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Nesting behaviour and nesting substrates of insect pollinators of Indian Himalayas

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Abstract
The present study was carried out in three experimental sites of Kashmir valley during 2013 to 2014. The nesting behaviors and habitat of all insect species pollinating fruit crops were investigated. Highest of 46 species were observed, belonging to 5 orders, 20 families and 31 genera of class Insecta. Total of 17 species were categorized in different landscapes of Himalayan areas as endogeic, 6 hypergeic and 23 were found to wander over grasses, herbs and dead material. Habitat components determining the structure of bee communities in surroundings of the foraging resources. For the organization of the bee communities study clearly demonstrate that a variety of nesting substrates and nest building materials played a key role. Generally, the potential bare grounds and nesting cavities are two factors influencing the entire bee community. The compositions of nest guilds at any potential areas also have a relative abundance of a dominant species. The important areas representing the huge density of nesting sites are necessarily the steep and sloping grounds, pithy stems, cracks and crevices, snail shells, beetle holes and pre-existing burrows. Nesting site varies across habitat and is clear determinant of bee community and forage resource availability and diversity. Principle component analysis (PCA) was done to determine the habitat requirements and Kruskal-Wallis rank sum test determined the nest density between the pollinators of different nesting habitat behaviours in three experimental locations and the difference were found statistically significant.

Keywords: nesting, pollination, insects, soil, habitat, lepidoptera, diptera

Introduction
Bees (Hymenoptera) are an integral part of our environment that decides the fate of majority of flowering plants (Dar *et al*. 2016; Dar *et al.* 2017a) [15]. They possess a wide range of nesting strategies based on the substrates they use and the materials with which they line their brood cells. Bees can be classified either burrowers or cavity-nesters, depending on whether or not they excavate their own nests or simply occupy a pre-existing cavity. Direct assessments of native bee nesting have focused on twig- and cavity nesting guilds that readily occupy trap nests. These guilds comprise less than15 per cent of all bee species; instead, the majority of native bees are solitary ground-nesters (Michener, 2007) [29]. Species *Osmia latreillei and O. submicans* are active soil nesters and cavities were excavated from early March to end of May (Wafa, 1971) [41]. Solitary soil-nesting bee species constitute 25 per cent and the species which do not nest in soil contribute by 32 per cent. The leaf-cutter bee, *Megachile analis* were rare in dunes; whileas, areas outside the dunes are inhabited by *Colletes halophilus*, inhibiting in soil nesting. The urban landscape offers a potential habitat to many different bee species. Wild bees are amongst those seeking a safe haven in gardens, roadside verges and industrial sites. It was found that between 13 to 40 per cent of wild bee species were found living in urban area. Mason bees being solitary bees that build nest of cardboard or paper straws, cut pieces of bamboo, or blocks of wood with pre-drilled holes of a specific diameter. The bees exhibit a variety of nesting strategies and architectures based on the material they use to line their brood cells. Kerr *et al*. (1967) [27] found that stingless bees like *Trigona spinipes* and *Dactylurin astundigeri* live in nests that can be aerial and constructed by them, but generally use natural hollows or man-made cavities for establishing their nests. Potts *et al*. (2005) [34] reported that miner bees excavate burrows in soil that are terminated by brood cells in which the female deposits larval food of pollen and nectar before laying an egg.

All of the Andrenidae, Melittidae, Stenotritididae, the Megachilid subfamily Fidelinae, and the majority of Halictidae, Colletidae and Anthophorinae belong to same arena (Cane 1991) [6]. Mason bees belong primarily to the Megachilidae, and occupy existing cavities such as hollow plant stems, snail shells, crevasses, abandoned burrows and wood-boring beetle tunnels. Carpenter bees excavate either branched or unbranched nests primarily in wood.

Females of most species of solitary wasps burrow one or more nests in the soil. The maintenance of solitary bee populations depends on the availability of adequate sites for nesting. Therefore, variations in the abundance and quality of sites can result in changes in the population density and diversity**.** Many species excavate their nests in exposed soil and can form large aggregations provisioned with pollen and nectar collected from flowers. Michener (2000) [28] found that females solitary bee species nest in twigs burrowed inside to construct their cells for egg laying. Above ground nesting behavior is observed in Apidae, Megachilidae, Helictidae and Xylocopinae (Cane, 1991) [6]. However, nesting behaviors vary widely among families. Females of several Crabronidae and Sphecidae species nest in pre-existing cavities. Wcislo (1992) [42] observed that nest entrance of species *Lasioglossum figueresi* was surrounded by chimney like turrets, more or less perpendicular to the bank, singly with length varying from 0 to 15 mm. However, turrets of *Priscomas arisnamibiensis* (wasp) were constructed in groups with maximum height of 13-17 mm above ground Gess and Gess (2010) [20]. The current investigation was done to conserve the insect pollinators and their habitat that is exposed to uniform abiotic factors (Dar *et al*. 2014, 2017f, 2018b) [48, 46] to increase the yield of fruit crops in Kashmir Himalayas.

Material and Methods

Nesting site location

The 30 minutes observation period were done to on dry days between 09:00h and 18:00hr of the blooming period of the plant species. The nests were discovered in the orchard and the bees entering and leaving it were collected and identified as per the procedure. Every pollinator do not have the same nesting requirement, therefore different substrates were observed for the nesting sites of the different stone fruit pollinators. The densities of the nests in the habitat that have provided the nesting sites in the orchard were determined. The diversity of the nesting sites that insect pollinators of the different orders use to construct the brood cells in which their young develop were observed near their good forging habitat. For different pollinators, bits of leaves from various shrubs, mud, fine pebbles, old underground rodent nests, cavities, grassy tussocks, wooden logs as well as mud walls were found from their nesting site. Nests of the wood boring bees were located by observing dead trees, snags or fallen logs on the land and old beetle tunnels. Ground nesting bees prefer loose, well-drained soil in a sunny spot. Some species nest in flat areas; whileas, others prefer earthen banks as a result observations were made in a variety of the areas (stone fruit orchards) with different slopes, preferably facing the South and had maximized exposure to the sun. The orchards with healthy and friable soil were selected and the vegetation was removed several yards across to observe the nests. Different ground conditions from vertical banks to well drained flat ground draw different bee species, so in the present investigation the flat ground of slope 5-10 per cent were preferably selected for the studying the nesting behaviour. The Hymenopteran species are essential ecosystem components that act as potential fruit pollinators and provide examples of the most sophisticated nesting behaviour among invertebrate animals. Since native bees contribute significantly to crop pollination and, on farms with sufficient natural habitat located nearby, may provide all of required pollination for peach, plum and cherry crops. Not every pollinator has the same nesting requirements. The nesting habitat for bees and wasps as well as egg-laying habitat for flies, butterflies, moths, and other insect pollinators are located close to good foraging habitat in the orchard. Nest density were determined as per the method used by Xie *et al*. (2013) [45].

Results

Ground nesters

Under temperate conditions of Kashmir division, the Lasioglossum species (Hymenoptera: Helictidae)were commonly found nesting in small to very large nest aggregations near to fruit orchards in all of experimental sites, such as along tracks in the social forestry, cultivated fields, sloppy areas, small bare soil patches, footpath inside the orchards, fallow lands, grass lands, meadows and pastures. In the present investigations about 17 species of order Hymenoptera nest in soil (Total 1). Generally they prefer loose, well-drained soil in a sunny spot, sloppy facing eastern direction at angel of 45-80 degrees. During the present investigation it was observed that few Lasioglossum species nest in flat areas. Whileas, most others prefer sloppy areas and earthen banks, so provide a variety of areas with different slopes, preferably east-facing to maximize exposure to sun shine hours. Females of solitary bees burrow one or more nests in the soil. In the present study it was observed that Andrenidae female seek sloppy sites for their nest burrow and usually prefer sandy soil near and under the shrubs so as to protect themselves from heat and frost. Most of female bees (Andrenidae and Helictidae) prefer the Plane areas for nesting and brood rearing, but few of the species were observed to nest in sloppy and vertical banks. The bees avoid the places that receive direct sunlight which could otherwise result in soil overheating. Other lazy flower visitors of peach, plum and cherry are ants. During the present study only two ant species viz. *Camponotus longus* and *Formica rufa* were found to visit the flowers during the blooming period. While as, the species Formica rufa were observed to build nest in ground with opening all along the Plane surface.

Cavity nesters

Cavity nesters build their nests inside hollow tunnels which may occur in the soft pithy centers of some twigs/stems (e.g. populous, willow and Rubenia); which may be left behind by wood-boring beetle larvae or, in the case of carpenter bees, *Xylocopa valga* and *X. violacea* tunnels are excavated by themselves. Carpenter bees were observed to create cavity nests by gnawing the wood in the trunks of dead trees and in old wooden structures. It inhabits both in forests and urban areas. Among the Hymenopteran species reported during the present studies, the species *Sphecodes tenatus* does not construct their own nest. Since the genus Sphecodes is cleptoparasitic, and the species *S. tenatus* makes 12-14 visits/minute to different nests and lay eggs in nest cells of genus Lasioglossum. The current study showed that the species *Megachile rotundata* and *Anthedium consolatum* were found to nest in wood. Females construct tubular shaped nests in rotting wood and in available cracks/crevices in trees and their nest were recorded to compose of string of individual cells. It was also observed that species of family Megachilidae nest in drilled blocks of wood and lay eggs too. The jacket wasp observed during the present investigation were found to nest in woody stems of social forestry plants.

Dipteran flower visitors

Dipteran flower visitors of peach, plum and cherry were found to live in under leaves/twigs/in dung/water/decomposed matter etc. During the present study it was found that Hoverfly larvae are aquatic and are often found in stagnant water, adults are terrestrial and residing on underside of leaves, flowers, stems, weeds and therefore found to visit stone fruit flowers from April to June. During the current investigation the species *Sarcophaga nodusa* were found to feed on dead flesh and lay eggs; while as, adults visit flowers and lives in moist habitat. The *Scathophaga stercoraria* and S. inquinata lives in dung and adults visit the peach, plum and cherry blossom for pollen and nectar. *Chrysomya megacephala* and *Musca domestica* lives close to human habitats. *Bibio johannis* and *Plecia* species larvae were found to grow up in grassy areas and are herbivores, feeding on dead vegetation and plant roots and are even found in compost. In all experimental locations during the present study the Bibio flies are regular flower visitors of peach, plum and cherry. *Ophyra* species were observed during the warm days and are often found in vegetations, feces and decomposing material. *Neomyia cornicia* lives in dung and were found nectaring on stone fruit flowers. Results showed that the Tachinid fly observed during the present investigations were adapted to live in their host and also found in all habitats, resting on foliage (Euphorbia), feeding on flowers or, flying quietly in search of hosts.

Other flower visitors

Lepidopteran flower visitors investigated includes, *Pieries brassicae*, *Vanessa cashmeriensis*, *Lycanadae* and *Pieridae* species needs large, open spaces, as well as farms and vegetable gardens for residing and feeding. 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 three experimental areas, these species were found to hover around 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 near slow moving streams, marshes, grass lands and fallow lands. Only adults were recorded to visit the flowers for nectar.

Table 1: Nesting sites of various insect pollinators of stone fruit crops investigated during the 2012- 2017

S. No.	Pollinator species	Endogeic (soil)	Hypergeic (wood)	Leaves/ twigs/ in dung/water/decomposed matter	Bee species abundance capture
1	*Lasioglossum marginatum*	✓			7.54
2	*L. regolatum*	✓			5.02
3	*L. himalayense*	✓			5.12
4	*L. sublaterale*	✓			4.98
5	*L. leucozonium*	✓			5.76
6	*L. nursei*	✓			4.8
7	*L. polyctor*	✓			3.31
8	*Halictusconstructus*	✓			3.1
9	*Sphecodes tantalus*	✓			3.24
10	*Andrena patella*	✓			2.76
11	*A. flordula*	✓			0.4
12	*A. cineraria*	✓			0.6
13	*A. Bicolor*	✓			1.56
14	*A. barbilabris*	✓			0.87
15	*Amegilla cingulate*		✓		0.98
16	*Megachile rotundata*		✓		1.01
17	*Anthediumconsolatum*	✓			2.56
18	*Xylocopa valga*		✓		3.25
19	*X. violacea*		✓		0.35
20	*Bombus* sp.	✓			3.24
21	*Componotus longus*		✓		3.5
22	*Formica rufa*	✓			1.43
23	*Vespa auraria*		✓		2.44
24	*Erisyrphusbalteatus*			✓	0.9
25	*Eristalistenax*			✓	1.22
26	*Sphaerophoriabengalensis*			✓	1.89
27	*Dideafasciata*			✓	1.66
28	*Eristaliscerealis*			✓	2.2
29	*Sarcophaganodosa*			✓	2.3
30	*Scathophagastercoraria*			✓	2.45
31	*S. inquinata*			✓	2.33
32	*Chrysomyamegacephala*			✓	1.5
33	*Bibiojohannis*			✓	0.6
34	*Plecia sp.*			✓	1.1
35	*Musca domestica*			✓	1.5
36	*Musca sp.*			✓	1.2
37	*Ophyra sp.*			✓	0.1

38	*Eupididae sp.*			✓	0.11
39	*Tachinid fly*			✓	0.67
40	*Neomyiacornicina*			✓	0.45
41	*Pieriesbrassicae*			✓	0.47
42	*Lycanadae sp.*			✓	0.11
43	*Vanessa cashmeriensis*			✓	0.09
44	*Ischnuraverticalis*			✓	0.08
45	*Pieridae sp.*			✓	0.10
46	*Oncopeltusfasciatus*			✓	0.09

*Chi square Test (N=46 (species), N=3 (Groups), *P*<0.05, significant difference found in abundance of pollinators (N=46) and between the three groups (N=3) of different nesting behaviours). During the study periods all the natural calamity (one example is heavy floods in 2014) were ignored and neither the construction or plantation or any factor that happen to effect in the three research areas selected were considered.

Fig 1 & 2: Principle component analysis (PCA) of the pollinator species habitat requirement in landscapes of Kashmir valley.

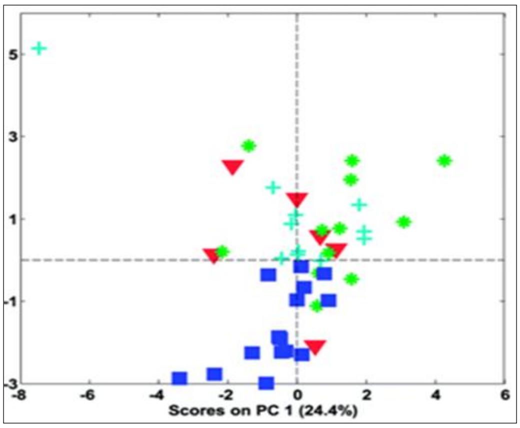


Fig 1: Species that wander over grasses, marshy areas and in dead decaying materials; red triangular dot are hypergeic species percentage

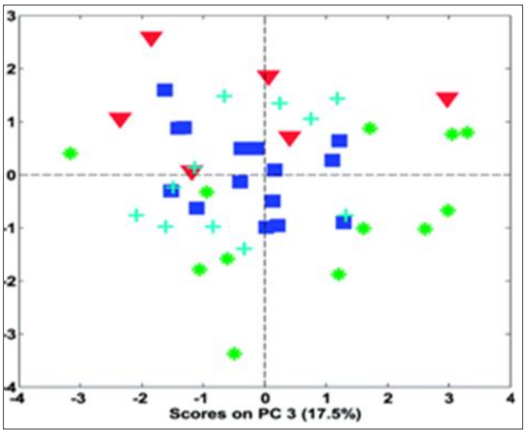


Fig 2: Species with Endogeic nature of habitat.

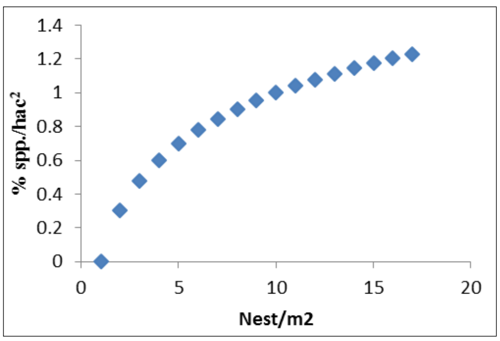
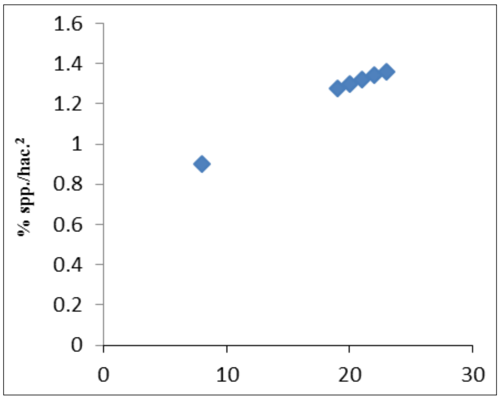


Fig 3: Proportional abundance nest sites/hac.^{2} Soil/sand (steep, slopes, plane, sand dunes, vertical walls, mud walls, or barren and cultivated lands) nester spp.



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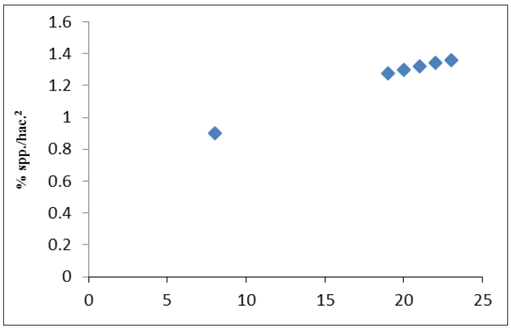

Fig 4: Proportional abundance nest sites/hac.^{2} wood (old buildings, wooden logs, creaks, crevices) nester spp.

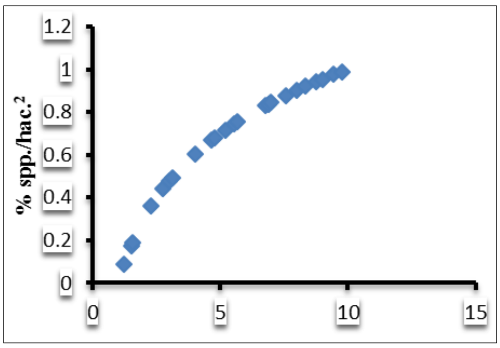

Fig 5: Proportional abundance of non-hymenopteran flowers visitors in surrounding veg. or litter/hac.^{2} Foliage/litter oriented spp.

*Conducting the Kruskal-Wallis rank sum test between the three groups of insect pollinators, the difference were found significant (N=3, P<0.05, significant)

Discussion

Study showed that not every pollinator recorded on peach, plum and cherry plants has the same nesting requirements and habitats, this is in confirmation with the findings of Center for Biodiversity and Conservation, American (CBCA, 2014) [7] that different nesting habitat of all insect pollinators were located close to good foraging habitat in the orchard (Dar *et al*. 2017b) [16]. However, Hopwood (2013) [23] observed that it is ideal to have nesting and forage resources in the same habitat patch, since bees are able to adapt to landscapes in which nesting and forage resources are separated, therefore it is important that these two key habitat components should not be too far apart. Further, the nesting material/substrate choice limit the geographical ranges and/or abundances of particular bee species. In current investigation, the ground-nesters (36.95%) excavate underground nests comprised of tunnels, egg chambers and the cells where young develop. Under temperate conditions of Kashmir division, all the members of genus Lasioglossum (Hymenoptera: Helictidae) are important and dominant pollinators on fruit crops (Dar *et al.* 2018a) [8] and wild shrubs (Dar *et al*. 2018b) [46] were abundantly found nesting in small to very large nest aggregations in soil near to fruit orchards along tracks in the social forestry, cultivated fields, sloppy areas, bare soil patches, vertical banks, horizontal ground, footpath, inside orchards, fallow lands, grass lands, meadows and pastures. This is in confirmation with Kaluza *et al*. (2016) [25] who found that natural habitat like forests, landscapes like gardens and agricultural fields promote the bee abundance and the most indicators of nest habitat quality (bare ground, soil surface irregularity, soil slope and soil hardness) were associated with higher incidence and richness of nesting bees. Most of the nests observed underground were of genus Lasioglossum of species *L. marginatum*. This is in consonance with findings of Buckley *et al*. (2013) [4] who reported that most Helictid nest underground, and each subfamily has its own characteristic nesting habit; e. g, larval cells are excavated either at slant or horizontally off of main lateral tunnel (Rophitinae), build vertical cell clusters (Nomiinae) or nest with sub-horizontal cells off of vertical burrows (Nomioidinae) and series of scattered and clustered cells (Halictinae).The results showed that 17 species of order Hymenoptera nest in soil. The bees most commonly encountered in the fields are Halictids (sweat bees), Colletids (cellophane bees), and Andrenids (mining bees) nest underground and are most important pollinators of fruit crops. The solitary bees dig hole and nest in the ground, create large bee communities in the orchardfor crop pollination. Most of the bees were observed to pollinate efficiently peach, plum and cherry and prefer the areas of bare or sparsely vegetated soil for nesting; this is in agreement with Grundel *et al*. (2010) [22] that ground nesting females of families Helictidae, Colletidae and Andrenidae nest in areas where vegetation is spare. Results showed that bees in general prefer loose, well-drained soil in sunny spots facing the southern direction at angel of 45-85 degree. However, it was observed that some Lasioglossum species prefer to nest in flat areas, while others prefer sloppy areas and earthen banks; so provide a variety of areas with different slopes, preferably south-facing to maximize exposure to the sun shine hours. This is in conformity with results of Wcislo *et al*. (1993) [43] that *Lasioglossum figueresi* nest in aggregations on horizontal/flat ground or vertical banks at an angel of 90 degrees. However, Evans (1964) [19] observed that species *Philanthus* (Hymenoptera: Spencidae) nest in sandy banks having steep slope, with firm sand at above and opening entrance at an angel of 45 degrees with respect to plane. Females of solitary bees burrow one or more nests in the soil and further it was observed that Andrenidae females seek the sites for their nest burrow and usually prefer sandy soil near and under the shrubs so as to protect themselves from heat and frost. Most of the females prefer the plane areas for nesting and brood rearing, but few of the species were observed to nest in sloppy and vertical banks. In present study the Cleptoparasitic helictid species *Sphecodes tenatus* (which don't construct their own nest) were observed to enter nests of Lasioglossum species, maybe to kill the egg or larva in the cell and the larva is cleptoparasite kills the other egg or larva before eating the host's stored food (Dar and Wani, 2018). The species *Halictus constructus* were observed to pollinate peach, plum and cherry and nest inside the ground, which is also in agreement with the observations of Richards *et al*. (2015) [35] that species *Halictus ligatus* and *H. poeyi* nest inside the ground. The blue banded bee *Amegilla cingulata* were observed as solitary creatures generally inhibiting burrows in the soil in the orchards. However, the literature says that female Blue banded Bees builds its nest often close to one another. They prefer soft sandstone, clay type, mud-brick houses and often burrow into the mortar in old building. During the present investigations at experimental location Budgam, the Bumble bee were observed to nest underground in an old rodent burrows under shade and sheltered places. The bee avoid the places that receive direct sunlight so as to avoid soil overheating. It is found that Bumble bee build their nests of wax cells in old rodent burrows, house wall voids, attics in addition bee avoids full sun exposure, nest overheating and directs the opening at an angel of maximum 39-90 degrees with respect to plane.

Overall, the species collected in present survey were representative of the Kashmir division cavity-nesting bee fauna (13.04%), and 100 per cent similarity were observed in nesting site selection across the three experimental locations. However, the natural habitats/woodlands within or adjacent to stone fruit orchards probability contain abundant natural nesting sites, this is also in accordance with observations of Morato and Martins (2006). Results showed that six Hymenopteran insect pollinator species of peach, plum and cherry plants act as wood-nesters that build their nests inside hollow tunnels. These tunnels may occur in soft pithy centers of some twigs/stems (e.g. populous, willow and Rubenia), or left behind by wood-boring beetle larvae. According to National Resource Conservation Service, USA (2013), the cavity nester bees occupy tree cavities, and a few even chew out the soft pith of stems of elderberry and blackberry to make nests. Most of the cavity nester bees used dead wood branches, vines and lianas as their nesting substrata. Nests were found tangled in vegetation in the understory of primary and secondary forests, where dead sticks are abundant (Wcislo *et al*., 2004) [44]. However, in the case of carpenter bees, *Xylocopa valga* and *X. violacea* tunnels are excavated by gnawing the wood in trunks of dead trees and in old wooden structures. In Kashmir valley, species *Xylocopa violacea* exhibits the preference for wood of various social forestry plants as their nesting site (Dar *et al*., 2016). It inhabits both in forests and urban areas. During the current study species viz., *Megachile rotundata* and *Anthedium consolatum* were found to nest in dead and decaying olden wooden logs and construct tubular-shaped nests in rotting wood and flower stems. In district Budgam, females also create nests in small holes in the ground or in available cracks/crevices in trees, composed of string of individual cells. This is in confirmation with the findings of Susan

(2007) [39] who reported that *Megachile rotundata* construct tubular shaped nests in wood and few species also nest in creaks/crevices, straws or drilled blocks of wood. National Centre for Pollination, Pollinators and Pollinizers, SKUAST-K, observed that in district Pulwama when these bees were managed for pollination, the females nest in drilled blocks of wood and lay eggs. Goettel (2008) [21] observed that females use nearly 15 leaves per cell and make a concave bottom to produce the thimble-shaped cell. During the present study the jacket wasp observed to nest in woody stems. They build them from wood fiber, and chew it into a paper-like pulp (Akre *et al.* 1980) [1]. The species *Camponotus longus* were found to build nests in dead and damp wood, which is in conformity with the results of Strauss (2005) [37] that Camponotus species commonly nest in infest wooden buildings and structures. According to Katherine *et al*. (2015) [26] the Dipteran insects cannot be neglected and plays an important part in fruit pollination studies. During the current study the true flies live in considerable abundance in all three experimental locations, and their larvae were observed to live in moist environments. Diptera occur all over world and the habitats used include meadows, mountains, forests, sea shores, sandy beaches, lakes, streams, rivers, fens, water polluted by rotting wastes, urban areas, cattle, horse and poultry farms. 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. Few species are pests on fruits and vegetables e.g. fruit flies; while some are flower visitors and help in crop pollination. Syrphid flies are important flower visitors among whole dipteran species. Current investigation 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. Others Dipteran species were found on decomposing vegetation. Results showed that the species *Sarcophaga nodusa* feed on dead flesh and lay eggs; while as, adults visit flowers and lives in moist habitat. This is in consonance that the adult Sarcophaga species feed on carrion and decomposed matter (Byrd and Castner, 2010) [5]. The *Scathophaga stercoraria* and *S. inquinata* lives in dung and adults visit the peach, plum and cherry blossom for pollen and nectar. According to the research conducted in Iowa state university (2016), larvae of Scathophaga live in dung; however, Otronen and Reguera (1997) [33] reported that these flies live in dung and lay eggs there as well. Fly species *Chrysomya megacephala* and *Musca domestica* lives close to human habitats, which are also in accordance with the results of Sung *et al*. (2006) [38] that flies of families Calliphoridae and Muscidae live close proximity of human dwellings and are the potential pollinators of mango flowers. *Bibio johannis* and *Plecia* species larvae were found to grow up in grassy areas and are herbivores, feeding on dead vegetation and plant roots and are even found in compost. This is in agreement with Denmark *et al*. (2015) [18] that the Bibionidae larvae feed on dead and decayed plant material, in moist to damp areas and in pastures under cow manure. The largest populations of *Plecia neartica* were found in grassy habitats such as Bahia grass, Paspalum spp., pastures, roadsides, oak hammocks, wooded ravines, and deciduous forests (Buchman, 1976) [3]. During the present study the Bibio flies were observed as regular flower visitors of stone fruit crops. Highest abundance were observed on cherry flowers. *Ophyra* species were often found in vegetations, feces and decomposing material. *Neomyiacornicia* lives in dung and the Tachinid fly mostly adapted to live in host including foliage and flowers. The Lepidopteran flower visitors includes, *Pieries brassicae* and *Vanessa cashmeriensis* species needs large, open spaces, as well as farms and vegetable gardens for residing and feeding. Bhattacharya *et al*. (2015) [2] 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 three experimental areas 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 (2016), the milk weed bug lives in fields and meadows containing milkweed or dogbane plants.

In our earlier studies we tested the effect of distance from orchards as well as of the landscape context on pollinator species relative abundance and various diversity indices (mentioned in earlier articles)**.** We also tested bee assemblage responses described by species' richness and abundance against landscape metrics and effect of various anthropogenic factors (for reference also read, Dar *et al*. 2017e) [12].

In present studies we did not examine how the landscape characteristics affected bee dispersal, mortality, and habitat use, as has been studied by other authors. Nevertheless, we infer that how effects of the landscape degradation (habitat disturbance) pose a significant barrier for all pollinator species. For larger species that nest in large cavities the presence of older and taller trees is necessary because they are the source of cavities that are capable of housing these colonies. Due to drastic environmental changes produced by urbanization and pollution, we expect a declining tendency in species richness and abundance as the consequences of unsuitable habitat (lack of suitable soil, plants, forage resources), as the replacement of vegetation with impervious surfaces will reduce diversity due to the loss of habitable area and plants thereof. In Kashmir valley loss of habitable area is enhancing; and urbanization intensity correlates with increased disturbance and the structural simplification of remaining vegetation by landscaping practices that remove woody plants, leaf litter and other microhabitats of natural communities. All of these factors combine to reduce habitat area and quality, and the urban matrix appears to reduce bee habitat requirement; however some researchers observed that urban matrix offer greater nesting opportunities for small bee species that nest inside or outside (aerial nests) a cavity. In present studies it is observed that both number and abundance of species increased in forage rich small fragments in comparison to the large ones, and bees (*Lasioglossum* spp.) composed a greater portion of the fauna present in the fragments as fragment sizes decreased, provided soil condition is suitable and sloppy southwards. Further, the larger fragments had more specialized bee species that nested in cavities (*Xylocopa* spp. etc) and rare in habitat fragments. Since, the nesting substrate may be a limiting resource for wood cavity-nesting bees in the fragments because older trees are relatively rare inside them. Fences, homes, and shade trees in wild areas may, in contrast, provide many suitable nesting sites. Cavity nesters increased more than ground nesters in remnant meadows surrounded and several cavity-nester bees (*Xylocopa*spp.) increased in abundance in fragments of dry forest areas. The bombus species were observed in vast areas surrounded by forest and barren lands adjacent to the cultivated lands, as these unmanaged and silent areas offer suitable nesting requirement to bombus species. It is observed that nesting habits of pollinators especially bees may be extremely useful for predicting how native bee faunas respond to habitat fragmentation in urban and, possibly, other settings during current climate change era. A decrease in insect pollinator diversity may be attributed to nesting substrate depletion. Insects in general adapt well to fragmented landscapes, but some species do not if there are habitat restrictions e.g. bumble bees. The landscape matrix refers to those areas that surround the fragments areas of scattered stone fruit crop plants and that are possibly permeable to some bees which fly short distances and are more demanding regarding habitats. The *L. marginatum* found new colonies of 20-24 individuals and have comparatively little ability to occupy new habitats differing in land slope, distance from forage and is disturbed. Carpenter bees nest exclusively on pre-existing cavities in tree holes; and in matrix, there are trees that could harbor these large body size pollinators. Isolated and scattered stone fruit area fragments have fewer and more common bee species that are able to occupy new niches, according to the quality of the matrix; however in real species composition in valley is even more diverse and large. Species that nest in large cavities require taller and older trees because they provide cavities capable of accommodating them. All 3 selected experimental areas subjected to same agro-climatic conditions (Dar *et al*. 2014, 2017f, 2018b) [48, 46] two are situated a low altitude and third one (Budgam) is comparatively at higher elevation. However, all the studied areas are connected to other fragments through corridors of vegetation; thereby boasting the bee species richness. Besides many steps needed for the conservation of bees as discussed in earlier articles (Dar *et al*. 2017d) [11], the requirement of nesting sites and areas near the foraging resources help in overall conservation of the bee fauna.

Statistical analysis

The sample size (pollinators) within the each three plots of the one experimental location varies, therefore each plot were sampled independently, the stratification done homogenously before sampling. The plots of every experimental location (strata) were mutually exclusive. The strata are collectively exhaustive, and no population elements were excluded. The Stratified Random Sampling were applied within each strata. Further each population per strata were its representative and the arithmetic mean of the population was done to determine the variability/exp. location (strata).The bee assemblage was ordinated using a PCA in order to identify patterns of bee habitat preference relative to abundance, diversity and more factors. Nest density represented per sq. hectare of the all locations. Considering the 17 and 6 frequent species of order hymenoptera, an index reflecting their relative response to habitat preference was generated (Fig 1&2).

Conclusion

Present investigation showed that not every pollinator has the same nesting requirements, and the nesting habitats for various insect pollinators are located close to good foraging habitat in the orchard (Dar *et al.* 2017c) [10]. Unlike honey bees that suffer from various diseases (Ullah *et al*. 2020) [40], the wild bees (specially solitary bees) are resistant to many diseases and change is soil conditions. In case of the change in biotic and abiotic factors, the bee nest guild shift to new place in coming season; however species especially the genus *Lasioglossum* is parasitized by Sphecodes and other predicators. In spite of all these factors, the wild bees species are able to maintain their populations for fruit crop pollination, although there is reduction in bee density. Generally the Hymenopteran insects nest in soil and most of bees observed to pollinate peach, plum and cherry and prefer the areas of bare or sparsely vegetated soil for nesting. Generally loose and well-drained soil in a sunny spot, sloppy facing eastern direction at angel of 45-80 degrees is preferred. The species of the genus Lasioglossum nest in flat areas and the females burrow one or more nests in the soil. The Andrenidae female seek sloppy sites for nest burrow and sandy soil near and under the shrubs, whileas few other species of Andrenidae prefer plane areas and vertical banks for nesting and brood rearing. Carpenter bees (*Xylocopa* spp.) were observed to nests in dead trees and old wooden structures both in forests and urban areas. The species *Sphecodes tenatus* does not construct their own nest and were found to be cleptoparasitic. Whileas, Dipteran flower visitors were observed to live under leaves, twigs, dung, water and decomposed matter. Present study also showed that barren and sloppy steep lands are more preferred as compared to cultivated lands of cereals and pulses or of any other crop that need regular intercultural operations (Dar *et al*. 2014, 2017f, 2018b) [48, 46]

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