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Insect pollinators and their conservation

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Abstract
To address the concerns regarding insect pollinator populations in state of Jammu and Kashmir, we surveyed and interviewed local farmers to gain a better understanding of current farming practices and their effects on bee populations. We also consulted a number of apiary and agricultural experts during the research phase from 2012 till 2016. The final product may be concluded in this manuscript which describes various native and managed pollinator species and their habitat requirements. The paper further suggests best management practices that have the potential to help promote the growth and stability of these pollinator populations in Kashmir division of J &K, India.

Keywords: Kashmir, bees, pollination, conservation, colony

Introduction

Kashmir agriculture and pollination problem

Jammu and Kashmir is a hill state having varied topography and the agriculture remains the backbone of economy of state with over 65 percent of its population depends on it. Agriculture sector contribute around 27 percent to the State's income. The diversity in physiographic features, agro-climatic variations at macro and micro level, existence of cold arid, temperate, inter-mediate and sub-tropical zones within a small geographical area of 2.22 lakh square kilometers, speaks volumes about the vast agricultural potential in the State. However, still state is facing the low productivity of all agricultural crops and there is massive deficit in its own production of food grains (40 percent), oil seeds (70 percent) and vegetables (30 percent). The net sown area of 7.52 lakh hectares (2004-05) is 35 percent of the reported area as against national average of 46 percent. For maximum of the crops sown in state the insect pollination is essential to get the potential yield. Therefore, to meet the required pollination needs, the management and conservation measures are essential. Fragile soil in hilly areas is susceptible to soil erosion, thereby affecting the wild bee population by habitat degradation. In horticulture sector the state is facing pollination problem also, as per Taj Partap, 2011 unpublished data (Honorable V.C. SKUAST) Jammu & Kashmir loses 1600 crores of rupees per year because of lack of pollination in apple orchards [18]. Since, production is increasing year by year but the quality of our fruit is so shameful that it is not able to compete with apple imported from other countries. Besides, majority of agricultural lands are being converted into horticultural orchards since last 25 years, but availability of pollinators is not meeting the requirements. However, this land conversion again impacting the wild bee diversity through habitat degradation, since wild bees needs a potential habitat for survival [7, 8]. Despite the efforts of SKUAST-K (RTCPPPM), till date the pollination problem has not being addressed seriously at ground level (growers level), leading to the major decline in the fruit productivity, quality and overall the great economic loss to the state.

Various Categories of Insect Pollinators

Hymenopteran pollinators

Bees as pollinators

The state has a large number of bee species, despite its small size. Honey bees are the primary managed species, although the majority of bees are actually native. This is because state does not have the commercial industry for bees that larger states do; in fact, the few farmers are also beekeepers or have their own hives on property. Although honey bees are the most commonly managed bee species for pollination; however, the bumble bee rearing is being started in recent years by SKUAST-K, Srinagar. The pollinator species described in this manuscript comprise only a short list of the species present in state (Table 1). There is little information known about most native bee species; however, what is known suggests that many bees share similar foraging requirements. Likewise, many bees share similar nesting requirements based on their preferred nesting location; for example, ground-nesting, tunnel-nesting, and social nesting [9].

Social bees

Eusocial bees, such as honey bees, live in very complex colony systems with several generations present at any given time. Social behavior in bees varies based on species; however, all Eusocial bees live in a family structure called a colony, consists of a queen, worker bees and drone bees. The females are born into their different social status as workers or queens. Worker bees are females that rarely reproduce, act as the primary foragers for the colony, and also care for offsprings. The worker bees build and maintain the nest, care for the brood, and collect the pollen or nectar for the colony food source. Queens specifically lay eggs, and are also cared for by worker bees. The drone bees are the males in the colony that are born solely for mating with the queen bee [54]. Some bees, including bumble bees (genus *Bombus*, family Apidae), carpenter bees (subfamily *Xylocopinae*), and sweat bees (family *Halictidae*), live in smaller colonies. Dar [9] reported that Halictidae bees especially *Lasioglossum marginatum* (Lasioglossum: Halictidae) live in the smaller colonies (19-24 individuals). A colony can be as small as having only two adult females, one as the queen and the other as the worker [42]. These colonies often begin with a single solitary female, but after daughters are reared, the nest becomes a colony; these are known as primitively social bees [42]. According to few researchers, less social bees may also aggregate in a communal structure where multiple reproductive females live in a single nest, sharing defensive responsibilities. Although there are varying forms of social behavior in wild bees, honey bees and bumble bees.

Fig 1: Halictid, Lasioglossum species foraging on cherry *P. avium* in Budgam, Kashmir [9].

Solitary bees

The solitary wild bee species make up the vast majority of total bee species and exhibit very different nesting behaviors than social bees. A solitary female individually creates a nest, lays eggs and provides food for her young. Typically she will either die or abandon the nest before or shortly after the eggs laid, or she has provisioned hatch [42]. Solitary males generally emerge from their pupae earlier than the females. This allows them to be ready to mate as soon as the females emerge [47]. Once females have emerged and mated they build their own nest, which generally occurs the year after they are laid as eggs. These nests can often be found in close proximity to other females, depending on species and food requirement, but they are all still individualized [47]. Some solitary bees may nest in large groups, but they do not actively help each other [13]. Most solitary bees are also native, though there are a few exceptions. The European wool carder bee, *Anthidium manicatum*, is an invasive solitary bee that may be detrimental to native bees due to the aggressive, highly territorial males. Likewise, native bees are usually, but not necessarily solitary. Bumble bees are a prime example of a social native bee. Some native sweat bees and carpenter bees are also social. The term “wild bees” or “pollen bees” can be used as a general catch-all for basically any bee that is not *Apis mellifera*.

Solitary bees tend to nest somewhere near the location where they emerged, including in dead wood, crevices, well-drained clay soil and were the availability of food is abundant within 150 meters from nest. According to G. Ramel [47], these bees tend to nest and emerged in places of abundant dead wood, crevices, well-drained soil and other suitable habitats. Each species has their own requirements for a nesting site, which is why they may return to the area from which they emerged, like bumble bee species Solitary bees can be highly efficient as pollinators [9]. Further, solitary bees tend to work faster and for longer hours than social bees, because their life cycles are typically shorter than those of social species. It is also typical to find that most solitary bees are more specialized pollinators than honey bees. Again, because they have shorter lives than honey bees they tend to have pollination preferences toward plants that bloom during the flight period of their life cycles. This characteristic of solitary bees can be very beneficial to growers. Many solitary species can be more specialized and more efficient in pollinating crops on a per bee basis [14]. However, there is minimal information available about whether this pollination is similar, inferior, or superior to the population size of honey bees [11]. Because honey bee colonies have so many more individuals, it is not certain whether their numbers ultimately produce the same type of pollination efficiency as solitary bees with lesser numbers on a given crop. However, Dar [9] reported that in far flung areas of the Kashmir valley, the major proportion to the fruit crop pollination is contributed by wild bees.

Native bee are native to America, and have been observed as more frequent floral visitors to watermelon, tomato and pepper plants than honey bees by Winfree *et al*.[58]. However, Winfree *et al*. [58] did note that pollination services are not equivalent to floral visitation; since, increased frequencies in visitation will likely result in an increase in pollination. Garibaldi *et al*. [11] also found that native bee visitation strongly influences fruit set in crops, even more than honey bee visitation regardless of whether the honey bees are from a feral or managed colony. It has also been determined that honey bees, although typically seen as the best pollinator for food crops, do not maximize pollination or fruit set compared to native bees [11]. This is even true for crops where honey bees are commonly used in high densities such as blueberries, watermelon, and almonds. Similarly, Gracler [15] from USA observed that native pollinators are 2-3 times more important for crop yield compared to honeybees.

Honey bee (*Apis mellifera*)

Honey bees are not native to North America and were introduced from Africa and eastern or western Europe for agricultural purposes [45]. The vast majority of honey bees in North America are managed for pollination; however, some colonies leave their managed hives in search of a new hive location. When these managed bees begin a new colony in the wild, they are classified as feral; there are no truly wild or native honey bees in North America. Therefore, most agricultural studies conducted have compared commercial honey bees with other native species, rather than comparing honey bees against their feral counterparts. Because of the lack of scientific data about feral honey bees, the information provided here will be regarding managed colony behavior and preferences. Honey bees range in size from small to large, with moderately hairy bodies [42]. They have characteristic black and yellow, sometimes orange, stripes that define their species. These animals are highly social and live in large colonies with complex social structures. Nests can either be exposed or constructed in a hive [42]. The nests are made exclusively of wax, secreted by the bees, that is shaped into a comb like structure [42]. The pattern of each nest will be slightly different based on the location, size, and preferences of the colony creating it. Although the overall nest size and shape differ from colony to colony, each individual cell in the comb is the same. The cells are hexagonal and of equal size, depth, and shape regardless of its use for worker eggs, honey, or pollen storage [42]. The only time a cell is different from the rest is if it is meant to rear a queen. Queen cells are irregular in shape and are not part of the comb, but instead hang individually from sections of brood cells [42]. One of the many reasons honey bees are used as commercial pollinators is that their nests are perennial [45]. Unlike their unmanaged counterparts, honey bee nests survive the winter and the colonies do not restart each season [45]. For this reason, it can be more economical to maintain honey bee hives, rather than purchase new bumble bee or mason bee colonies each growing season.

Additionally, honey *A. mellifera* are highly sophisticated in their communication with other colony members, using dance and vibrations to tell each other where the best sources of pollen and nectar can be found [53]. This communication between individuals allows this species to be more competent as a population than their native equivalent in pollination services [45]. Additionally, the large number of individuals, averaging 50,000 to 85,000 individuals per colony, generally allows honey bees to be more effective in pollination of a given crop than bee populations with a lesser number of individuals. Losey and Vaughan [36] found that the efficiency of honey bee pollination is typically enhanced by native bee populations. Honey bees are also generalist foragers, which promotes pollination of a wide variety of food crops on any given farm. This lack of flower preference can distract honey bees from the blooming crop and push them toward other non-target flowers. However, when honey bees forage, they typically forage the same species of flower per trip [48]. This means that if a honey bee visits an apple blossom first, then the following flower visits will also have been on apple blossoms. Each foraging trip will follow this same pattern, proving the honey bee to be a very dependable cross-pollinator [48].

Bumble bees (*Bombus* spp.)

Bumble bees are some of the largest bees in the Northeast, ranging from medium to very large in size [42]. They are completely covered in hair [42], which sets them apart from other large bee species, such as carpenter bees. They are famously colored with various patterns of fuzzy black and yellow stripes, and they are typically found in cooler climates across North America and Europe [42]. Bumble bees have many similarities with honey bees, including their preference for social nesting. However, despite being social and living in colonies, they are much less social than honey bees and live in vastly smaller colonies [39]. The nests are also annual, with the colony dying off at the end of a season and only the queen over-wintering [39]. These nests are commonly established in old rodent nests, old bird nests, bunch grasses, and vegetation [42]. The nests are maintained by worker bees, which bring in additional nesting materials throughout a season to preserve the roof and structural integrity of the expanding colony [42]. Bumble bees are also unable to communicate the location of pollen and nectar sources the same way as honey bees. This can be an advantage of bumble bees as pollinators because an individual that finds a superior pollen or nectar source at a non-crop flower cannot communicate the location of that source to other colony members [11]. Because they cannot communicate well, they are less likely to get distracted away from the target crop.

Bumble bee are important pollinators in agriculture

Bombus spp. has the ability to perform buzz pollination, or sonication, which is a process that uses bodily vibrations to release pollen that is firmly attached to flower anthers [35]. This pollination process is vitally important to the pollination success of many food crops [37], such as blueberry, cranberry, tomato, eggplant, and pepper. There have been multiple studies that focus on the success of bumble bees as a managed pollinator species due to their ability to utilize buzz pollination. Studies have specifically focused on using bumble bees in greenhouses where peppers, tomatoes, and other crops are grown [45]. Although bumble bees are commercially available, it is likely that native populations are easier to attract [39]. Bumble bees are highly susceptible to some of the same diseases and parasites that have been known to destroy honey bee colonies, making it difficult to maintain a commercial colony of bumble bees [45]. In addition to performing buzz pollination, bumble bees are also generalist foragers, which are beneficial to the agricultural industry because they pollinate a variety of crops in addition to those requiring buzz pollination. Some examples of bumble bee pollinated food crops include tomatoes, cucumbers, eggplants, peppers, potatoes, blueberries, melons, cranberries, cantaloupe, and other berries [37, 39]. Bumble bees have also been identified as the single-most efficient and effective pollinator of cranberry crops [35]. They are faster, more efficient, and more consistent about pollen foraging on cranberry flowers than honey bees [38]. Bumble bees are also more tolerant of inclement weather and will visit flowers in rain and windy conditions, while other species will not [11, 48]. Additionally, bumble bees have long tongues, providing an advantage over other bee species to pollinate certain crops [48]. In Kashmir region, the bumble bee species observed generally nest in soil in rodent burrow [9]. Whileas, the burrows of small mammals and areas of undisturbed, tussocky grass are the natural places for bumble bee nests in Europe [2]. Bumble bee nest site preference is species-specific with some species nesting below the ground and others on, or just below the soil surface [27]. According to the descriptions of Alford [2], three of the four bumble bee species introduced to New Zealand, *B.terrestris* c *B. ruderatus* (Fabricius), and *B. subterraneus* (L.), occupy subterranean nests. Whereas, *B. hortorum* (L.) usually nests near the soil surface. *B. terrestris* queens preferred to search along banks [27] and in areas of open ground [52]. *B. hortorum* queens were most commonly observed searching for nests in habitat containing tussocks [27]. Most species showed searching behaviour in patches of withered grass [52]. Interestingly, no nest seeking bumble bees were observed within annual crop fields [52], suggesting that disturbance makes the areas unsuitable for nesting.

Fig 2: Bumble bee moving away after foraging on peach, *Prunus persica* in Srinagar; Nesting cavity of Bumble bees observed in Budgam, Kashmir [9].

Squash bees (*Peponapis* spp. and *Xenoglossa* spp.)
Squash bees are unique because they are oligolectic, meaning they only pollinate specific crops [49], in this case from the Cucurbitaceae family. Cucurbits include cucumbers, pumpkins, melons, gourds, and squashes of all varieties. The most common squash bee is *Peponapis pruinosa*, which is present almost anywhere that squashes are grown [6]. As pollinators, squash bees begin pollination much earlier in the day than do other bee species [59]. Once blooms close midday the squash bees become fairly inactive and return to their nests. Some males become trapped in the closed flowers and will even spend the night inside the closed flowers [39, 59]. Their life cycles are ultimately dependent on cucurbit blooms so they do not require year-round food sources [51]. Also, because of their proficiency and effectiveness in pollinating cucurbit crops, squash bees essentially eliminate the need for honey bees to pollinate these crops.

Nesting biology of Squash bees: Squash bees are solitary ground nesters that establish their nests at the base of cucurbit plants or at the edge of a field [11, 51]. Their nests consist of one main tunnel that terminates into small chambers and branches where the eggs are laid [59]. The larvae remain in the ground developing and hibernating for the entire season [51]. The tunnels that squash bee adults create are typically 5 to 10 inches deep [51]. This specific depth in combination with the incubation period of the larvae, make them extra susceptible to death from tilling practices. It is best to attempt to avoid deep tilling to decrease direct mortality. Although this species is highly vulnerable to death from tilling, populations can still be successful because of their strong philopatry[24]. This is the behavior of returning to an individual's place of origin [60]. If squash bees establish their nests in areas that are safe from tilling or other ground disturbance, rather than near cucurbit plants, then populations may flourish because of their highly philopatric behavior [49]. Another factor is that *Peponapis pruinosa* is fully dependent on crops in the Cucurbitaceae family; therefore, they are not dependent on other floral resources for forage and new bees will continue to establish nests where the crop is planted, regardless of tilling fatalities [24].

Mason bees (*Osmia* spp.)
Mason bees can be a variety of colors. Some are shades of black or brown, while others have a blue or green metallic coloring [37]. They tend to be small to medium in size and are solitary, cavity nesters by nature [37]. Cavity-nesting is a type of tunnel-nesting; they do not create their own tunnels to nest in, but rather find preexisting nests or cavities to inhabit. Due to this preference, man-made nest blocks and stem bundles are extremely attractive to mason bees. There are also commercially available mason bee nest blocks, especially for the blue orchard mason bee. The most common native species of mason bee is *Osmia lignaria*, the orchard mason bee. In recent years there have been many studies that examine the effectiveness of their use as managed pollinators. Mason bees tend to be polylectic, or generalist, foragers; however, they tend to demonstrate a strong preference for fruit trees. This preference has led to their use as a managed pollinator species [5]. *O. lignaria* has been found to be a very useful and efficient pollinator of apples, almonds, and other tree fruits [45]. Similar to bumble bees, mason bees are also willing to continue flight during inclement weather [48], which provides an advantage over other species for pollination services.

Nesting activities: Matthew and Yong [40] conducted a study to investigate nesting activities and associated behaviours of *Osmia cornifrons* by using a digital video recorder with infrared cameras. Nesting activities of the species involved the behaviour, including cell provisioning and partitioning, oviposition, grooming, resting, sleeping, nest-searching and repairing behaviours along with number of nesting trips per hour, which agrees with information reported by Lee *et al*. [33]. The average number of cells per nest in *O. cornifrons* were 9.5 and the average number of trips to complete a cell were 31.3 [41].

Sweat bees (*Halictus* spp., *Lasioglossum* spp. and *Augochlorella* spp.)
The Halictidae family is one of the most common groups of bees found on farms and in the wild [9]. This group of bees tends to be most abundant in the late spring and summer months. Their common nickname "sweat bee" stems from the

bees' affinity for the taste of salt in human sweat [37]. Halictids tend to be small in size and are a range of colors from dull browns to metallic blue and green [37, 39]. Sweat bees are commonly ground-nesting bees [9]; however, there are some instances where they will create nests in rotting wood as well [42]. They are traditionally a solitary group of bees with a variety of nesting habits. Some sweat bees will nest individually [9], far removed from others, while other sweat bees will be found in densely populated areas using shared entrance holes [39]. They typically produce only one generation per year [37], although some sweat bees demonstrate a variety of social behaviors, like *Lasioglossum marginatum* [9]. While some females will share a common entrance and construct individual cells separately, others will communally share the nest. In this case, there will be a few egg laying females with the others acting as workers to construct the cells, feed the broods, etc.

One difference between this sociality of sweat bees and other social groups, such as honey bees, is that the adults do not have sophisticated communication systems to utilize to exchange information with one another [44]. Due to their vast numbers, the ability to perform buzz pollination, and their generalist preferences, halictids are important in agriculture. Buzz pollination is the act of holding onto the anther of a flower and using full body vibrations to release pollen [32]. This type of pollination is specifically required for certain crops, such as blueberries, cranberries, tomatoes, and others. Sweat bees, along with other buzz pollinating species, are able to pollinate these crops more efficiently than species which cannot perform buzz pollination [45]. These bees are also able to pollinate flowers of crops that do not require buzz pollination. All of these traits together demonstrate how valuable sweat bee populations are to the overall crop production of a farm.

Nesting activities: Halictid bees display the most diverse gradation in social behaviour from solitary to eusocial. Some species exhibit solitary behaviour depending on time of year, geographic location and altitude [42], while as a dominant species *Lasioglossum marginatum* behave ecosocialy. The genus *Lassioglossum* is one of the largest genera of bees, with an incredibly diverse array of behaviors. Dar [9] observed that the species *Lassioglossum marginatum* gregariously nest in ground and various nest physical, chemical and gravimetrical parameters across landscapes of Kashmir valley were evaluated as well.

Carpenter bees (*Xylocopa* spp.)

Carpenter bees are important pollinators of the stone fruits crops [10]. It is very common to mistake large carpenter bees, such as *Xylocopa virginica*, for bumble bees since they are both large, robust bees. Carpenter bees, however, tend to have less hair and a shiny abdomen. Smaller species have much less hair and have more blue-black coloring than some of the larger species. Carpenter bees are classified as tunnel-nesting bees due to their strong preference for establishing nests in wood [10]. They typically burrow into solid wood, with various tunnels branching out in the direction of the wood grain [42]. Some smaller species prefer to use preexisting tunnels from beetles in dead wood or snags, while the larger carpenter bees will create their own new nests [10, 26, 37]. It is common for these bees to target soft woods, while ignoring hard woods, painted wood, or wood with bark [39].

Although most carpenter bees prefer solid wood, some species do nest in the hollow stems of plants [10, 42]. These bees have very acute maternal instincts and care for their offspring, unlike many other solitary species [42]. Because of this, carpenter bees tend to have a higher survival rate than other species laying the same number of eggs. They also tend to live longer than most solitary species [39]. This characteristic sets carpenter bees apart from many other solitary species.

Carpenter bees have not been used extensively in agricultural research projects; therefore, there is little information about specific food crops pollinated by native carpenter bees. Despite the lack of research as pollinators, it is known that they are capable of sonication, or buzz pollination [11], similar to the bumble bees and sweat bees previously discussed. This can prove useful in the pollination of tomatoes, peach, plum, cherry [9] and apple. There is minimal information about their preferences toward buzz pollinated crops, and it has been accepted that they tend to be active generalists when in a natural setting [26]. Carpenter bees visit any flowering plant that is available and attractive to them, which can complement the work of both honey bees and non-generalist species of bees.

Conversely, carpenter bees can also be nectar robbers. They do pollinate many flowers and crops, but they do not always visit a flower in a way that allows pollen collection [16]. Specifically, carpenter bees will create a slit in the side of a flower in order to get to the nectar while avoiding all contact with pollen; this process is known as flower robbing [26, 11]. Sometimes this can increase the amount of flower robbing by other bee species who would have otherwise visited the flower normally [11].

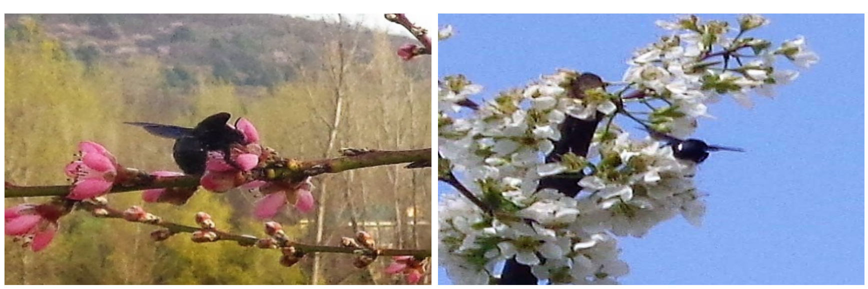

Fig 3: *Xylocopa violacea* foraging on peach and plum in Kashmir valley, Srinagar [9].

Mining bees (*Andrena* spp.)

These bees are typically hairy and range from small to large in size. Mining bees can be easily identified by a variety of colors; all black, gray haired, red haired, metallic blue or green [42]. They are typically most active in the early spring [9]. Mining bees are solitary, ground-nesting insects by nature [9, 42]. These bees usually only produce one generation per year; however that does not necessarily mean they will only have one brood. The offspring of these bees mature and overwinter as adults in their nest cells and therefore will not reproduce until the following year when they finally emerge [42]. There are a few specific Andrena species that do produce two generations, but it is not common throughout the genus [42]. Mining bees are either polylectic pollinators, meaning they are generalists and will visit any flower available to them, or oligolectic pollinators, visiting only a small number of specific flowers [42]. The preference for these bees will depend on the species, but both are beneficial for farming purposes. Some common crops pollinated by mining bees include cucumbers, watermelon, apples, and cantaloupe [37, 46] and stones fruits [9].

Fig 4: Andrena species (Andrenidae: Hymenoptera) foraging on cherry, *P. avium* in various locations of Kashmir valley [9].

Dipteran flower visitors: According to Dar [9] and Katherine *et al*.[25], the Dipteran insects cannot be neglected and plays an important part in fruit pollination studies. Dar [9] observed that true flies live in considerable abundance in all locations of Kashmir, and their larvae were observed to live in moist environments. Diptera occur all over world and the habitats used include meadows, mountains, forests, seashores, sandy beaches, lakes, streams, rivers, fens, water polluted by rotting wastes, urban areas, cattle, horse and poultry farms [23,31]. Many species have co-evolved in association with plants and animals (decomposed and degenerated matter) and use it as a habitat for feeding, mating and oviposition. Study showed that hoverfly larvae are aquatic and are often found in stagnant water, adults are terrestrial and residing on leaves/flowers and found to visit the stone fruit flowers; particularly to feed on flower nectar and pollen [1].

Fig 5: Dipteran flower visitors on cherry and peach flowers in Srinagar and Budgam, Kashmir [9].

Lepidopterans and other flower visitors: Dar[9] observed that Lepidopteran flower visitors of peach, plum and cherry includes, *Pieries brassicae* and *Vanessa cashmeriensis* species needs large, open spaces, as well as farms and vegetable gardens for the residing and feeding. Bhattacharya *et al*.[3] reported that *Pieries brassicae* generally prefer gardens and fields of Brassica; however, sheltered places like hedgerows and edges of coniferous woods were also found as their habitat to live. Some favored locations observed during the study include walls, fences, tree trunks, and food plant like stone fruit flowers, which is important for their survival since they need to have access to their food source for survival. In all the areas of Kashmir Velley, these species were found to hover around the locations containing both wild and cultivated crucifer as well as oil-seed rape, cabbage, brussels sprout and fruit trees. Whileas, the species *Oncopeltus fasciatus* and *Ischeria verticalis* were found to present near slow moving streams, marshes, grass lands, fallow lands and adults visit the stone fruit flowers for nectar. However, according to Iowa State University [22], the milk weed bug lives in fields and meadows containing milkweed or dogbane plants, and contribute a little to pollination.

Fig 6: *Pieridae* sp., *Ischnura verticalis*, and *Oncopeltus* sp. nectaring on peach and plum flowers in Srinagar, Kashmir [9].

Conservation techniques for the management of wild bees

Potential Habitat management

The main factor which is important for the management of the wild bees is their habitat management and conservation [8, 20]. Various anthropogenic factors like land degradations, erosion and shifting agriculture is a major threat to them [7]. Therefore, fruit growers must take a more active role in increasing the numbers of bees around farms by following three things to make land more hospitable for pollinators.

1) Increase the available foraging habitat to include a range of plants blooming at different times to provide nectar and pollen throughout the seasons [50, 57]. The wild flower planting function by attracting pollinators from the surrounding landscapes to the farmscape and ideally to "spill over" to provide pollination services [4, 57]. The wildflower plantings have been demonstrated as an effective practice for benefiting pollination by increasing crop production [12].

2) Create nesting sites by providing suitable ground conditions or tunnel-filled lumber and appropriate nesting material [9]. About 70% of bee species nest in the ground and 30% use tunnels bored into wood. Bumble bees-a small, but very important group of bees for crop pollination-require small cavities in which to fashion their nests.

3) Reduce the risk to bees from the use of insecticides and herbicides, which directly kill pollinators or the plants they rely on. Select less toxic insecticides or utilize alternative strategies to manage pest insects and minimize the use of insecticides. Pesticide residue analysis of bee-collected pollen revealed contamination by upto 32 different pesticides spanning 9 chemical classes. The most common pesticides types detected in pollen samples were fungicides and herbicides [34]. So, in European countries there is maintenance and control over the use of Neonicotinoids pesticides in orchards [28].

Wild Bee Houses

The simplest type of bee house is the bundle of sticks model. It is some number of hollow sticks or reeds, bundle up, and put them out where bees can find them. Usually, the bundle will be contained in some sort of shelter to keep the sun and rain off, but put out plain sticks tied up with wire. Bamboo is a popular material for its availability and durability. A bundle of first-cut bamboo stakes of appropriate lengths is desirable for bees. Phragmites is easier to cut than bamboo. Raspberries, bee balm, Joe-Pye weed, cup plant, sumac and certain asters with a large hollow stem provide good nesting places for bees. Warr**[55]** developed a move wild bee simulator to track the wild bee nesting sites in the barren lands.

Wood block model

This design mimics the holes in trees that cavity-nesting bees will use in the wild. It is simply a block of wood of any size with some deep holes drilled partway through it (this will require a power drill and a very long bit). The bees would nest in it, but there are several problems with that. The tunnels in this case are even less accessible than the bundle of sticks, making the block very difficult to keep clean and the bees inside impossible to see. Green [19] reviewed; providing artificial nesting cavities for solitary bees and wasps is a venerable pursuit that has evolved three basic lineages over the years. At first, the emphasis was on basic biological study. Published accounts go back to the legendary naturalist Jean-Henri Fabre in the early 1900s, who used reeds for the purpose and throughout the first part of the century several researchers followed suit with a variety of methods. However, no person did more to popularize the concept than Karl Krombein, one of the world's great hymenopterists, who in 1953 began systematically setting out pine blocks with borings of several different diameters to lure in solitary wasp and bees species that normally would either excavate tunnels in natural plant material or use pre-existing cavities, such as hollow stems or the galleries of other insects, in which to nest. The blocks were then split lengthwise to inspect the contents and subsequently taped back together for re-use. His unique masterpiece, Trap-Nesting Wasps and Bees: Life Histories, Nests and Associates (Smithsonian Press) provided 11 years' worth of data gleaned from more than 3,400 traps utilized by about a hundred species and almost as many parasites and predators that exploited them.

Perhaps the main disadvantage of the wood block model is the lack of variety in tunnel diameters compared with the bundle of sticks. With too little variation, the nest will not attract as many different kinds of bees, though this can be overcome to some extent by using several different sizes of drills. However, if one want to attract a certain kind of bee (for example, the blue orchard bee for apple pollination), the uniformity of this nest is actually beneficial.

Clear-topped wood block or observation block

It is similar to other wood block nests, only instead of drilling holes, one use a router to cut U-shaped grooves in the outer face(s) of the block. These grooves are then covered with a transparent lid to make a tunnel for bees to nest in. The nests can be easily seen without opening them, so one can even watch the bees at work during nesting season and monitor their progress. When cleaning is needed, the lids can be removed for easy access to the interior, then replaced when they are ready to be used again.

How to make bee house successful

The nesting tunnels should be open on one end and closed on the other end. Being open on both ends increases exposure to parasites and pathogens. If using a bundle of reeds like bamboo, cut the segments so that one end is closed by a natural node. Generally, the ideal tunnel depths are between 5 and 8 inches, and diameters from 1/8" to 1/2". Variation in tunnel dimensions accommodates more bees of different species and sizes, and also helps bees distinguish their nest from others nearby. If all the tunnels look the same, the bees may become confused and lose track of their nests. It should be obvious, but do not use treated wood or aromatic insect-repellent wood (such as cedar) for nest blocks. If grower make clear-topped wood blocks, he must get high-quality wood with as few knots as possible, as knots can weaken the walls between adjacent tunnels. To create more nest variation to help the bees orient themselves, paint the tunnel entrances different colors. Blue, black, and unpainted raw wood make a good contrast. Keep in mind that bees cannot see reds. Bright, fluorescent blue is highly visible and attractive to bees. Painting parts of nest or shelter box color might attract more bees from longer distances.

Major Threats to Pollinators

Habitat Loss, Degradation, and Fragmentation

Much pollinator habitat has been lost to agriculture [1], resource extraction, and urban and suburban development [1, 35, 7, 8]. Although, land use provide floral resources and benefit some pollinators. Many bees and butterflies are habitat-specific, and the loss of habitat that provides sites for overwintering, foraging for pollen and nectar, or nesting can be detrimental to these species. Habitat degradation, the decline in habitat quality, is another serious concern [13, 17]. For example, the loose, friable soil required by ground-nesting bees may be trampled by heavy foot traffic or the use of off-road vehicles. In cities, ground-nesting species may be particularly limited due to the large amount of landscape that has been covered with concrete or other impervious surface. Many pollinators are adversely affected when large, intact tracts of habitat are broken up into smaller, isolated patches by road construction, development, or agriculture [35, 50]. These habitat fragments may not be large enough to meet all pollinator needs by themselves. Establishing and maintaining connectivity-safe passage among patches-is key to pollinator persistence in these areas.

Non-native Species

Plants or animals brought here from other places can decrease the quality of pollinator habitat [19]. When non-native shrubs such as autumn olive and multi-flora rose take over open fields, they crowd out the wildflowers needed by certain butterfly and bee species for pollen, nectar, or larval food. For example, Japanese barberry shades out native spring ephemerals like Dutchman's breeches, which provide food for early spring bumble bees. Some non-native plants also attract pollinators away from native species that are superior food sources. West Virginia white butterflies sometimes lay their eggs on non-native garlic mustard instead of native toothwort, for example, and the young caterpillars fail to thrive. In other instances, non-native species can compete with native plants or animals for resources-in fact, in some habitats European honey bees have been shown to compete with native bees for pollen and nectar.

Thus far, 16 species of non-native bees have been documented in New York City, including the European Honey Bee. It is unclear if many of them are having a negative effect on native bees. Research indicate that populations of these non-native bees currently are not very large in most locations, suggesting that right now they may not be having a major impact on native bees. However, given the history of introductions that subsequently cause major ecological damage, it is important to carefully monitor populations of introduced bee species.

Although they were intended to be beneficial at the time, some non-native organisms introduced as bio-control agents have caused problems for native species. For example, non-native lady beetles introduced to this country for aphid control have eliminated New York's state insect, the nine-spotted lady beetle. These introduced lady beetles have even been found to feed on Monarch butterfly caterpillars. Since the 1950s, the tachinid fly *Compsilura concinnata*, introduced in the early 1900s to control gypsy moths, has likely contributed to the regional decline of the large sphinx moths that pollinate flowers such evening primrose and certain orchids.

Pollution, Including Pesticides

Pollution is a very real problem for bees and other pollinators that rely on scent trails to find flowers [43, 49]. Light pollution can harm moth pollinators by increasing their susceptibility to predation by bats or birds when they are attracted to artificial lights at night. Pesticide misuse and drift from aerial spraying are a major threat to insect pollinators, especially spraying with so-called persistent chemicals that remain in the environment for a long time before degrading. Systemic insecticides applied to seeds can contaminate the pollen grains that are an essential source of food for bees and their young [7, 17, 19, 43, 49]. Pesticides often kill directly [17, 43], but sub-lethal amounts can also be detrimental to bees and other pollinators by impeding their ability to navigate or forage [43, 49]. The use of herbicides that eradicate important forage plants for bees and other pollinators is an additional problem.

Climate Change

Studies predict that climate change will alter the close relationship between insect pollinators and the plants [7, 17, 19] that depend upon them for reproduction [17]. Flowering plants migrating north or to cooler, higher elevation habitat in response to warming temperatures or other changes may not move in sync with their pollinators. The composition of pollinator communities is expected to change. According to the Xerces Society, anecdotal observations have found that bumble bees adapted to cooler temperatures are in decline, while bumble bees adapted to warmer temperatures are expanding their ranges northward. What effect this will have on local plants is unknown.

Disease and pest

Pollination services from native (wild bees) and managed bee species greatly impact the agriculture industry. Recent declines in pollinator populations due to colony collapse disorder and mite attack have increased concerns for food security, food quality and farming practices around the world. The most important factor responsible for decline of honey bee populations in India and abroad, is a combination of several factors; known as Colony Collapse Disorder (CCD) [43]. According to Heid[21] the average beekeeper had lost 45% of her colonies in winter. This mysterious phenomenon (CCD) is characterized by large numbers of dead adult bees surrounding the colony, with the queen and eggs remaining virtually unharmed [43]. Factors contributing to CCD include disease, mismanagement of hives, introduction of invasive species, GMO crops, and chemical contamination through disease management and pesticide use [56]. The largest declines in the United States have been observed in honey bees, the most heavily managed pollinator species; however, there have also been sharp declines in native populations, such as Bumble bees [56]. A concern for population declines of pollinators is widespread because there are so many benefits acquired from pollination services. Animal pollination is required for nearly three quarters of 240,000 flowering plant species worldwide [45]. Pollination is vital to agriculture, as nearly all of the fruit, vegetable and seed crops that are produced and used for fuel, pharmaceuticals, animal feed, and the food consumption require animal pollination [45]. Roughly one third of all food crops produced require insect pollination [17]. Native pollinator populations have the ability to provide sufficient pollination services for crops [9]; however, agricultural intensification, habitat fragmentation and habitat loss have all produced negative effects on these species [30, 24]. If populations continue to decline, there could possibly be an overall decline in crop production and an increase in food prices [29]. Kashmir bee virus (KBV) infects many types of bees including *Apis mellifera*. The virus affects both brood and adult bees. Infected adults die within a few days of exposure to the virus but infected larvae may survive and develop into seemingly unaffected adults.

Apis mellifera is the species of bee used in the US for crop pollination and commercial honey production. In 2000, an estimated $14.6 billion of US crops were pollinated by *A. mellifera*. However, recently, many *A. mellifera* colonies have been disappearing due to Colony Collapse. Although it is unclear exactly what causes CCD, a group of related bee viruses including KBV have been implicated. It seems as if these viruses interact with parasitic mite infestations and other environmental factors to cause CCD. A better understanding of KBV and other bee viruses could aid in the control and prevention of CCD, rescuing the world from a potential food crisis.

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Table 1: Abundance (No. insect /m^2/10 min.) of insect pollinators on cherry *Prunus avium* in Kashmir valley [9].

S. N.	Species	Srinagar	Budgam	Pulwama	F-value	±SE
1	*Lasioglossum marginatum*	6.07	4.83	5.17	1.32	0.58
2	*L. regolatum*	4.39	3.84	4.11	2.04	0.69
3	*L. himalayense*	5.39	3.95	4.56	5.95	0.90
4	*L. sublaterale*	4.23	3.67	4.10	1.00	0.80
5	*L. leucozonium*	4.30	3.33	4.00	10.39	0.96
6	*L. nursei*	5.38	4.45	3.94	3.08	0.35
7	*L. polyctor*	3.50	2.67	3.44	23.78	0.87
8	*Halictus constructus*	3.53	2.33	3.25	5.26	0.34
9	*Sphecodes tantalus*	2.72	1.50	1.94	74.84	3.07
10	*Andrena patella*	2.60	2.08	2.11	0.60	0.38
11	*A. flordula*	2.55	0.94	1.11	1.12	0.51
12	*A. cineraria*	1.00	1.23	1.39	2.88	0.44
13	*A. bicolor*	0	0.72	0.72	5.46	0.97
14	*A. barbilabris*	0	0.51	0	1.06	0.21
15	*Amegilla cingulata*	1.41	0.78	0.72	1.61	0.36
16	*Megachile rotundata*	1.46	0.83	1.22	24.69	1.20
17	*Anthedium consolatum*	0.78	0.34	1.11	0.32	0.10
18	*Xylocopa valga*	1.67	0.97	0.45	1.09	0.27
19	*X. violacea*	1.37	0.61	1.17	1.67	0.42
20	*Componotus longus*	3.22	1.67	0.91	0.74	0.09
21	*Formica rufa*	2.82	1.39	2.28	7.67	0.92
22	*Vespa auraria*	0	0.28	0	2.10	0.11
23	*Erisyrphus balteatus*	2.22	1.22	1.28	37.13	2.16
24	*Eristalis tenax*	1.82	1.05	1.94	32.37	2.24
25	*Sphaerophoria bengalensis*	2.72	1.11	0.81	0.50	0.95
26	*Didea fasciata*	1.11	0.45	1.00	4.08	0.71
27	*Eristalis cerealis*	0.52	0.73	1.43	1.21	0.14
28	*Sarcophaga nodosa*	1.04	0.57	0.89	5.66	0.79
29	*Scathophaga stercoraria*	1.80	0.82	0.93	27.53	1.19
30	*S. inquinata*	1.44	0.66	1.12	6.25	0.71
31	*Chrysomya megacephala*	2.00	1.21	1.45	6.96	0.43
32	*Bibio johannis*	2.50	1.36	1.33	23.32	0.67
33	*Plecia* sp.	2.13	1.38	1.52	86.16	1.17
34	*Musca domestica*	1.88	0.90	1.05	47.76	1.15
35	*Musca* sp.	1.11	0.51	0.78	2.80	0.46
36	*Ophyra* sp.	0.82	0.45	0.61	1.52	0.19
37	*Eupididae* sp.	1.38	0.40	1.28	2.31	0.31
38	*Tachinid fly*	2.66	0.88	0.55	7.38	0.81
39	*Neomyia cornicina*	0.80	0.67	0.83	5.80	0.68
40	*Vanessa cashmeriensis*	0.50	0.34	0.77	2.16	0.29
41	*Ischnura verticalis*	0.66	0.39	0	2.73	0.22
42	*Oncopeltus fasciatus*	1.21	0.55	0.50	2.13	0.30
43	*Pieries brassicae*	0	0.61	0.53	15.35	0.19
44	Lycanidae sp.	0	0.40	0.11	2.83	0.20
45	Pieridae sp.	0	0.11	0.10	1.45	0.17

Orchard Patch sites in Srinagar: [(Shalimar (n=3, 2170m MSL), Cheshma Shahe (n=3, 2200m MSL), Harwun (n=3, 2197m MSL). N= 39)]; Budgam: Chairshrief (n=3, at height 1933m MSL), Khansahib (n=3, at height 1972m MSL), Checkshara (n=3, at height 1967m MSL). N=45; Mean (x) =n (1/3+1/3+1/3); Pulwama: Pompore (n=3, 1592m MSL), Kakpora (n=3, 1589 MSL), Rajpora (n=3, 1590m MSL). N=42; Mean (x), n= (1/3+1/3+1/3)

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