major cause of decline in pollinator's population. The EU decided to ban three neonicotinoids *viz*., clothianidin, imadaclorpid and thiamethoxam, that were blamed for killing the bees. A catastrophic decline in insect pollinators is probably attributable to the accidental introduction of invasive species which results in global decline in pollinators. So keeping in view the importance of pollinators, steps must be taken to prevent their further decline. Protecting, restoring, enhancing or creating new habitat is the best way to conserve the pollinator's population. Judicious use of pesticides is also an important tool to conserve the pollinators by using minimal use of insecticides, avoid spraying during bloom, and switch to more pollinator-friendly pesticides. Providing artificial nests for pollinators and encouraging flowering plants to provide blooms through-out their growing season, also became an alternate option to enhance their population. Suggested measures include the use of environmentally comparable schemes to enhance floristic diversity in agricultural landscapes. The national wildlife federation calling for the Environmental Protection Agency to suspend uses of neonics until further research shows there is no unacceptable harm to native bees, monarch butterflies and other pollinators. In the present review, different strategies have been discussed that can be further used to combat pesticide population.

Keywords: Pollinators, biodiversity, bees, pesticides, strategies

1. Introduction
The term pollinator's decline in simple words can be defined as reduction in the abundance of insect and other pollinators in many ecosystems worldwide beginning at the end of the 20th century and continuing into the present (Carrington, 2017) [7]. Pollinators participate in the sexual reproduction of many plants, by ensuring their crop pollination that is essential for some species and is a major factor in ensuring genetic diversity for others. Since plants are the primary foods source for animals, the reduction of one of the primary pollination agents, or even their possible disappearance, has raised concern and conservation of pollinators has become part of biodiversity conservation efforts. Pollinators which are necessary for 75% of the food crops, are declining globally in both abundance and diversity (Dirzo *et al.*, 2016) [12]. Bees, in particular, are thought to be necessary for the fertilization of upto 90% of the world's 107 most important human food crops. The decline in bee number has attracted much of the public attention. Members of the British Beekeepers' Association have issued numerous warnings in the 21st century that the country's bees are in rapid decline (Evans and Ambrose, 2017) [14]. Winter losses of beehives had increased in recent years with a hive failure rate of up to 50%. In France, the honey harvest for 2017 has been estimated at around 10,000 tons, representing a decline of two-thirds against the average annual harvest during the 1990s.

2. Pollination and Pollinator
"Pollination" occurs when pollen grains are transferred from one flower to another of the same species by wind or animals. Successful pollination results in the production of healthy fruit and fertile seeds, by allowing plants to reproduce (Free, 1993) [15].

It is not possible to produce healthy fruits without pollinator visits to crops, in case of some crops. Almost 90% of all flowering plants rely on pollinators for fertilization, and there are about 2,00,000 species of pollinators. Of those, 1,000 are hummingbirds, bats, and small mammals such as mice. The rest are insects like beetles, bees, ants, wasps, butterflies and moths etc. In recent years, much attention has been paid to the importance of pollinator and their contribution to the agricultural economy, reason being the decline in insect pollinators. Pollinators play an important role in keeping our environment healthy through flower pollination in natural areas. As the population of pollinated plants has declined, the population of pollinators has also been declined.

2.1 Insects and Crop Pollination

Entomology is by far the most common mean of pollen transfer and plays a vital role in the evolution of angiosperms. The mutual association of insect and flowers is believed to exist since 60-100 million years ago. There are about 2,50,000 species of flowering plants globally which are pollinated by 2,00,000 species of animals. Out of, 95% cross pollinated flowers, more than 85% depend upon insects for pollination. 50% of the plant species propagated by seeds are depending upon insect pollination. 1/3rd of the food supply is either directly or indirectly dependent on insect pollinated plants. Currently more than 65% of all flowering plants that are insect pollinated. Many wild plants in nature are being propagated through insect pollination which maintains the sustainability of ecosystems, environmental quality and help in conservation of biodiversity (Free, 1993) [15]. In India, of the 160 million hectares of the cropped area, more than 55 million is under bee dependent crops. Bee husbandry in agricultural systems is a crucial link in food and fibre production and sustainability.

According to previous studies, in total world crop pollination 73% is by bees, 5% by beetle, 19% by flies, 4% by birds, 6.5% by bats and 5% is by wasps. Thus, pollination is highly dominated by one or two species of pollinators, in most cases managed honeybees. (Klein *et al*., 2003) [18].

Previous reports have shown that average crop yield have been increased within the range of 18-71% by insect pollination, depending upon the crop. While in pollination may also enhanced the yield quality attributes of some crops. For example, adequately pollinated oilseed rape had higher oil and lower chlorophyll contents, in buckwheat, the proportion of empty seeds had decreased, and improved commercial grade of strawberries. It has also been observed that the overall yield was consistently enhanced by higher visitation rates, but not by higher pollinator richness (Figure 1) (Bartomeus *et al.*, 2014) [2].

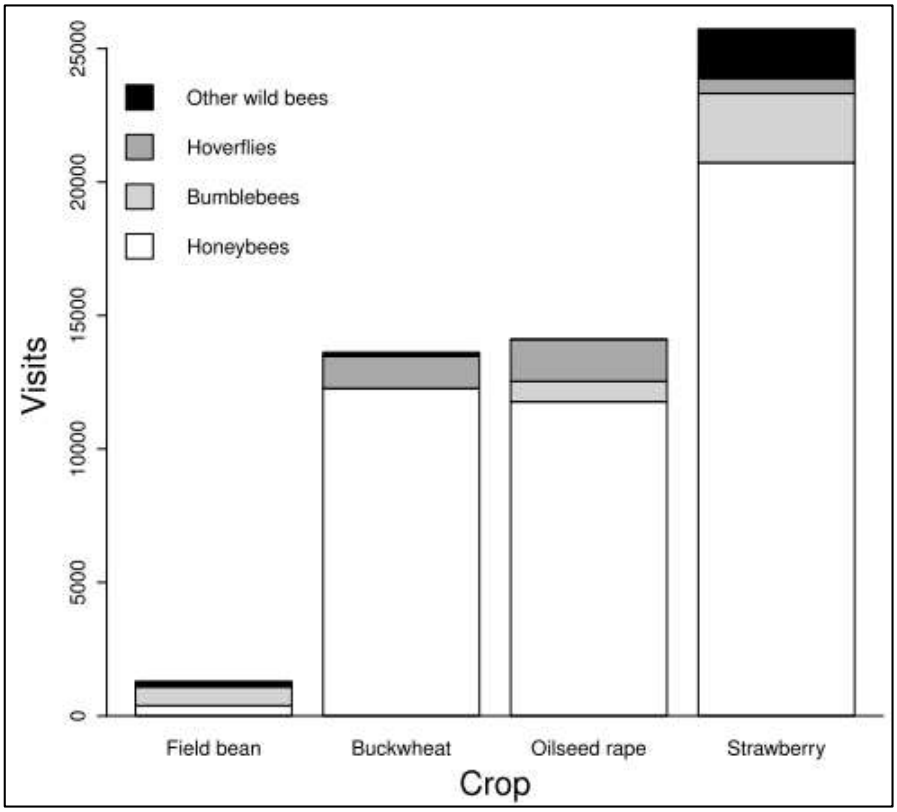

Fig 1: Number of visits recorded per pollinator in different crops (Bartomeus *et al.*, 2014) [2]

3. Decline in Insect Pollinators over A Few Decades

According to previous reports, it has been reported that the global insect populations are hurtling towards extinction, threatening a "catastrophic collapse of nature's ecosystems". It was found that 41% of the world's insect populations are declining while a third are endangered. The extinction rate of insects is eight times faster than mammals, birds and reptiles and thus they could totally vanish within a century. The impact of fewer insects would be devastating with birds, reptiles, amphibians and fish that rely on them for food starving to death. The knock-on effects could eventually have repercussions for the survival of mankind. The following infographic provides a closer look at some of the species experiencing major declines in population. Over half of the world's butterflies have died over the past decade with nearly half of all beetles and bees also perishing. Dragonflies have seen their ranks fall by 35% while a quarter of all flies have also died (Figure 2) (McCarthy, 2019) [19].

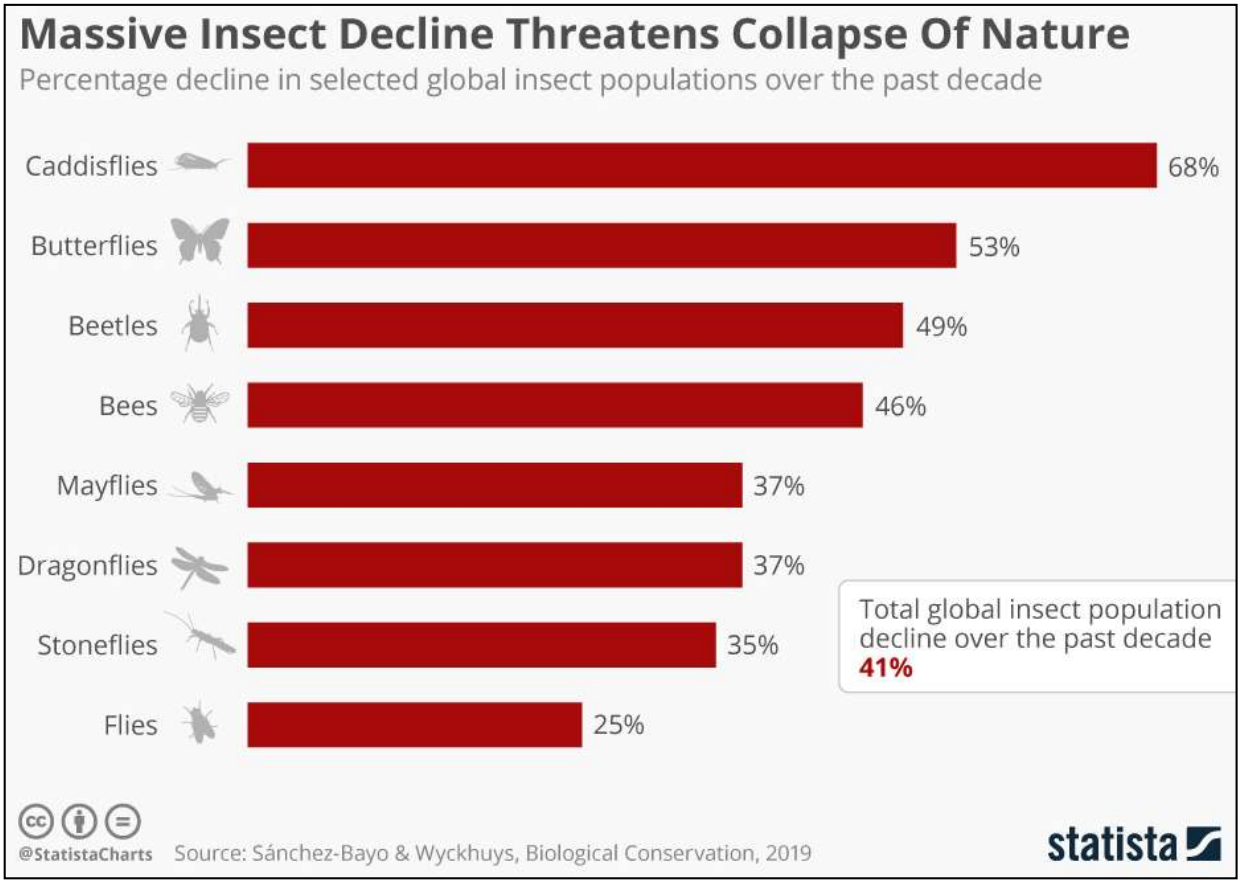

Fig 2: Percentage decline in global insect population over the past decades (McCarthy, 2019) [19]

4. Consequences of Decline of Pollinators

A huge decline in rate of pollination is one of the major consequences due to decline in pollinator's population, which may further lead to decrease in reproduction of a number of flowering plants. Some reports have shown that 87.5% of the flowering plants throughout the world are animal pollinated (Ollerton *et al.*, 2011) [20]. A sudden reduction in pollination due to decline in pollinator's diversity may lead to following consequences as explained in Table 1.

Table 1: Consequences due to decline in pollinator's population

Reduced pollination in crop plants may lead to:	• Gradual decrease in seed and fruit production • Reduction in regeneration rates. • Inbreeding problem in self-compatible flowering plants • Pistil senescence • Beekeeping sector in danger in several areas

Insect pollinators may contribute directly or indirectly to the qualitative and quantitative parameters of large number of crops including vegetables, fruits, oils, nuts, coffee, etc. Due to this, the service of pollinators has been considered very valuable throughout the world. In the previous reports it has been mentioned that global pollination worth 9.5% of global food production (Gallai *et al.*, 2009) [16].

5. Causes of Decline of Pollinators

5.1 Use of Pesticides

Use of pesticides to control agricultural pests has negative impact on pollinators. It was observed that there are huge losses in colonies whenever agriculture and beekeeping coexists with each other. These losses are due to poor handling and application procedures or failure to follow the recommendations printed on the label. If applies from the air, factors such as wind velocity have significant impact on the area covered by the pesticides, with the result that wild pollinators of the area adjoining the field are endangered. Neonicotinoides are the group of pesticides that are highly toxic to insects including bees, at very low concentrations. This group include imidacloprid, thiamethoxam, clothianidine etc. which are widely used to coat seeds. Herbicides affect the pollinator's population by eliminating plant species. Herbicides like glyphosate are toxic to bees and potentially harmful to other pollinators (Figure 3) (Woodcock *et al.*, 2016) [32].

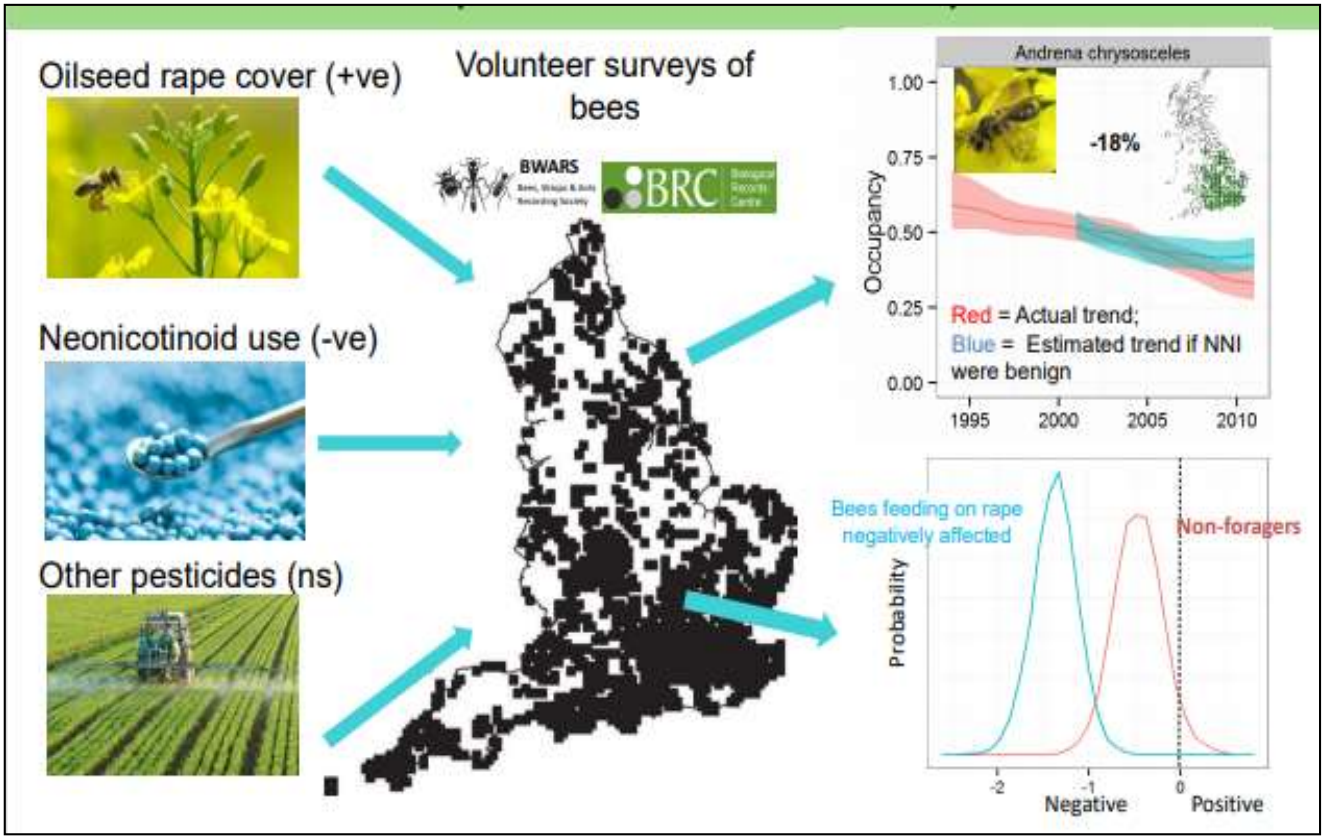

Fig 3: Pollinator decline due to use of neonicotinoids (Woodcock *et al.*, 2016) [32]

5.2 Use of Transgenic Crops

The main purpose for the development of transgenic crops was to repel the insect pests. But the potential impact of insecticidal protein in the pollen may impact the non target species such as pollinators, beneficial insects. This is due to the lack of information on lethal threshold of transgenic insecticidal protein and sub-lethal effects of the protein on the physiology and reproductive behaviour of the insects feeding on them. Genetically altered organisms are potentially hazardous to bees. Bt corn were planted in USA over 20% of the total area to evaluate the risk of Bt corn for monarch butterfly and concluded that replacing 80% of the conventional corn with Bt corn would provide hazardous to only 0.05% Monarch butterfly (Brodsgaard *et al*, 2003) [4].

5.3 Habitat Loss

Habitat loss may also results in loss of biodiversity.

5.3.1 Deforestration

The introduction of new cropping practices and intensive farming have resulted in significant loss of forestland. This means decline in the type of habitat that could provide nesting site for pollinators and flora needed for pollinator survival. The excessive use of green manures employing leguminous plants and reduction in plant diversity in the fields (Figure 4) (Woodcock *et al.*, 2016) [32].

5.3.2 Urbanization

Transforming the rural landscape in favour of urbanization, major infrastructure operation and development of industrial zone also cause disruption of floral species and plant pollinator imbalance. Habitat fragmentation and loss reduces the availability of the plants capable of meeting the needs of food throughout the season which increase competition among local species and decline in population (Figure 5) (Woodcock *et al.*, 2016) [32].

Fig 4: Deforestation

Fig 5: Urbanization

5.3.3 Buffer Zone
Wild areas bordering the farmland act as buffer zones. It was reported that the number of pollinators and visitation rate is reduced by 50% when natural habitats were 0.6 km apart from the crops while variety is declined by 50% with the distance of 1.5 km (Ricketts *et al.*, 2008) [23].

5.3.4 Grazing
Due to more excessive pasr=ture land for cattles many pollinators and floral resources suffered from a huge decline in diversity as well as abundance. Uncontrolled sheep grazing in mountain meadows removed enough flowering plants to eliminate pollinators (Figure 6) (Hatfield and Lebuhn, 2007) [17].

Fig 6: Land use for grazing (Vanbergen *et al*., 2014) [29]

5.3.5 Modern Agriculture
Tillage: Primary and secondary tillage can be detrimental to underground nest of bumble bees and thus may affect bumblebee population (Figure 7).

Fig 7: Tillage

5.4 Exotic Species
Exotic species are those which have been introduced from some other places. Some of the exotic species introduced as follows in Table 2.

Table 2: Effect of some exotic species on pollinator's decline

S.No.	Exotic species	Description	References
1.	Honeybees	• *Apis mellifera mellifera*, *A. m. carnica*, *A. m. ligustica* and *A. m. caucasica* • These races of honey bees, like other pollinating insects, have been imported from one part of the globe to another which have negative impact on wild bees. • A handful of bee colonies can collect hundreds of kilograms of nectar and dozens of kilograms of pollen per year. • Thus, can reduce the amount of nectar and pollen available in different natural plant communities. • The behaviour of native species that use the same flowers as the honey bee, e.g., wild bees, hummingbirds and ants, may therefore be altered.``	Paton, 1993 [21]
2.	Pathogens	• It was reported that bumble bees from commercial operations used for pollination in greenhouses often carry greater amounts of various pathogenic agents than wild bumble bees. • Propagation of these pathogenic agents within wild bee populations occurs when commercial bees escape from greenhouses and interact with their wild counterparts near the flowers.	(Colla *et al.*, 2006) [8]
3.	Effect of invasive plants on pollinators	• Invasive plant species affect not only pollinators but also plant pollination by disrupting the structure and function of ecosystems. • Invasive plants can alter the composition of the floral community in natural habitats, causing a loss of available resources (food, shelter, etc.) for all fauna species because pollinators co-evolved with the plants they visit.	Vila *et al.*, 2011 [31]
4.	Impacts on Native Pollinators	• The Africanized bee displays a considerable capacity to dislodge native pollinators. • The experimental introduction of Africanized bees into a community of neo-tropical wild bees resulted in reduced numbers of native bees and their decreased use of floral resources.	Bohan and Vanbergen. 2020 [3]

5.5 Climate Change
Global warming lead to alteration in the seasonal behaviour of insect species, due to which the risk of extinction of pollinators has been increased. Climate change may allow or cause bees to emerge at the times in the year when there is no flowering plants (Emily, 2014) [13].

Global climate change may affect the abundance of pollinators along with the phenology of plants. In simple words, the term phenology is the timing of physiological stages such as growth and reproduction, while, flowering phenology refers to the seasonal timing of flowering. The three mostly known factors that affect the phenology of both

plants as well as the pollinators are temperature, moisture and photoperiod. Many plants have reacted to increasing temperatures by earlier flowering. It was studied that insect pollinated plants react more strongly to increased warming as compared to wind pollinated plants and species. The onset of flowering is correlated with the mean temperature in the month of flowering or in the months prior to flowering (Devi *et al*., 2019) [11].

Table 3: Influence of global warming and climate change on pollinators (Devi *et al.*, 2019) [11]

Global warming and climate change results in	• Altered phenology of plants
	• Altered composition of pollinators
	• Emergence of new insect pollinators
	• Asynchronization between pollinator activity and plant physiology

5.6 Effect of Ecological Interactions on Pollinators

Ecological interactions along with certain non-pollinator species belonging to different trophic level *viz*., predators, parasitoids, leaf herbivores, soil fungi and bacteria that affect plant biomass and physiology, can also indirectly affect pollinators abundance and behaviour (Figure 8) (Barbar and Gordon, 2015) [1].

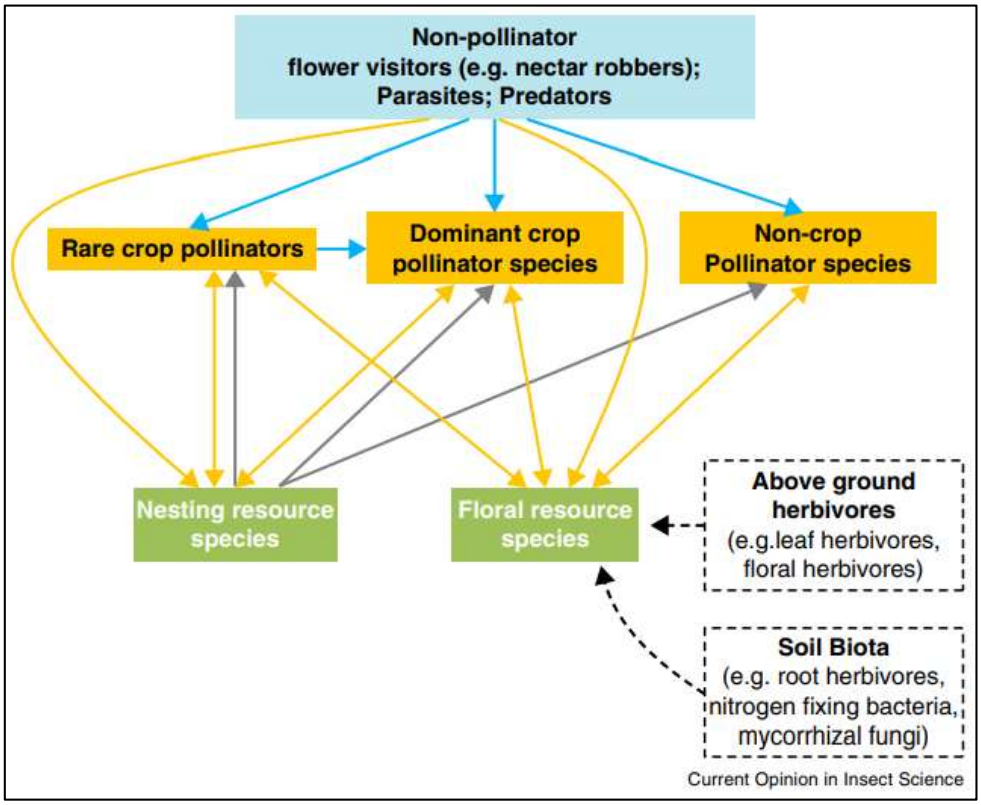

Fig 8: How ecological interaction can affect crop pollinators (Senapathi *et al.*, 2015) [26]

5.7 Other Potentials

Apart from all above mentioned causes there are some other causes of pollinator's decline.

Table 4: Other potential causes responsible for pollinator's decline (Woodcock *et al.*, 2016) [32]

S. No.	Other potentials	
1.	Pollution	• Heavy metals • Nutrients (e.g. Nitrogen) • Particulates (e.g. diesel) • EMR: visible light; other wavelengths (e.g. 3/4/5G)
2.	Fungicides	• Their interactions

6. Conservation of Pollinators

6.1 Creating High Quality Habitat

The three things that pollinators need in the landscape to thrive –

- Flower
- Nest site
- Place to overwinter.

Each of these habitat requirements is vital for a different phase of the pollinators annual life cycle (Pywell *et al.*, 2005) [22].

6.2 Habitat Management

The most valuable form of field margin management for bumblebees has been found to be the sowing of either wildflowers or a pollen and nectar mix consisting of agricultural crops (Pywell *et al.*, 2005) [22].

6.3 Improving Nesting Site

- Reducing tillage or leaving unploughed strips of vegetation will usually increase the availability of nesting.

- Sowing of field margins with grasses.
- Logs, stump, snags and clumps of grasses are often suitable (Pywell *et al.*, 2005) [22].

6.4 Individual and Community Initiatives

While the problem of pollinator reduction is of worldwide significance, a number of things can be done at the community as well as individual level to stave off this decline. The total area covered by community and private gardens throughout the regions can clearly play an important role in the preservation and protection of local pollinators (Pywell *et al.*, 2005) [22].

6.4.1 Gardening

Citizens can help protect pollinators in their own yards through their gardening practices. In so far as possible, each home owner should set aside a section of his property to let it develop naturally and allow native plants to grow and reproduce. This would promote the development of local species. In urban areas, such measures could provide sites for reproduction and islands of resources along corridors taken by pollinators as they move from one place to another. It is not enough to let native plants grow but, pollinator-friendly ornamental plants should also be selected. The plants selected should flower at different times, display an array of colours with different heights and flower shapes. To create diversity, it is important to grow plants that flower from early spring to late fall. There are several horticultural concepts that are often easy to introduce and help promote plant biodiversity which in turn supports pollinator species (Pywell *et al.*, 2005) [22].

6.4.2 Control Use of Insecticides

Naturally pesticide use should be reduced or completely eliminated whenever possible. This means carefully judging whether pesticide treatment is absolutely necessary and if so, read the label carefully and then apply the insecticide as per the standard guidelines. Before applying insecticide it should be kept in mind that never apply insecticide when a plant is in its flowering state. The least harmful formulation should always be selected. There are a number of ways of chasing harmful insects without endangering pollinators. Information on these alternatives may be obtained from support and information organizations such as the Coalition for Alternatives to Pesticides (CAP), CIBRC etc. (Vaughan and Black, 2007) [30]. *Bacillus thuringiensis (Bt)* is generally considered to be a bee safe pesticide (Riedl *et al*., 2006) [24].

6.4.3 Govt Responsibilities

6.4.3.1 Legislation

A study on federal and provincial laws was conducted by the International Network of Expertise for Sustainable Pollination at the request of the North American Pollinator Protection Campaign (NAPPC). The main purpose of this study was to determine the extent to which existing laws had the capacity to ensure the protection of native and wild pollinators. Their analysis mainly focussed on strict, enforceable laws passed by federal and provincial legislatures than on proceedings that are not legally binding such as agreements, conventions and strategies. Insect pollinators could be covered by federal jurisdiction since the latter applies in all national parks and national wildlife reserves. Some provincial laws could also provide a better protection of pollinators since they apply in the other regions. However, there is no explicit provision for insect pollinators in either federal or provincial law. According to the recommendations outlined in this report, legal provision could be made at the federal level by modifying the Parks Act, for instance, to allow pollinator insects to be acknowledged for the essential ecological services they perform and for the vital role they play in ensuring ecosystem integrity. The authors recommend replacing the term "Lepidoptera" with "Insecta" in the federal Species at Risk Act. Protection would thereby be potentially granted to all pollinating insect species (Tang *et al.*, 2007) [27]. The Pest Control Products Act, administered by Pest Management Regulatory Agency (PMRA), could be amended to include a specific reference to wild and managed pollinators, particularly with the licensing of new pesticides. Studies to examine the toxicity of these products to wild bees could be required under this Act. Several contentious pesticides should be submitted to a new battery of assessment tests that are applicable to bees (lethal and sublethal effects) and their broods (larvicidal and ovicidal effects). These tests should be designed using rigorous experimentation protocols drawn up by a committee of qualified, independent experts, including wildlife ecotoxicologists. Provision should also be made for a continuous post-licensing survey of these populations and their environment. It should be mentioned that the Agency has begun considering pollinating insects in the light of the significant agricultural services they provide (Tang *et al.*, 2007) [27].

6.4.3.2 Conservation Areas

According to national databases on conservation areas, there are approximately 3500 identified protected areas. These areas are managed by different levels of government. They include national or provincial parks and conservation or wildlife management areas. A number of parks have also been created at the municipal level. While the creation of natural reserves is effective in protecting conservation, restoration, public awareness or education require partnerships, with the creation of strategic coalitions and mobilization of existing resources. It is important to conserve habitats for pollinators, simply setting space aside is not enough. For long-term conservation, it is also important to make sure that necessary resources are available and that the areas set aside are as large as the vital habitats of the species targeted. Because of the diversity of species involved, not all pollinators can be preserved in parks and natural reserves. Conservation and protection programmes must therefore include not only reserves but also other types of habitats that are important for ensuring pollinator biodiversity. This means woodlands, the margins around clearings, hedges, grasslands, old orchards, canals, abandoned gravel and sand pits, wet ditches, gardens and other green spaces suitable for adequate flora (Tang *et al.*, 2007) [27].

6.4.3.3 Communication and Establishment of Action Plans

In order to protect wild pollinators, it is essential to establish concrete action plans that will promote local, national and international coordination. Projects focusing on research, facilitate communication between the parties concerned to ensure the success of these types of partnerships (Tang *et al.*, 2007) [27].

6.4.4.4 Financing Local Initiatives

The financing of structured local initiative programmes for the conservation and restoration of habitats to promote the preservation of plants and wildlife is crucial if the intended

goals are to be achieved. Governments cannot act alone (Tang *et al.*, 2007) [27].

7. Various Recommendations for Research and the Advancement of Understanding

7.1 Developing Expertise in Pollinator Taxonomy

A number of recommendations aimed at halting pollinator decline require knowledge of the species found in an environment. Documentation and assessment of the number and diversity of pollinator groups are advised. However, when it comes to furthering our understanding at the species level, it is often difficult to find an expert for the identification or validation of specimens. The decline in specialists in insect pollinator taxonomy is cause for as much concern as the decline in the insects themselves. Some species are on the list of endangered species drawn up by the International Union for Conservation of Nature and Natural Resources. It is important to recognize these species so that appropriate measures can be taken to ensure adequate conservation of their habitat, but as according to Toole pointed out, without more sustained funding in the area of bee taxonomy, we run the risk of not really knowing what we are trying to preserve (Toole, 2002) [28].

7.2 Identifying Native Pollinating Species of Use in Agricultural Production

In agricultural ecosystems, good management of insect pollinators can provide a complement to pollination of some crops. At present, the quality and extent of these pollination services are not fully understood. The first step is to identify the different species found on a crop's flowers, followed by identification of species with a valuable potential for pollination. Lastly, the contribution of these species to agricultural production should be quantified (Toole, 2002) [28].

7.3 Identifying Native Pollinators That Could Be Commercialized

Some wild bee species could be managed for pollination, as is the case with bumble bees and honeybees. Some natural pollinators of various legumes, apples, pears and cherries, etc., are both efficient and reliable. Some solitary bee species, such as the squash bee (*Peponapis pruinosa*), play an important role in the pollination of pumpkins. There could be a considerable advantage in extending the use of pollinators found on the flowers of one cultivated plant to other crops. Care should be taken, however, that a prospective introduced (or managed) pollinator does not have the potential to become an invasive exotic species (Toole, 2002) [28].

7.4 Studying Plant-Pollinator Relationships

Several plant-pollinator interactions are already well understood. It would be advisable to make sure that the state of our knowledge concerning rare and keystone species from an ecological or commercial point of view is complete and properly interpreted. Botanical species differ in the way they respond to disruptions. We do not know how a disturbance in the landscape can influence the beneficial effects resulting from the co-evolution of plants and their pollinators. It is important to know that the relationship that might exist between dwindling pollinator populations and the potential for the cascading disappearance of plant species that shelter these insects and depend on them for reproductive purposes (Toole, 2002) [28].

7.5 Developing a Viable Agricultural Landscape

The preservation or restoration of wild plants in an agro-ecosystem could prove beneficial for crop pollination by attracting surplus pollinators to the crops and the environs. In return, these pollinators could serve to complement the activity of pollinators introduced to improve yields. On the other hand, the presence of wild plants could provide competition and exert a negative influence on production by attracting introduced pollinators away from the target crop. A proper understanding of the importance of plants in an environment for the maintenance of pollinators is essential. A good grasp of the phenology of the flora and pollinating fauna found in an agricultural landscape could help determine positive or negative outcomes and the extent of influence these plants have on crop pollination (Toole, 2002) [28].

7.6 Protecting Foraging Sites and Restoring Degraded Habitats to Promote Pollinator

There is a positive correlation between the diversity and abundance of pollinators in wooded land with the size of these wooded areas. A loss of pollinators in these areas is followed by a reduction in total flower seed production. Urban sprawl and agricultural development have cut into the areas available as habitats for wild bees. Research on native bees should focus not only on conservation of the species. It should also be concerned with conservation of habitats and ecosystems. A better understanding of the dynamics of pollinator migration is needed. If the insects are to be protected, it is also important to be able to identify foraging sites along the migration corridors taken by the pollinators (Toole, 2002) [28].

7.7 Acquiring a Better Understanding of the Impact of Pesticides

The improper use of agricultural pesticides adversely affects the development of honeybee colonies. A better understanding of the impact of pesticides on wild bee species as well is of crucial importance. The development of a tool to measure this impact would make it possible to provide these populations with greater protection. With a better management of pesticides, it would be possible to reinforce natural pollinator populations which contribute to improved crop yields (Toole, 2002) [28].

7.8 Studying the Pathogens of Wild Insect Pollinators

If the use of introduced pollinators for crop pollination is to be encouraged, continued efforts must be made to control diseases and parasites. Several avenues of research have already been explored in the case of the honey bee (*Apis mellifera*) to study the different pathogens (diseases and parasites) attacking the species. Less work has been done on the parasites of other introduced species. These pathogens are potentially capable of being transmitted to wild populations of the same species (Toole, 2002) [28].

7.9 Using the Honeybee as A Bioindicator

The honeybee (*Apis mellifera* L.) is recognized throughout the world as an effective environmental indicator. It is used on a planetary scale as a tool for biological monitoring to assess the environmental risks of harmful products. A honeybee hive is a complex, organized living organism which is highly sensitive to a number of chemical pollutants at extremely low levels, sometimes as low as 2 to 3 ppm, as in the case of systemic insecticides (Bromenshenk *et al.*, 1995) [5].

8. Work Done By Different Researchers To Reduce Pollinator Population Decline

8.1 Field assessment of Bt *cry1Ah* corn pollen on the survival, development and behavior of *Apis mellifera ligustica*

Bt and non-Bt corn groups were compared to study the behaviour of *A. mellifera ligustica.* This study showed that there was no significant difference in the immature stage between the non-Bt and Bt corn groups. The average overall survival rate of bees observed was 39.2% after feeding for 24 days and was not significantly affected by exposure to Bt versus non-Bt corn pollen. The weights of newly capped bees that were fed non-Bt vs. Bt corn pollen were not significantly different. No significant differences were found in the weight of newly emerged bees that were fed with Bt corn pollen compared to a control treatment in which bees were fed non-Bt corn pollen.

The most consistent endpoints that served as indicators of foraging activity were the number of foragers returning with pollen loads, the pollen load weight, and forager weight. There were no significant differences in the percentage of bees loaded with pollen (Figure 8A), the weight of foraging bees (Figure 8B) or the weight of pollen loads that were carried back to hives by foraging bees (Figure 8C) between the Bt and non-Bt corn groups (Dai *et al.*, 2012) [10].

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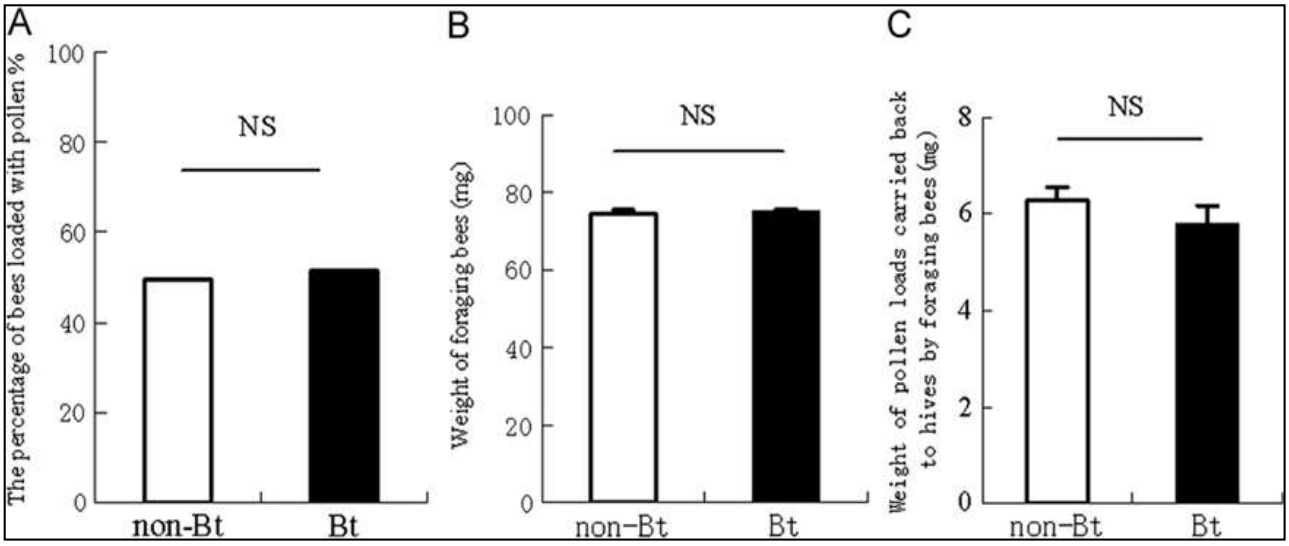

Fig 8: Percentage of bees loaded with pollen (A), mean7SE weight of foraging bees (three replicates per treatment with 10 individual bees per replicate) (B), and weight of pollen loads carried back to hives by foraging bees (three replicates per treatment with 10 individual bees per replicate) (C) (Dai *et al.*, 2012) [10].

8.2 Effect of pesticide application on butterfly fauna

Percent occurrence of butterfly species at different crops growing areas showed decreased number of butterfly species after insecticides application (Santhose and Basavarajappa, 2016) [25].

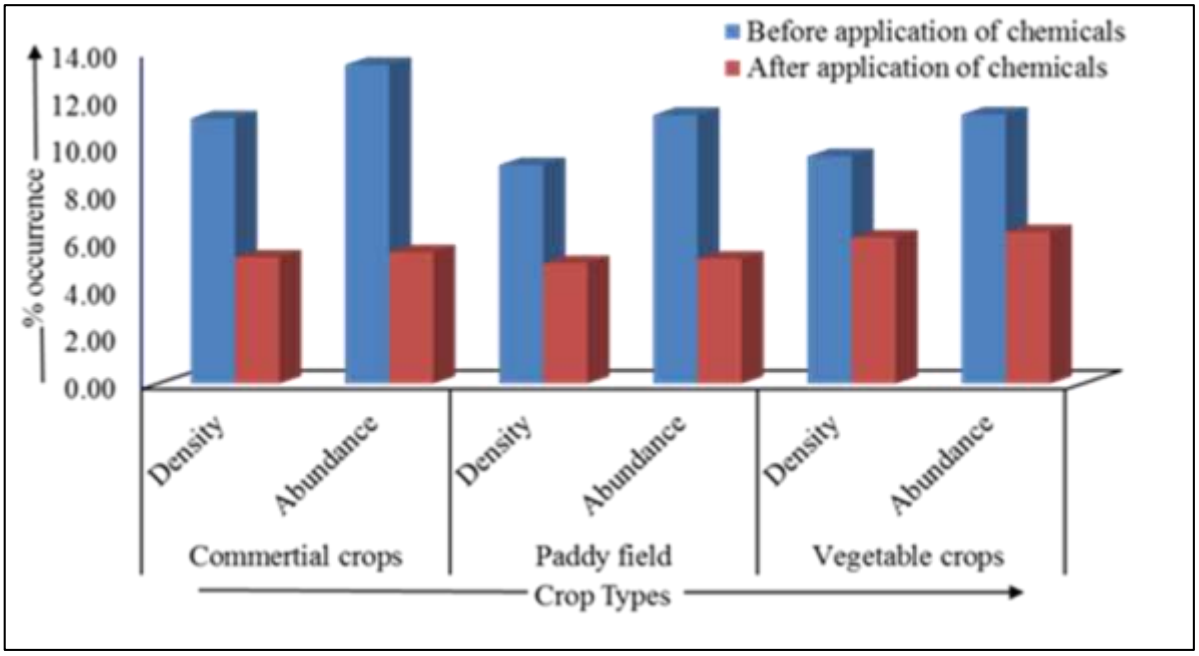

Fig 9: Density and abundance of butterflies before and after pesticide application.

8.3 Effect of heavy metals and metalloids on honeybees

Newly emerged bees were chronically exposed to selenium contaminated food for 7 days. Chronic exposure to 6 mg/kg sodium selenate or methylseleno-L-cysteine significantly increased mortality during the 7 days of treatment compared to control bees (Burden, 2016) [6].

8.4 Effect of increase in carbon dioxide concentration on honeybees

During the three minute exposure of workers to 20%, 40% and 60% CO_2/air, no anaesthesia was observed. The locomotor activity of bee workers declined with the increase in CO_2 concentration from 20% to 60%. The workers stayed in one place, making only single movements with their heads, antennae or legs and showed accelerated breathing movements. With less than 80% CO_2 concentration in air, workers entered a state of light anaesthesia. Only workers treated with 100% CO_2 reached a state of deep anaesthesia (Czekonska, 2009) [9].

9. Conclusion

Protecting, restoring, enhancing or creating new habitat is the best way to conserve population of pollinators. Judicious use of pesticide is also helpful to conserve bees. Minimize insecticide use, avoid spraying during bloom, and switch to more pollinator-friendly pesticide. Providing artificial nests for pollinators are an option to increase pollinator's population. Encourage flowering plants to provide blooms through the growing season.

The key points in pollinator conservation in urban, semi-urban and agricultural areas are the following:

1. Identify wild pollinators and their established habitats
2. Create nesting sites for bees
3. Supply a range of native flowers that blossom throughout the growing season
4. Make changes in the management practices involving existing fields to avoid harming the pollinators that are already present
5. Improve, restore or create habitats for butterflies and bees.
6. Avoid using pesticides

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