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Diversity, Importance and Decline of Pollinating Insects in Present Era

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Abstract

Pollination is a multi-million-year-old co-evolutionary process involving flowering plants and pollinators. It is one of the most important mechanisms in preservation and promotion of biodiversity as well as life on Earth. Pollinator diversity is essential for maintaining overall biological diversity in many habitats including agro-ecosystems. Pollinators are responsible for assisting reproduction in over 80% of the world's flowering plants. In their absence, humans and wildlife would go hungry. Insects are the most efficient pollinators as they play a crucial part in pollination ecology. Pollinators and their habitats have ecological, economic, cultural and social benefits. Pollination efficiency is highly dependent on certain attributes and characteristics of pollinators such as vision, anatomy, food preferences, olfaction, behaviour and learning ability. With the rapid growth of human population, our demand for food has also risen. Our agricultural systems will need to produce more food in a sustainable manner in the future to cope with this. Pollinators play an important role in these ecosystems and will continue to do so in the future. Because pollinators are so important to agriculture, we need to learn more about which crops require specific pollinators and how to best maintain and promote both wild and controlled species. Their diversity needs protection because there are specific relationships between certain crops and pollinators. Pollinator communities are suffering as a result of man-made habitat disruptions, including severe biodiversity loss. This diversity must be protected by combining conservation measures with sustainable farming practices which could increase crop yields while protecting insect pollinator species.

Keywords: Insects, Pollinators, Species, Crops, Diversity

1. Introduction

Pollination is a multi-million-year-old ecosystem process from which both flowering plants and pollinators get benefitted. Pollinating animals come to flowers for a variety of reasons, including food and shelter. Pollen rubs or falls onto pollinator's bodies when they visit flowers. As the pollinator passes from one flower to the next, it transfers the pollen to another flower. This transfer is important in the life cycle of all flowering plants because it is required to begin seed and fruit production. Pollinators are important for healthy, productive agricultural ecosystems and nature.

Indeed, the interactions between plants and their pollinators are among the most beautiful examples of coevolution on the planet. While some pollinators are generalists, visiting a wide variety of flowers, many pollinators have acquired preferences for certain flower kinds, and vice versa. Most pollinators have their favourite colour of flower: Bees prefer blue flowers, butterflies prefer pink and red flowers, flies choose yellow and white flowers, beetles and bats prefer white flowers, while hummingbirds prefer red flowers. In addition, the phenology, form, and food reward offered by the flower can all impact which pollinators visit [1]. Bees, for example, can see ultraviolet light and have a better sense of bilateral symmetry. As a result, flowers that want to attract bees will likely use these visual signals to lure the bee to the flower's centre [2].

Though some plant species depend on wind or water currents to carry pollens from one flower to another, but majority of plant species (approx. 90%) prefer animal assistance in this task. Around 200,000 different species of animals do this task of pollen transfer. Out of these, 1,000 are of vertebrates (birds, bats and tiny mammals), with the remainder being invertebrates, such as moths, bees, flies, beetles and butterflies [3].

Plant-pollinator interactions may be one of the most ecologically significant types of animal-plant interactions: without pollinators, many plants would be unable to set seed or reproduce, and without plants to provide pollen, nectar, and other rewards, countless animal populations would decline, with knock-on effects for other species [4].

Plants and their pollinators have had a significant impact on each other's growth, frequently leading to diversification and even an exclusive partnership. The Madagascar Star Orchid (*Angraecum sesquipedale*), which possesses a foot-long nectar tube that can only be pollinated by a species of hawk moth (*Xanthopan morgani praedicta*) with its 8–14 inch long proboscis, is a good illustration of this. The exquisite Star Orchid-Hawk Moth relationship even helped Darwin supporting his theory of evolution [2].

2. Pollinator diversity

Mutualisms between plants and pollinators extend back to the Cretaceous period, when insects began to feed on flowers and flowers achieved higher reproductive success through the transfer of pollen by insects. At least 67 percent of blooming plants rely on insects for pollination today [5], with the rest relying on birds and mammals. Pollinators are just as important as light and water for these plants to survive [6].

Pollinators comprise a diverse group of animals that include species of butterflies, flies, moths, wasps, beetles, ants, birds, weevils, thrips, midges, bats, monkeys, marsupials, rodents, and reptiles, but are dominated by insects, particularly bees. Bees and flies visit more than 90% of the world's major plant types, while the other species visit fewer than 6% of the crop varieties (**Table 1**). The western and eastern species of honey bees i.e., *Apis mellifera* and *Apis cerana*, as well as some bumble bees, stingless bees and a few solitary bees are managed and the vast majority of world's known species of bees (20,077 species) are wild in nature, i.e., free-living and unmanaged [7].

Many species of flower visitors have been reported to visit flowering crops in the literature. For instance, a mega-study that included 90 percent of all agricultural pollination studies from throughout the world discovered that 785 different bee species visit crop blooms [8]. Bees are the most prolific and diverse pollinators in most parts of the world, with over 20,000 species recorded [9, 10]. With over 1,20,000

Sr. No.	Pollinator group	Species name
1.	Bumble bees	<i>Bombus affinis</i> Cresson, <i>Bombus californicus</i> Smith, <i>Bombus hortorum</i> Linnaeus, <i>Bombus hypnorum</i> Linnaeus, <i>Bombus impatiens</i> Cresson, <i>Bombus lapidarius</i> Linnaeus, <i>Bombus (Thoracobombus) pascuorum</i> Scopoli, <i>Bombus sonorus</i> Linnaeus, <i>Bombus terrestris</i> Linnaeus and <i>Bombus vosnesenskii</i> Radoszkowski
2.	Beetles	<i>Carpophilus hemipterus</i> Linnaeus and <i>Carpophilus mutilatus</i> Erichson
3.	Honey bees	<i>Apis cerana</i> Fabricius, <i>Apis dorsata</i> Fabricius, <i>Apis florea</i> Fabricius and <i>Apis mellifera</i> Linnaeus
4.	Hover flies	<i>Trichometalea pollinosa</i> Townsend, <i>Eristalis cerealis</i> Fabricius and <i>Eristalis tenax</i> Linnaeus
5.	Stingless bees	<i>Nannotrigona testaceicornis</i> Lepeletier, <i>Melipona favosa</i> Fabricius, <i>Melipona subnitida</i> Ducke, <i>Nanotrigona perilampoides</i> Cresson, <i>Trigona cupira</i> Smith, <i>Tetragonula iridipennis</i> Smith, <i>Tetragonula (Lepidotrigona) terminata</i> Smith, <i>Tetragonula (Tetragonoula) minangkabau</i> Sakagami, and <i>Scaptotrigona depilis</i> Moure
6.	Thrips	<i>Thrips hawaiiensis</i> Morgan and <i>Haplothrips (Haplothrips) tenuipennis</i> Bagnall
7.	Wasps	<i>Blastophaga psenes</i> Linnaeus

Table 1.
Species list of known pollinators for global crop.

species, flies are an important group in agriculture, although only a few families are effective pollinators [11]. In colder climates, such as high altitude/latitude environments, flies outweigh bees in both diversity and quantity as pollinators [12]. In addition to bees and flies, butterflies, beetles, moths, wasps, ants, thrips and vertebrates also pollinate plants, including some crops. Pollinating butterflies and moths are found all around the planet, but in the tropics they are more numerous and diversified [13]. The enormous variety of insect pollinators was discussed by Kevan and Baker [14]. Some birds and bats, in addition to insects, are essential pollinators [15, 16]. Bird pollinators are mostly found in warm (tropical/subtropical) climates, whereas bats pollinate tropical forests and some desert cactus. Pollinators that are less well-known have also been reported for a variety of plant species. These include, among others, cockroaches [17], mice [18], squirrels [19], lizards [20–22] and snails [23]. The less well known pollinators are not known to have major roles in supporting agricultural production.

2.1 Bees

Bees play a significant role in pollination in most terrestrial environments around the world. Honeybees and thousands of species of native bees pollinate garden crops, meadows and woodland plants in the United States. The majority of bees visit flowers in search of pollen or nectar to nourish themselves and their young ones. Crop pollination and honey production are significantly reliant on honeybees. Solitary bees are among the most common native pollinators and named because most of them live solitary lives and do not assemble to live in colonies. Blueberries, sunflowers, apples, watermelon, alfalfa and strawberries are among the commercial crops pollinated by solitary bees. Solitary bees build their nests in a variety of unusual locations, such as sticks, mud mounds, and termite holes. A few species build mud nests and saps, plant resins on the edge of rocks and trees to make domed nests. Many bees excavate their nests into the soft inner pith of stems and twigs, or exploit abandoned beetle burrows. Some solitary bees, on the other hand, create

tunnels in bare or partially vegetated, well-drained soil to make their nests. These bees can be generalist or specialist feeders, depending on the species. Generalist bees visit a wide variety of floral types collect nectar and pollens. Being more hardy species, these are able to thrive in degraded settings dominated by weedy or invasive plants. While specialists are more vulnerable to the detrimental effects of landscape or habitat changes since they depend on a single plant species for nectar and pollen.

Bumblebees are social bees, which means these bees reside in colonies, share tasks, and have many generations that overlap in the spring, summer, and fall. The bumblebees require a suitable sized cavity in to build their nest. These bees usually build their nest underground in abandoned rat burrows and sometimes in hollow trees or walls or under a clump of grass above ground. Bumblebees usually feed on a wide variety of plants.

2.2 Ants

Ants are gregarious insects that enjoy nectar in large quantities. These active insects are frequently seen visiting flowers in search of energy-dense nectar. Ants do not have any wings, so they have to crawl into each bloom to get their meal. They are more likely to collect nectar from flowers that are not efficiently cross-pollinated. Ants are drawn to low-growing, inconspicuous blooms close to the stem. Small's stonecrop (*Diamorpha smallii* Britton), alpine nailwort (*Paronychia pulvinata* Grey) and Cascade knotweed are examples of ant-pollinated plants in North America (*Polygonum cascadenae* Baker).

2.3 Butterflies

Butterflies, like all pollinators, are inextricably related to their surroundings, and abrupt changes in the ecosystem can have fatal consequences for localised populations or species. The butterfly's habitat requirements differ from stage to stage, and each has its own set of requirements that must be taken into account in order to create acceptable habitat. The life cycle of a butterfly is divided into four stages: egg, caterpillar, pupa, and adult. Butterfly deposit its eggs on leaves of trees and shrubs, flowers and grasses.

Being oligolectic, most butterfly species remain confined to one or a few closely related species of plants as these plant species effectively act as host plants for their caterpillars. The females usually lay their eggs on or near the host plant for the survival of their caterpillars. The caterpillars of monarch butterflies, for example, only consume milkweed, and adult females of monarch butterflies lay eggs on or near milkweed plants. Newly hatched caterpillars feed on the leaves, stalks, flowers and fruits of their host plants, which also act as a protective barrier against predators. Caterpillars begin to transform into adult forms after several weeks of eating and growing. This is the pupal stage of a butterfly's life, which is a non-feeding, sedentary stage. Pupae do not require nourishment, but they do require a safe place to convert into their adult forms, such as sticks, tall grass or a pile of leaves.

Adult butterflies feed almost entirely on nectar. Butterflies prefer flowers that are brightly coloured, aromatic, and have flat, broad surfaces on which to land. Adult butterflies like the nectar of daisies such as zinnias, asters, marigolds, golden-rods, dahlias and asters, dogbane, butterfly weed, ironweed, phlox and milkweed. Rotting fruit, tree sap, mud puddles, animal excrement and urine are also sources of nutrients, minerals and salt for adult males of some species. Adult butterflies can feed, bask, and rest on the leaves and stems of the host plants, which provide perching locations. Wind, rain and predators can all be protected by vegetation and modest woodpiles.

2.4 Moths

The moths are nocturnal in nature and some species are pollinators of night-blooming flowering plants, especially in the southern United States and Mexico. The female yucca moth, for example, has mouthparts that allow her to capture pollen and lay her eggs in the stigma of the yucca flower. The life and propagation of yucca plants are entirely dependent on the yucca moth. Each flower's pistil (female component) terminates in a three-lobed stigma. Pollen masses must be driven down into this centre stigmatic opening in order for pollination to occur. Using her particularly modified mouthparts, the female yucca moth collects pollen from flower anthers. She gathers the sticky pollen and rolls it into a ball. She then "stuffs" or "combs" the pollen ball into the stigmas of the flowers she visits. The yucca flower will not develop into a fruit or pod with seeds unless this procedure occurs.

When a female moth visits a flower, she walks up to the base of the flower and inserts her ovipositor into one or more of the six chambers to lay an egg. The egg is protected in the chamber while it develops. The yucca will have begun to grow a pod with little seeds by the time the egg hatches into a tiny caterpillar. In this association, both the yucca plant and the yucca moth benefit.

2.5 Flies and beetles

Flies and beetles are two important pollinator groups. Certain species of flies show resemblance with bees by mimicking bee coloration and patterns. Both bees and flies possess transparent membranous wings and but flies can be distinguished on the basis of having only one pair of wings. Some pollinating beetles are small in size and difficult to spot as these beetles resemble with the black specks present on the petals of flowers, while others are large and more colourful. There are hundreds of thousands of species of pollinating flies and beetles, many of which have yet to be documented. The habitat requirements of different species vary. For each of their life phases, such as egg, larva, pupa, and adult, flies and beetles require food, water, and cover in adequate quantity and quality. Pollination is greatly aided by syrphid flies.

2.6 Wasps

Wasps, like bees, have extremely high energy requirements that must be satisfied in order for them to survive. Pollen and nectar from a variety of flowers are vital for wasps. True wasps have stingers, which they utilise to catch insects or spiders for their larvae to feed. Small fig wasps are common throughout the tropics. Many tropical ecosystems rely on figs as a keystone species. Fig wasps pollinate about 1,000 different varieties of figs.

Figs are unique because of how the flowers are contained within the immature fruit. To mate, lay eggs, and pollinate the small flowers, fig wasps enter through a tiny pore. Both are severe examples of obligatory symbiosis, in which the plant and the insect are entirely dependent on one another to survive.

2.7 Importance of pollinators

These small insects perform one of the most important ecosystem services on the planet, ensuring that both our culinary experiences and the world's environment flourish. Nearly 75% of the plant species cultivated for food, fibre, spices, beverages, condiments and pharmaceuticals are pollinated by animals (**Table 2**). The status of pollinator populations has huge economic impacts on agriculture.

1.	Fruits, berries and nuts	Almonds, Apple, Apricot, Avocado, Blackberry, Blueberry, Cacao, Cashew, Cherry, Chestnut, Citrus, Coffee, Coconut, Cranberry, Date, Fig, Gooseberry, Grapes, Guava, Huckleberry, Kiwi, Litchi, Mango, Olive, Papaya, Peach, Pear, Plum, Pomegranate, Raspberry, Strawberry, Vanilla, Watermelon
2.	Herbs and spices	Black Pepper, Cardamom, Chive, Clove, Coriander, Fennel, Lavender, Mustard, Nutmeg, Parsley, Pimento, Tea, White Pepper
3.	Legumes	Beans, Cowpea, Lima Beans, Lupines, Mung Bean/Green or Golden Gram, Soybean
4.	Seeds and grains	Alfalfa, Buckwheat, Canola, Flax, Oil Palm, Safflower, Sesame, Sunflower
5.	Vegetables	Asparagus, Beet, Broccoli, Brussels Sprouts, Cantaloupes, Carrot, Cauliflower, Celeriac, Celery, Cucumber, Eggplant, Endive, Green Pepper, Leek, Lettuce, Okra, Onion, Parsnip, Pumpkin, Radish, Rutabaga, Squash, Tomato, Turnip, White Gourd
6.	Others	Cotton, Kenaf

Table 2.
Common agricultural crops benefited by insect pollination [24].

While some crops such as corn and wheat, are wind pollinated and some others like potatoes reproduce vegetatively, a whopping 35% of agricultural yield relies on animal pollinators [25]. Roubik published a comprehensive list of 1330 tropical crop species, including a list of viable breeding systems and pollinating taxa [24].

Williams examined the pollinator requirements for 264 crop species in Europe and found that 84 percent of them rely on animal pollination to some extent [26]. To put this in context, pollinators contribute over about \$200 billion to the global economy [27].

The benefits of pollinators can easily be expanded to global biomes exceeding our gardens, kitchens, and dinner tables. With so many of the world’s plants depending on pollinators for reproduction, these flower-loving friends are inadvertently supporting soil stabilisation, carbon sequestration and animal habitats. Sustaining healthy pollinator populations leads to supporting healthy ecosystems. The native pollinators not only provide a significant portion of the food and add to the economy, but they also play an important part in the natural ecosystem. The native pollinators help to keep the plant communities healthy and able to reproduce. They also support plants to provide cover and food for wildlife, to prevent erosion and keep waterways clean. The fruits and seeds produced by pollinated plants form an important part of the diet of birds and mammals. Many insects, including butterflies, use flowering plants as egg laying and nesting places.

2.8 Dependence on pollinators

The significance to a plant or the loss of its pollinators depends on whether the pollination relationship is facultative or obligate [28]. Some plants grow as a result of vegetative reproduction and are thus unaffected by the loss of pollinators. Others have vast seed banks or live a long time, so they may not be in immediate risk of extinction if their pollinator goes extinct. Most plants have several pollinators, and most pollinators pollinate multiple plant species, rather than a rigid one-pollinator-one-plant relationship. The composition of communities varies with environment, and what appears to be a specific relationship between a plant and a pollinator species may shift over time. Plants that are dioecious and self-incompatible, those with a solitary pollinator, and those that proliferate only by seeds are the most vulnerable to pollinator loss.

2.9 Decline of pollinators

Many pollinator habitats have been destroyed or disrupted as a result of human activities. Invasive plant species have fragmented and damaged many remaining habitat regions and such habitats become less suitable for pollinators and other wildlife. These habitat alterations may result decline in food sources, nesting and mating sites of native pollinators. Many pesticides have negative effects on pollinators and their habitats due to overuse and poor application. Herbicides diminish forage plant diversity by eliminating wildflowers, and some pesticides harm pollinators directly, particularly pollinating insects. Honeybees, for example, might outcompete indigenous pollinators for local nectar resources, putting them at greater risk of extinction. Pollinator populations have declined significantly as a result of habitat degradation and fragmentation. At least 185 pollinator species are designated as threatened or extinct by the International Union for Conservation of Nature (IUCN), and two bat species and 13 bird species are recognised as endangered in the United States.

2.10 Threats to pollinators

A number of threats to pollinators have been identified. These include habitat alteration, habitat fragmentation, introduction of alien pollinators and pesticide poisoning [28].

Habitat alteration: Agriculture, grazing, fragmentation of native landscapes and development of areas that once supported wild vegetation all are responsible for the loss of native food plants, rendezvous plants and nesting sites used by pollinators. Pollinators may depend on native plants because they are not always able to access food rewards from introduced flowers [29].

Many bees not only require large numbers of flowers to provide nectar and pollen, but also need a variety of flowering plants for their sustainability throughout the growing season. Oligolectic insects, such as some bees and butterfly larvae depend on specific plants for survival and persistence of their populations.

In addition to food requirements, pollinating organisms often have specific nesting requirements. Some bee species nest in cavities in the ground such as old rodent burrows, spaces under rocks, or holes excavated in sand or soft dirt. Many other types of bees nest in hollow twigs. As land is developed for human activity, the availability of twigs, rodent burrows and suitable nesting substrates typically decrease.

In the present scenario, large-scale monoculture of crops and intensive cropping practices reduce the amount of land available to support wild vegetation. With the increasing mechanisation of agriculture, the decrease in number and area of hedgerows and uncultivated patches reduced the number of native plants available as pollen and nectar sources [29, 30].

Gess and Gess determined that grazing livestock alters habitat sufficiently to affect pollinators [31]. They documented changes in availability of nesting sites, water resources, and vegetation that have direct negative effects on species diversity and population size of bees and wasps. Trampling of vegetation by livestock can directly destroy the nests of ground-nesting species and can compact the soil, constraining nest formation. In addition, the people who tend livestock in these areas of South Africa collect wood for fuel, thus reducing the availability of hollow twigs that provide nesting sites for some bee pollinators. Grazing also affects bees by decreasing water availability. Both ground-nesting and cavity-nesting bees must collect water for use in nest construction. Most bees cannot obtain water from

livestock water tanks with steep sides, or even ponds without sloping edges, but need to stand at the edge of shallow water.

Tampering with the natural water supply to provision cattle or produce crops often modifies water availability for bees. Dramatic reductions in bee number and species diversity have been documented in areas of the Guana caste Province of Costa Rica that were deforested to support cattle [32, 33]. Vinson *et al.* observed a decrease in the number of pollen collecting bees in the destroyed forest areas [33].

Habitat fragmentation: Development can fragment natural habitats, isolating remnants of plant populations. Endangered plants often exist in “ecological traps” [34] surrounded by different habitats. Such plants may lack the genetic diversity that would allow them to colonise these different habitats. Small populations can also suffer from reduced pollen delivery or reduced quality of the pollen delivered. For example, Lamont *et al.* found that population fragmentation reduced fertility to zero in *Banksia goodii* (Proteaceae) which is a highly outcrossing species pollinated by birds (honeyeaters) and mammals (honey possums) [35]. Flowers in small populations either receive fewer visits from pollinators or receive pollen from sibling plants, which results in low seed production. Furthermore, small populations are sometimes bypassed by pollinators as some pollinators exhibit density dependent foraging behaviour, preferring large floral displays to isolated flowers.

Although habitat fragmentation is a problem, preserving large tracts of a particular vegetation type may not be enough to maintain pollinator populations. Janzen and colleagues censured euglossine bee populations in parks and reserves in Costa Rica and determined that even within the same park, different habitats vary dramatically in bee diversity [36]. Many of the bee species travel long distances to pollinate plants that do not occur within the habitats in which they were collected. This finding indicates that preservation of diverse patches within an area may be essential to maintain adequate pollinator populations.

Introduction of alien pollinators: It can have both beneficial and detrimental consequences and occurred both intentionally and accidentally. Honey bees have spread around the world, here they have become competitors with native bees, birds, and other pollinators, and bumblebees have also been introduced to islands and continents where they did not occur naturally. These introductions have sometimes benefited agriculture, but their consequences for native plants and animals can be deleterious.

Several studies have indicated that introduced honeybees decrease the foraging success of native pollinators by competing with them for resources [37–42]. Such example is provided by honeybees in Australia. Honeybees were introduced in Australia approximately 150 years ago, and so far they were considered beneficial to the native flora. However, Paron concluded in a recent study that honeybees may actually be harmful to the native flora as they may displace native pollinators, they may be ineffective at pollinating native flowers and they may interact in complex ways with native pollinators to reduce the amount and efficiency of pollen transfer [38].

Pesticide poisoning: Pesticide usage is another major problem for pollinators. Chemicals applied to crop plants and to rangelands can cause high bee mortality. In the United States, pesticide use has created local problems since late 1800s, but the problems increased drastically after World War II, when there was a substantial increase in the use of pesticides on crops, range lands, and forests [43]. Herbicides have also been applied extensively to control weeds in crops and along road sides, thus reducing the availability of the native wild plants that provide food for pollinators.

Foraging on pesticide-treated plants is a major source of bee mortality, yet honeybees are often expected to pollinate crops that have been treated with pesticides.

The susceptibility of bees to chemical poisoning is usually related to their surface area-volume ratio. Bumblebees are often more tolerant of pesticides than honeybees because of their smaller surface area-volume ratio and honeybees are in turn more tolerant than most small native bees. Chemical poisoning results in abnormal communication dances and mistakes in indicating distance and direction to food sources, in addition to direct mortality.

One source of pesticides that affects pollinators is the broad-spectrum insecticides used to control grasshoppers on rangelands in the South-Western United States. The rangelands are sprayed with these insecticides to save the grasses for cattle forage. The sprays kill many other insects in addition to grasshoppers, including local pollinators. The grasshopper-spraying campaigns overlap the flowering period of a number of endemic rangeland plants that grow among the grasses and many of these plants are listed as endangered or threatened [44]. Additionally, these campaigns also imbricate the period of emergence and active foraging of majority of the native bee species [45].

Another example of how pesticide application can affect plant reproductive success through its action on pollinators comes from the studies conducted in forests of New Brunswick, Canada [46]. These forest areas were sprayed with Matacil (aminocarb insecticide) to control spruce bud worm, *Choristoneura fumiferana* Clem referable to family Tortricidae of order Lepidoptera. The pesticide application adversely affected the native bees of families Andrenidae, Helictidae and Anthophoridae and syrphid fly populations. Several insects displayed convulsions followed by death. The native understory lilies namely *Maianthemum canadense* (Asparagaceae) and *Cornus canadensis* (Cornaceae) showed significant reductions in fecundity. Commercial blueberry fields in New Brunswick also suffered reduction in fruit set when adjacent forest lands were sprayed with Fenitrothion to control spruce budworm [47].

2.11 Attracting pollinators

An area must have sufficient food, shelter, water, and nesting grounds to lure local pollinators. To ensure that habitat demands are met, habitat management actions should be implemented. For instance, landowners can acquire, build, or plant extra nesting sites for bees and butterflies. Depending on the type of native pollinator targeted, various habitat management strategies are used.

Plant-appropriate vegetation: Planting gardens or meadows with a variety of native wildflowers, trees, grasses and shrubs is the easiest approach to attract local pollinators. Wildflowers and indigenous grasses will offer food such as nectar, pollen and larval host plants. For pollinators, trees and dense shrubs provide crucial shelter, nesting and overwintering places. Considering pollinator species have different preferences, planted areas should have diverse amounts of vegetation and areas of light, full shade and partial shade. Planting should take place in wind-protected areas.

Native plants should be chosen since these have evolved with local pollinators and are adapted to local soils and temperature. Native plants should make up at least 75% of a habitat's surface area. The cultivation of invasive species should not be avoided because such plants disrupt the ecosystem's natural structure and composition resulting in degrading pollinator and other wildlife habitat. The area of mowed lawn should be restricted in favour of native wildflowers, shrubs, and grasses. The existing lawns should be mowed less frequently to allow plants to offer pollinator habitat. Annuals should be avoided in favour of perennials. Perennials are often higher in nectar content and provide a more reliable food source than annuals because they bloom year after year. Plants that reproduce in "doubles," such

as marigolds and roses, should be avoided because such plants are designed for ornamentation rather than pollen and nectar availability. The species of wildflowers should be grown in a clump to attract more pollinators and not grown individually. Throughout the growing season, nectar and pollen flowers should be available. The variation in flower shape and colour will deliver nectar and pollen to a variety of pollinators. Bell, tube, or trumpet-shaped flowers, as well as those with clusters of tubular florets, are favourites of birds and butterflies, especially when surrounded with a flat surface for perching. They favour flowers that are brilliantly coloured such as oranges, yellows and reds. Yellow, blue, and purple flowers are most appealing to bees. The flowers that bloom at night attract moths and bats.

Use pesticides carefully: Pesticides, the chemical toxins, do not distinguish between beneficial and harmful insects. As an insecticide is used to kill a crop-eating insect, it may also harm important natural pollinators. Pesticide treatment has the potential to harm or kill all pollinator species, as well as to effect other wildlife. Pollinators can be poisoned by such chemicals through contaminated food or directly from the contaminated surfaces of florets, leaves, soil, or other things when they come in contact with them. To sustain the whole spectrum of native pollinators, usage of such chemicals should be restricted or kept to a bare minimum. To address pest infestations, landowners should use non-chemical or organic methods.

Provide water: The pollinator species require water to survive. Bees and butterflies should be attracted to a source of pesticide-free water mud and other beneficial insects drawn to a birdbath, fountain, tiny pond, or mud puddle. For butterflies and bees, a moist salt lick can be made. A damp patch on the earth can be created by using a dripping hose, drip irrigation line, or birdbath and additionally, a small amount of sea salt or wood ashes can be mixed to meet the mineral needs of butterflies and bees.

3. Conclusions

Insects, being diverse and dominant, are the key component of a healthy ecosystem. Humans determine whether an insect is beneficial, benign or pestiferous. Majority of them are beneficial to humans either directly or indirectly as food, pollinators, pollution indicators, scavengers, for production of useful products etc. The insects represent their dominance as pollinator. Bees and flies visit more than 90% of the world's major plant types, while the other species visit fewer than 6% of the crop varieties. The effectiveness of pollinators varies according to factors such as their abundance; their ability to reach individual plants of the same species and to collect, transfer and deposit the pollen to the appropriate plant organ. Insect pollinators are in decline which is tentative, considering the lack of comprehensive data [48], but it is still a matter of concern. Losses in diversity and abundance are particularly strong under intensive agricultural management [49, 50]. Despite their significance, pollinators are declining and often overlooked in terms of their contributions to healthy ecosystems. No pollinators would mean no seeds or fruits and therefore the collapse of agriculture. No plant reproduction in the wild means that many plants will become locally extinct. Human activities have destroyed and fragmented native pollinator habitats. This diversity needs protection by integrating conservation measures with sustainable agricultural practices, which may raise crop yields and protect both wild and managed species of bees and other pollinators.

A range of conservation measures in intensively-farmed regions can help to maintain diversity, by preserving the resources that pollinators need. Some of the measures are at farm-level such as planting flower strips among crops, reintroduction of hedges and planting trees while as others are implemented at landscape-level

such as the conservation of natural and semi-natural habitats in agricultural landscapes. There is no “one size fits all” approach to conserve all species, due to their varying preferences for different food sources and nesting sites. Reversing the decline in pollinators is the key to feed mouths in future and must be seriously given a thought and action plan.

Conflict of interest

The authors declare no conflict of interest.

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References

- [1] Reverté S, Retana J, Gómez JM, and Bosch J. Pollinators show flower colour preferences but flowers with similar colours do not attract similar pollinators. *Annals of Botany*. 2016; 118: 249-257. DOI: 10.1093/aob/mcw103
- [2] Wasserthal LT. The pollinators of the Malagasy star orchids *Angraecum sesquipedale*, *A. sororium* and *A. compactum* and the evolution of extremely long spurs by pollinator shift. *Botanica Acta*. 1997; 110: 343-359.
- [3] Ollerton J, Rachael W, Sam T. How many flowering plants are pollinated by animals? *Oikos*. 2011. DOI:10.1111/j.1600-0706.2010.18644.x.
- [4] Kearns CA. Endangered mutualisms: the conservation of plant–pollinator interactions. *Annual Review of Ecology and Systematics*. 1998; 29: 83-112.
- [5] Tepedino V. The importance of bees and other insect pollinators in maintaining floral species composition. Pages 39-150 in great basin naturalist memoirs nr 3: the endangered species a symposium; 7-8 Dec: 1979. Provo (LT): Brigham Young University.
- [6] Levin DA. The origin of reproductive isolating mechanisms in flowering plants. *Taxon*. 1971; 20: 91-113.
- [7] Michener CD. 2007. *The Bees of the World*. 2nd edn. 2007. pp. 992. Johns Hopkins University Press, Baltimore, Maryland, USA.
- [8] Kleijn D, Winfree R, Bartomeus I, Carvalheiro LG, Henry M, Isaacs R, Klein AM, Kremen C, M'Gonigle LK, Rader R, Ricketts TH, Williams NM, Lee Adamson N, Ascher JS, Baldi A, Batary P, Benjamin F, Biesmeijer JC, Blitzer EJ, Bommarco R, Brand MR, Bretagnolle V, Button L, Cariveau DP, Chifflet R, Colville JF, Danforth BN, Elle E., Garratt MPD, Herzog F, Holzschuh A., Howlett BG., Jauker F., Jha, S., Knop, E., Krewenka, K.M., Le Feon, V., Mandelik Y., May, E.A., Park, M.G., Pisanty, G., Reemer, M., Riedinger, V., Rollin, O., Rundlof M., Sardinas H.S., Scheper, J., Sciligo, A.R., Smith, HG., Steffan-Dewenter, I., Thorp, R., Tscharnkte, T., Verhulst, J., Viana, B.F., Vaissiere, B.E., Veldtman, R., Westphal, C. and Potts SG. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. *Nat Commun*. 2015; 6: 7414. <https://doi.org/10.1038/ncomms8414>
- [9] Neff, J.L., Simpson, BB. Bees, pollination and plant diversity. In: Gauld, I.D., LaSalle, J. (eds.) *Hymenoptera and Biodiversity*. 1993. CAB International, Wallingford
- [10] Klein, A.M., Vaissiere, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Tscharnkte, T. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society of London series B*. 2007; 274: 303-313.
- [11] Larson, B. M. H., P. G. Kevan and D. W. Inouye. Flies and flowers: I. The taxonomic diversity of anthophiles and pollinators. *Canadian Entomologist*. 2001; 133(4): 439-465.
- [12] Elberling, H. and Olesen, JM., 1999: The structure of a high latitude plant-flower visitor system: the dominance of flies. *Ecography*. 1999; 22: 314-323.
- [13] Scoble MJ. *The Lepidoptera: form, function, and diversity*, 2nd ed. 1995. Oxford University Press, Oxford
- [14] Kevan PG, Baker HG. Insects as flower visitors and pollinators. *Annual Review of Entomology*. 1983; 28: 407-453.
- [15] Proctor, M., Yeo, P. and Lack, A. *The Natural History of Pollination*. 1996. Harper Collins, London.

- [16] Willmer, P. Pollination and Floral Ecology. 2011. Princeton University Press, NJ, USA Nagamitsu and Inoue, 1997
- [17] Nagamitsu, T. and Inoue, T. Aggressive foraging of social bees as a mechanism of floral resource partitioning in an Asian tropical rainforest. *Oecologia*, 1997;110: 432-439.
- [18] Wester, P., Stanway, R. and Pauw, A. Mice pollinate the Pagoda Lily, *Whiteheadia bifolia* (Hyacinthaceae) - First field observations with photographic documentation of rodent pollination in South Africa. *South African Journal of Botany*, 2009; 75: 713-719.
- [19] Yumoto, T., Momose, K. and Nagamasu, H. A new pollination syndrome – squirrel pollination in a tropical rainforest in Lambir Hills National Park, Sarawak, Malaysia. *Tropics*, 1999; 9: 133-137.
- [20] Olesen, JM, Valido, A. Lizards as pollinators and seed dispersers: an island phenomenon. *Trends in Ecology and Evolution*, 2003; 18: 177-181.
- [21] Hansen DM, Beer K, and Muller CB. Mauritian coloured nectar no longer a mystery: a visual signal for lizard pollinators. *Biology Letters*. 2006; 2: 165-168.
- [22] Ortega-Olivencia, A., Rodríguez-Riaño, T., Pérez-Bote, J.L., López, J., Mayo, C., Valtueña, F.J. and Navarro-Pérez, M. Insects, birds and lizards as pollinators of the largest-flowered *Scrophularia* of Europe and Macaronesia. *Annals of Botany*, 2012; 109: 153-167.
- [23] Sarma, K., Tandon, R., Shivanna, KR. and Mohan Ram, HR. Snail pollination in *Volvulus nummularium*. *Current Science*, 2007; 93: 826-831.
- [24] Roubik, DW. Pollination of cultivated plants in the tropics. 1995. Food and Agriculture Organization of the United Nations, Rome.
- [25] Klein, A.M., B.E. Vaissiere, J.H. Cane, I. Steffan-Dewenter, S. Cunningham, C. Kremen, and T. Tscharntke. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, 2007; 274(1608): 303-313.
- [26] Williams, IH. The dependence of crop production within the European Union on pollination by honeybees. *Agricultural Zoology Reviews*. 1994; 6: 229-257.
- [27] Gallai N., Salles, JM., Settele, J. and Vaissiere, BE. Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline; *Ecological Economics*, 2009; 68(3): 810-821.
- [28] Bond, WJ. Do mutualisms matter? Assessing the impact of pollinator and fdisperser disruption on plant extinction. *Philosophical Transactions of the Royal Society of London Series B – Biological Sciences*. 1994; 344:83-90.
- [29] O'Toolc C. Diversity of native hees and agroecosystems. 1993. Pages 169-196 in LaSalle J, Gauld ID, eds. *Hymenoptera and biodiversity*. Oxon (UK): C.A.B. International.
- [30] Williams PH. 1986. Environmental change and the distributions of British bumble bees (*Bombus* L.Hr.). *Bee World*. 1986; 67: 50-61.
- [31] Gess FW, Gess SK. Effects of increasing land utilization on species representation and diversity of aculeate wasps and bees in the semi-arid areas of southern Africa, 1993. pp. 83-113. In *Hymenoptera and Biodiversity*. (Edited by J. LaSalle and I. D. Gauld). CAB International, Wallingford, UK.

- [32] Janzen DH. The deflowering of Central America. *Natural History*. 1974; 83: 49-53.
- [33] Vinson SB., Frankie GW, Barthell J. Threats to the diversity of solitary bees in a neotropical dry forest in Central America. 1993. Pages 53-82 in LaSalle J, Gauld ID, eds. *Hymenoptera and biodiversity*. Oxon (UK): C.A.B. International.
- [34] Stebbins GL. Rare species as examples of plant evolution. 1979. Pages 113-118 in *Great Basin naturalist memoirs nr 3: the endangered species*; 7-8 Dec 1979. Provo (UT): Brigham Young University.
- [35] Lamont BB, Klinkhamer PGI and Witkowski ETF. Population fragmentation may reduce fertility to zero in *Banksia goodii* demonstration of the Allee effect. *Oecologia*. 1993; 94: 446-450.
- [36] Janzen DH, Devries P, Higgins MI and Kimsey LS. Seasonal and site variation in Costa Rican euglossine bees at chemical baits, in lowland deciduous and evergreen forests. *Ecology*. 1982; 63: 66-74.
- [37] Gimhurg HS. Foraging ecology of bees in an old field. *Ecology*. 1983; 64: 165-175.
- [38] Paron DC. Honeybees in the Australian environment. *BioScience*. 1993; 43: 95-101.
- [39] Pyke GH, Balzer L. The effects of the introduced honeybee (*Apis mellifera*) on Australian native bees. 1985. *Ocasional paper nr 7*. Sydney (Australia): New South Wales National Parks Wildlife Service.
- [40] Roubik DW, Moreno JE, Vergara C, Wittmann D. Sporadic food competition with the African honey bee: projected impact on neotropical social bees. *Journal of Tropical Ecology*. 1986; 2: 97-111.
- [41] Schaffer WM, Jensen DB, Hobbs DE, Gurevitch J, Todd JR., Schaffer. MV. Competition, foraging energetics and the cost of sociality in three species of bees. *Ecology*. 1979; 60: 976-987.
- [42] Sugden EA, Pyke GH. Effects of honey bees on colonies of *Exoneura asimillima*, an Australian native bee. *Australian Journal of Ecology*. 1991; 16: 171-181.
- [43] Johansen CA. Pesticides and pollinators. *Annual Review of Entomology*. 1977; 22:177-192.
- [44] Bowlin, W.R., VJ. Tepedino, T.L. Griswold. The reproductive biology of *Eriogonum pelinophilum* (Polygonaceae). *Proc. Southwestern Rare and Endangered Plant Conf., Santa Fe, 1993*. pp. 296-302.
- [45] Peach, ML, Tepedino, VJ, Alston, DG, Griswold, TL. Insecticide treatments for rangeland grasshoppers: potential effects on the reproduction of *Pediocactus sileri* (Englem.) Benson (Cactaceae).1993. In: R. Sivinski; Lightfoot, K., eds. *Proceedings of the southwestern rare and endangered plant conference*. Misc. Pub. 2. Santa Fe, NM: New Mexico Forestry and Resources Conservation Division: 309-319.
- [46] Thomson JD, Plowright RC, Thaler CR. Matacil insecticide spraying, pollinator mortality, and plant fecundity in New Brunswick forests. *Canadian Journal of Botany*, 1985; 63: 2056-2061.
- [47] Kevan PG. Forest application of the insecticide Fenitrothion and its effect on wild bee pollinators (*Hymenoptera:Apoidea*) of lowbush blueberries (*Vaccinium* spp.) in Southern. New Brunswick, Canada. *Biological Conservation*. 1975; 7: 101-309.
- [48] LeBuhn G, Droege S, Connor EF, Gemmill-Herren B, Potts SG,

Minckley RL, Griswold T, Jean R, Kula E, Roubik DW, Cane J, Wright KW, Frankie G, Parker F. Detecting Insect Pollinator Declines on Regional and Global Scales. *Conservation Biology: The Journal of the Society for Conservation Biology*, 2012. December, 1-8. doi:10.1111/j.1523-1739.2012.01962.x.

[49] Biesmeijer, JC, Roberts, SPM., Reemer, M., Ohlemuller, R., Edwards, M., Peeters, T., Schaffers, AP., Potts, SG., Kleukers, R., Thomas, CD., Settele, J. and Kunin, WE. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*. 2006; 313: 351-354.

[50] Le Feon V, Schermann-Legionnet A, Delettre Y, Aviron S, Billeter R, Bugter R, Hendrickx F, Burel F. Intensification of agriculture, landscape composition and wild bee communities: A large scale study in four European countries. *Agriculture, Ecosystems and Environment*. 2010; 137: 143-150.