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Importance of hedgerows for wild bee abundance and richness in Kashmir Valley

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ABSTRACT: The investigations on value of various landscapes categories as a foraging habitat for wild bees were carried out in mosaics of small scale agriculture and natural vegetation areas of Kashmir valley during the spring seasons of year 2013 and 2014. In present study we tested the importance of habitat area, landscape composition and configuration on wild bees in valley. The habitats selected were hedgerows, agricultural fields, grasslands, and native woodland. We observed that bee differ in their response to many factors of landscapes. The hedgerows were attractive foraging habitat for native bees. The total species richness was highest in hedgerows. The overall bee faunas overlapped among habitats, bee assemblages in hedgerows were more similar to those in fields than to those woodlands. The flowering shrubs were important in attracting bees. Species richness and abundance of wild bees were surveyed on with independent gradients in local and landscape factors. Total wild bee richness was positively affected by complex landscape configuration, large habitat area and high habitat quality which provide them with assured nesting sites.

KEY WORDS: Hedgerows, Habitat, Bees, Wild, Ecology

INTRODUCTION

Insect pollinators are estimated to support 9.5% of world food production (Gallai *et al*., 2009) and wild bees have an important role in the delivery of this ecosystem service (Garibaldi, 2013). However, wild bees have undergone global declines (Woodcock *et al*., 2016) that have been linked to habitat loss and fragmentation, pathogens (Camerona *et al*., 2016), climate change and insecticides (Biesmeijer, 2006; Goulson *et al*., 2008; Ollerton *et al*., 2014; Potts, 2010; Winfree *et al*., 2009). Habitat degradations lead to severe decrease of bee abundance and richness in isolated semi-natural habitats (Krewenka *et al*., 2011). Agricultural landscapes are increasingly important settings for biological conservation, especially for the conservation of important pollinators such as bees of families Halictidae, Andrenidae, Bombus, Anthophoridae and Megachilidae (Jauker *et al*., 2012; Klein *et al*., 2007). Since, wild bees are the dominant providers of pollination services (Colla and Ratti, 2010) and research with a range of crops suggests that maintaining abundant and diverse native bee communities (Meiners, 2016) can provide insurance against the loss of pollination services in the face of reduced honeybee populations due to colony collapse disorder (CCD). The importance of wild bees to act as alternative pollinators for horticultural and agricultural crops is one reason to focus on their management and conservation in various

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landscapes. Therefore, the effective conservation of bee abundance, diversity and richness depends on understanding how their habitat requirements assured in different landscape categories (Jauker *et al*., 2012). Cultivated land are insufficient to provide various resources like, pollen, nectar, floral oils, nest sites, nesting materials and overwintering sites necessary to sustain local bee populations (Kremen *et al*., 2007). Since, the intensive cropped areas tend to lack floras and continuity of floral resources (Corbet, 1995), which are very important for the bees. The landscape from urban areas offers a potential refuge to different species (Samnegard, 2016). Cornelissen (2012) observed that between 13-40% of wild bee species living in urban settings, and the effects of hedgerows were known to restrict movement of some species (Kueûer *et al*., 2010). For the nesting sites of the wild bees, the hedgerows are important; however the pollen and nectar sources are not evenly distributed among the habitats (Westrich, 1996). Since, the flight ranges of the bees are limited, so they have to lie within their flight range for various requirements (Gathmann and Tscharntke, 2002). In present study the use of hedgerows with two corridors in south-eastern Kashmir, noted for high diversity of bees and flowering plants, was investigated.

MATERIALS AND METHODS

The Valley Kashmir is a temperate region and considerable area is under various fruit crops. During the survey in various locations the nests were observed mostly in barren, dry lands, irrigated, orchards and grass lands. Almost 15 % of the nests were located in plane areas and rest 85% on sloppy grounds. So, nest dominant areas were selected for the bee survey. Geographically Kashmir is stretched between 32^{o} 17^{-} to 37^{o} 60^{-} N latitude and 73^{o} 26^{-} to 80^{o} 30^{-} E longitudes. The mountain range in the Himalayas region varies in altitude 5,550 m on North-east dip down to about 2,770 m on South. Generally, the Kashmir contains the upper stages of the forest vegetation including pinus, populus, willow, rubenia and some other social forestry trees and lower stages of agricultural and horticultural crops including apple, pear, peach, plum, apricot, almond and cherry.

The Kashmir receives 25-35% and 50-60% of its precipitation during the winter and monsoon periods, respectively. The Budgam and Pulwama are largely characterised by agricultural landscapes with relatively small fields, less than 2.5 ha, and a mosaic pattern of habitat types with variable sizes. The hedgerows separated the fields. The forest areas are interspersed with areas of cultivated fields and hedgerows. On 10 locations we surveyed the hedgerows and agricultural fields for the abundance and diversity of wild bee species. We took 5 locations in south and 5 in north region for investigations. Generally, the agricultural fields were made up of contiguous farms. The field to field variations were minimized by standardised the farms into various habitat types having different management practices-like pesticide and fertilizer applications, mowing, grazing, ploughing etc. The crops like maize, oats, wheat, beans and brassica are common; however, the large areas in experimental sites are under paddy and considerable areas are irrigated pastures and mixed grass lands and forbs for cattle. On each farm, various types of social forestry tree were used to graze cattle for at least a part of year. There was no aerial application of any type of pesticide. In district Budgam walnut and almond orchards and in Pulwama the apple orchards were also surveyed for the bee species richness and abundance. The bees were surveyed in 10 habitat types and we establish the 30 transits in each category of landscape. Each transit of 2.5 m by 45 m rectangular plot, the maximum length of transits being constrained by length of hedgerows on some farms. All along the hedgerows we placed a transit and a second transit in an approximate centre of the adjacent field, running parallel to the largest dimension of the field. A third transit was placed randomly in nearest woodlot. The minimum distance between hedgerows and woodlot transits was 150m; however, the distance between hedgerows and fields transits were only 80 m. Based on the presence of dominant native perennial herbs, grasslands and economic shrubs, we identified the potential and important woodland sites which are probably the habitats for wild bees. The second transit were placed 250 m away from the woodland habitat. Normally, the minimum distance of native and woodland transits were 350-650m away from agricultural fields.

Survey and Sampling

The timed periods of observations and hand-netting were used during investigations to sample, collect and assemblage the bees. During the investigations, the afternoon survey were also done, and completed between 9:00 am and 4:30 pm, and were only conducted in clear cloud free weather.

Two observers were used during the active flowering seasons of 2013-2014, observers alternated the transects they surveyed, and the order in which transects at a given site were surveyed. In each survey, the observer spent 45 min in the 40-45 meter transect area, catching and collecting the insect specimens and recording the flower species, if any, visited by each bee on the flowers or near the flowering plants. Generally, the stopwatch setting and handling time was not included in the observation time; the clock was turned off when a bee was caught and while it was being processed. The 45 min total observation time was divided into five 9-min periods (one for each subplot) in order to spread observer attention across the transect area. Data from the four subplots were combined to make one sample per transect, since the individual plots act as a replica, so data were pooled to get an average. During the survey, we caught all bees detected, or photographs were taken while foraging. Voucher specimens were deposited in pollinator lab of entomology, identified and preserved as per Schauff (1986), SKUAST-K, Srinagar.

Data analysis

For the comparison of the species richness among habitats we estimated total species richness for each habitat using Manitab and O.P.Sherom software, to determine the significance among the species pertaining to particular orders. The Student's t-test were used to compare the diversity and abundance of the bees captured from each habitat. One way ANOVA were used to compare the mean species richness and abundance among habitats, so that statistical comparisons of species richness and abundance were made among observations made in the same sampling periods. For estimation of dissimilarity, we calculated the Bray–Curtis index.

RESULTS

Species richness

Overall, we collected 687 bee individuals from all experimental locations during 2013 to 2014 (Table 1). The collection constitutes 20 bee species from 9 genera and 5 families. Generally, the sampling frequency varied among habitats, with a range of n = 75 to 120 samples (one sample equals one survey of one transect during one sampling period in 1 year). So roughly, 45-50 days were utilized for sampling the bee from different landscape categories. Therefore, to compare species richness among habitats, we randomly sub-sampled results of 65 surveys in each habitat. This analysis yielded a total of 16 species in fields, 18 species in hedgerows, 20 species in fruit orchards near hedge rows, 16 species in native woodland, and 13 species in woodlots. In total, 85-90% of the species recorded were common across different landscapes. In addition all of the species were recorded near by the stone fruit orchards on sloppy to plan areas of the valley.

For the given level of sampling effort (n), the hedgerows were observed to have highest estimated species richness and highest total population count with p-value, 0.0032 (i.e. statistically significant). The overall estimated species richness in fields, hedgerows, and native woodland also differ significantly. The species richness in woodlots was significantly lower than in the other three habitats. The flowering commences later at higher elevation, abundances of workers and male bees were also shifted later; therefore elevational comparisons play an important role in species richness (Pyke *et al.,* 2011), generally due of forage availability. Since, the observed species richness was highest in hedge rows near orchards, so jackknife estimates of actual species richness were highest for hedgerows with (J) 1st order: 19 species, 2nd order: 20 species so on. Among the all species observed the species

Table 1. Wild bee species richness and overall mean abundance (bees/m²/10min.) on three stone fruit crops in Kashmir valley during 2013-2014

S. No	*Species*	Peach (*Prunus persica*)	Plum (*P. domestica*)	Cherry (*P. avium*)	Mean abundance
1	*Lasioglossum marginatum* Brulle	4.23	4.73	5.35	4.77±0.23
2	*L. regolatum*	3.00	3.00	4.11	3.37±0.29
3	*L. himalayense* Bingham	3.94	4.22	4.63	4.26±0.39
4	*L. sublaterale* Blüthgen	2.84	2.33	4.00	3.05±0.02
5	*L. leucozonium* Schrank	2.45	2.00	3.87	2.77±0.12
6	*L. nursei* Blüthgen	4.00	3.00	4.59	3.86±0.11
7	*L. polyctor* Bingham	2.39	1.33	3.20	2.30±0.41
8	*Halictus constructus*	1.34	1.00	3.03	1.79±0.01
9	*Sphecodes tantalus* Nurse	0.00	0.34	2.05	0.79±0.04
10	*Andrena patella* Nurse	1.50	0.88	2.26	1.54±0.19
11	*A. flordula*	0.89	0.66	1.53	1.02±0.14
12	*A. cineraria* Linnaeus	0.34	1.33	1.20	0.95±0.03
13	*A.bicolor* Fabricius	0.44	0.00	0.48	0.30±0.05
14	*A. barbilabris* Kirby	0.00	0.00	0.17	0.05±0.07
15	*Amegilla cingulata* Fabricius	0.733	0.44	0.97	0.71±0.22
16	*Megachile rotundata* Fabricius	0.77	0.67	1.17	0.87±0.31
17	*Anthedium conciliatum* Fabricius	0.73	0.11	0.74	0.52±0.03
18	*Xylocopa valga* Gerstaecker	1.11	0.34	1.03	0.82±0.01
19	*X. violacea* Linnaeus	0.73	0.39	1.05	0.72±0.00
20	*Bombus* spp. Litreille	0.05	0.00	0.01	0.02±0.01
	N=20	N=18	N=17	N=20	-
	Total samples	199	167	321	387

of family Halictidae were most dominant. Among the Halictidae family the genus *Lasioglossum* was the most abundant and dominant flower visitor, representing 46 to 48.01% of all individuals collected during surveys. Among these wild bees the species *L. marginatum* was the most abundant species (Fig. 1). The foraging ranges of this species were nearly 100 m from the nesting habitat. The cherry *Prunus avium* recorded the highest of relative abundance and peach *Prunus persica* recorded comparatively less. On stone fruit (peach, plum and cherry) flowers from three districts (Ex. Locations), the mean relative abundance of species were significantly highest of 4.77±0.23 (t=4.21, t. stat. =2.31, p.value <0.01) and comparatively lowest 0.02±0.01 pollinators/m²/10 min. (t= 7.30, t. stat= 1.94, p.value < 0.01) with ANOVA for pooled relative abundance of pollinators/m²/10 min. (F. ratio 0.81; CV, 13.04; SE, 0.77; CD $_{(0.05)}$= 0.43; Pearson's correlation= 0.79, T-test=4.03,p.value < 0.001). The mean relative abundance of genus *Lasioglossum* Curtis on three stone fruit crops were in order viz. *L.marginatum*> *L.nursei*> *L.Himalayans*> *L.regolatum*> *L.sublaterale*> *L.leucozoni*> *L. polyctor* (Fig. 1). On all three crops the the relative abundance of *Halictus constructus* were comparatively minimum. While as, on all the three crops, the species of genus Andrena has the relative abundance in order viz. *Andrena patella*> *A. flordula*> *A. Cineraria*> *A.bicolour*. In family Apidae the species *Xylocopa valga* maximum and *Xylocopa violacea* showed minimum of the mean abundance during both years of studies. The species *Megachile rotundata* and *Anthedium consolatum*

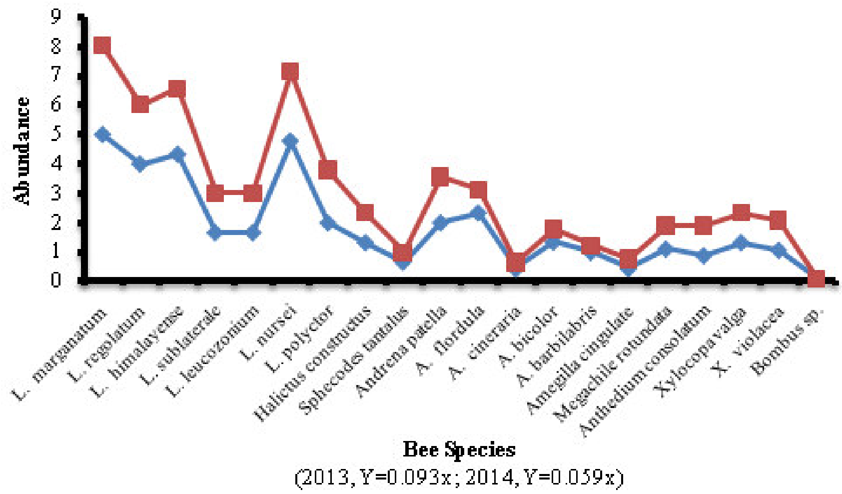

Fig.1 Relative bee abundance of stone fruit (*Prunus persica, P. avium, P. domestica*) crops in Kashmir during 2013-2014.

of family Megachilidae also showed less relative abundance during investigations. Overall, the species richness was more on *Prunes avium* compared to *P. persica* and *P.domestica* (Table 1).

Species composition and overlap

The cumulative bee faunas of the fields, hedgerows (orchards), woodlots, and native woodland overlapped. The species composition from hedgerows were overlapped and sheared with other habitat categories. Nearly, 61-62% species from hedgerows also occurred in fields during both years of studies.

Likewise, 48-49% species also occurred in woodlands, and 70-71% in native woodlands. In hedgerows, about 7.21-7.33% of bee species were found exclusively. The fields, woodlots and woodlands shared the majority of the species present there with other habitats, and had small number of unique species. We compared the bee assemblages at the transit level- summing the abundance of the bee species occurring on a given transecting the pre, early and late monsoon over the period of two years. Strongest differences were between fields and each of the hedgerows, which are mainly occupied by orchards, woodlots and native woodlands. Studies showed that the hedgerows were significantly more similar to woodlots and native woodland than to assemblages in agricultural fields and grass lands. Among the transects and within habitats a considerable variation were recorded in bee assemblage and also a wide overlap in species composition among habitats were found.

Spatial analysis and spatial autocorrelation

In various experimental locations, the huge data tables of bee specimens obtained from censuses and surveys were analyzed to extract the main trends in bee abundance and species composition across many habitats. The autocorrelation statistics measure and analyzed the degree of dependency of bee composition on various habitats. It measuring a spatial bee abundance matrix that reflects the intensity and suitability of the habitat and its relationship with the bee species. e.g., the abundance of the forage, distance from nesting habitat, anthropogenic pressure, and aspect of the habitat with respect to sun. From the dataset of cumulative bee assemblages, summing bee abundance data for each transect across all sampling periods in 2013 and 2014, to test for one way ANOVA in bee species composition. Sample sizes in this dataset are lower than the total number of transects surveyed, as only those transects that had been in four of six sampling periods, and a minimum of three species in their cumulative bee assemblages, were included in the analysis. T-test showed a statistically significant (t. test<0.05%), though relatively weak. This result was apparently primarily due to correlation among native woodland transects along the Pulwama and Budgam districts.

Abundance and species richness *vs* sampling periods

The patterns of the bee abundance were variable across 2013-2014. Generally, the abundance was highest in 2013 and lowest in 2014. Current study showed that bee abundance was highly variable among transects within habitats. There were some consistent patterns; however, bee abundance in hedgerows peaked in the pre-monsoon, declined in the early monsoon, and then increased slightly in the late monsoon. During the pre-monsoon period, fields and hedgerows tended to have higher abundance than either native woodland or woodlots. Bee species richness was also variable within habitats, and there were few significant differences among habitats.

During the year 2013, the pre-monsoon species richness was highest in hedgerows compared to 2014. Since, the valley of Kashmir was hit by floods and various foraging habits were affected so bee assemblage and abundance were low during 2014. During the early moon soon the fields tended to have the most species per transect compared to other habitats. Generally, the woodlots had the lowest mean species richness in most sampling periods. Habitats varied in the pollen specialist species, and hedgerows attracted a relatively large number of specialists- more than both fields and native woodland. Conducting the equal sampling frequency efforts in all habitats, the highest number of specialist species were in order; hedgerows>fields>native woodlands>woodlots (Fig.2).

DISCUSSION

The various landscape categories like, fields, grasslands, meadows, pastures, roadsides, hedgerows, edges, and wild barren lands can be managed to provide important habitats for wild bees. However, in current study, the hedgerows acted as net exporters of bees into adjacent fields. Sydenham *et al.* (2016) and Brosi and Ehrlich (2016) observed that hedgerows acted as an export for bees in landscapes. The study showed that hedgerow creation may be essential for enhancing native pollinator abundance and diversity and for pollination services to adjacent crops**.** Semi natural grasslands provide important habitats for bees, but are often lost due to changes in land use, particularly reduced livestock grazing (Murray *et al*., 2012; Stoate *et al*., 2009). The anthropogenic landscape elements, such as power line clearings, hedgerows (Morandin and Kremen, 2013), and orchard field edges (Sydenham et al., 2016), may also provide important habitats for bees in the agricultural landscape matrix. In Budgam and Pulwama, the mixed farm and natural landscapes contribute to available foraging habitat for local native bee populations.

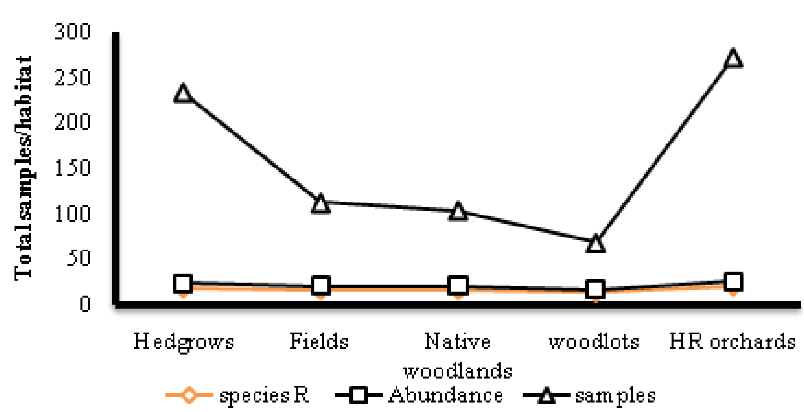

Fig.2 Population abundance and total bee samples collected from various habitats during 2013-2014 in Kashmir valley

The survey of two years showed that diverse assemblages of bees are finding nectar and pollen resources in hedgerows and a total of 20 bee species from 9 genera and 5 families were observed in hedgerow visiting various flowers for nectar and pollen. Due to the extreme temporal variability in native bee faunas, it is important to look at habitat use by season, not just in assemblage. During 2013 and 2014 the hedgerows were arguably the best foraging habitat for bees, and attracted more diverse bee assemblages than fields, woodlots or native woodland. The flora of dominant tree, native woodland and shrubs attracting majority of native bees foraging in hedgerows in pre-monsoon. The trend was apparent in both years of the study, but only statistically significant in 1 year; the non-significant difference in 2014, which is mainly due to floods in valley, caused the drop in floral availability in among the transects in both hedgerows and fields. Hedgerows bloom and so provide food for insects. Current study showed that native wild plants, shrubs and trees within hedgerows provide important foraging resources for wild bees and managed honey bees. During the pre-monsoon periods (2013 and 2014), the agricultural fields and hedgerows were better foraging habitats, with higher bee abundance and species richness, than either woodlots or native woodland. During the year, 2013, the fields attracted bees in higher or comparable numbers to hedgerows during the pre-monsoon and also in later sampling periods. However, in European, both hedges and fields were equally attractive to wild bees for at least some seasons. The bumblebees in agricultural habitats find much higher numbers foraging in the herbaceous understories of hedgerows than in adjacent fields (Croxton *et al.*, 2002). Under Kashmir conditions, the pasture and hay crop fields generally supported perennial and annual flowering weeds. The available forage is extended by irrigation of the fields, and the increase the foraging periods for the bees beyond that of natural habitats, since, the available flower resources are tied to seasonal rains during spring and summer seasons. This expanded blooming period could boost the total bee species richness observed in fields. Research showed a greater total species richness in agricultural habitats than in native forest (Meiners, 2016). But, surprisingly, the patterns of bee species richness were found opposite to one we observed. Since the species and abundance of bees were less in wood woodlands so it was mainly due to absence of the early and late flowering periods, with no flowers.

We observed that the healthy and managed hedgerows are home to a rich plant community, and provide crucial bee habitat same were earlier confirmed by Monkman (2013). The hedgerow shrubs such as cherries, plants of family rosacea and wild apple trees are a reliable and plentiful source of nectar and pollen in May and June, a time of year when many other plants have not yet flowered. The hedgerows appeared to offer additional resources for native bee species that were also using other agricultural and natural habitats in the landscape. The hedgerows comparatively provide the forage for much time of the year. The hedgerows shared 87-90% of their bee species with at least one other habitat. During the sampling periods, the dispersed pattern of bee species distribution among hedgerows and other available habitats was more evident in each habitat. Similarly, the USA New Jersey similar pattern of wide overlap in the bee faunas of agriculture and native forest were observed (Meiners, 2016). During the current investigations, a relatively small proportion of species occurring in agricultural or forest habitat were unique. Same were earlier reported by Winfree *et al.* (2009) from USA. Due to the close overlap of the many proximal habitats, the broad overlaps in bee faunas were observed. The typical bee foraging distances are estimated at 150 m to more than 1.55 km, and multiple agricultural and natural habitats are often available within a radius of 500 m to 1 km, well within the flight ranges of many native bee species like Bumble bees and Andrena. However, the flight ranges of the most Halictidae were only 150-210 m from nesting site. The foraging behaviour of wild bee species may also explain their wide distributional pattern among available habitats on and off farms. Since, the multiple habitats were utilised or visited by solitary bees to gather the resources they require, build their nests, foraging for resources and to track patchy and ephemeral floral resources.

During the current study, in intensive cultivated farm fields there was low field diversity (lack of hedgerows), and bee abundance and diversity were lowest; which was also confirmed by Venturini *et al*. (2017) that insect pollination reservoirs may offer growers a practical tool for increasing wild bee populations and decreasing reliance on managed bees. The factors such as effectiveness, reservoir-to-crop ratios, and costs and benefits are important in particular habitat. Further the relevant aspect includes plant-pollinator relationships, landscape context, wild bees as pollinators, flower selection, and limitations. Recent research clearly suggests that pollination reservoirs can increase wild bee populations, crop yield, and profit. However, due to dominance and abundance of the resources in hedgerows, it shared the majority of their bee fauna with other habitats, and attracted some native bee species that were otherwise uncommon in the other habitats. In the hedgerows, the floral diversity was higher so were the unique floral cues which attracted the major and uncommon bee species. Among the species sheared, the most abundant examples were the species of genus Lasioglossum of family Halictidae (Dar, 2016). Overall, the higher population of the bees were attracted and stimulated by hedgerows than other habitats. More specifically, the members of family Andrenidae were dominant in the hedgerows and were uncommon in other habitats.

The Lasioglossum species preferentially visited the flowers of a native shrub, agricultural crops and fruit plants like stone fruits (Dar *et al*., 2017a; Dar *et al*., 2017b). Hedgerows may indirectly contribute to local bee diversity by providing forage to an assemblage of native bee species that vary widely in foraging ecology and seasonal activity period. Further the bee fauna in hedgerows included some species that are generalists in both habitat use and pollen collection.

Trait-Specific Responses

Since, the land-use intensification and loss of semi-natural habitats have induced a severe decline of bee diversity in agricultural landscapes (Dar *et al*., 2017c). The hedgerows are among the most important bee habitats in temperate areas, but they are threatened by decreasing habitat area and quality, and by homogenization of the surrounding landscape affecting both landscape composition and configuration. In present study we tested the importance of habitat area and quality as well as landscape composition and configuration on wild bees in Kashmir valley. We hypothesised that bees with different traits might differ in their response to the tested factors of landscapes. Species richness and abundance of wild bees were surveyed on with independent gradients in local and landscape factors. Total wild bee richness was positively affected by complex landscape configuration, large habitat area and high habitat qualities (i.e. steep slopes) which also provide them with assured nesting sites e.g. *A. Cineraria* (Dar *et al*., 2017d). Sphecodes bee richness was positively affected by complex landscape configuration and large habitat area; whereas, habitat specialists, e.g. Bumble bee assumed in current studies, were only affected by the local factors, habitat area and habitat quality. Small social generalists (*Andrena* spp.) were influenced by habitat area (Dar, 2016). Our results emphasize a strong dependence of habitat specialists on local habitat characteristics. We conclude that a combination of large high-quality patches and heterogeneous landscapes maintains high bee species richness and communities with diverse trait composition. Such diverse communities might stabilize pollination services provided to fruit crops and wild plants on local and landscape scales, since pollinators exhibit the trait specific response to the habitat disturbances in the landscapes (Bommarco *et al*., 2010; Hopfenmuller *et al*., 2014; Goulson *et al*., 2008; Ockinger *et al*., 2012).

Hedgerows were observed to have value as habitat for bees. It can also be a refuge for pollinators. The management of habitats for pollinators have a significant impact on bee conservation. The hedgerows include a diversity of native wild-flowers with overlapping bloom times, to provide forage for pollinators throughout the growing season. Landscape categories can be of great benefit to bees. Best management practices include consideration of timing and frequency of mowing, spot spraying rather than broadcast use of herbicides, and surveys to identify existing habitat that provides native plant resources for wild bees. The habitat managers must develop a management strategy that addresses safety concerns while also benefiting the wildlife such as bees.

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REFERENCES

Biesmeijer J.C. (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science 13: 351-354

Bommarco R., Biesmeijer J.C., Meyer B., Potts S.G and Poyry J. (2010) Dispersal capacity and diet breadth modify the response of wild bees to habitat loss. Proceedings of the Royal Society B: Biological Sciences, 277 (1690): 2075-2082.

Brosi B.J., Daily G.C., Ehrlich P.R. (2016). Bee community shifts with landscape context in a tropical countryside. Ecological Applications 17(2):418-30

Camerona S.A, Haw C.L., Jeffrey D. L., Michelle A. D and Robbin T. (2016). Test of the invasive pathogen hypothesis of bumble bee decline in North America. Proceedings of the national academy of sciences 113(16): 4386-4391.

Colla S.R and Ratti C.M. (2010) Evidence for the decline of the western bumble bee (*Bombus occidentalis* Greene) in British Columbia. Pan-Pacific Entomologist 86(2):32-3.

Corbet S.A. (1995) Insects, plants and succession: advantages of long-term set-aside. Agriculture Ecosystems and Environment 53: 201-217.

Cornelissen A.C.M. (2012) Bijen in en rond de stad; een literatuur studie. Plant Research International, Wageningen UR Postbus 69, 6700 AB, Wageningen. Entomologische Berichten 72 (1-2): 120-124.

Croxton P.J., Carvell C., Mountford J.O and Sparks T.H. (2002) A comparison of green lanes and field margins as bumble bee habitat in an arable landscape. Biological Conservation 107: 365-374.

Dar S.A and Mir S.H. (2017a) Diversity and abundance of insect pollinators of Sweet cherry *Prunus avium* in different landscapes of Kashmir valley. Indian Journal of Entomology (accepted).

Dar S.A. (2016) Species diversity, relative abundance and nesting behaviour of insect pollinators of peach, plum and cherry and Kashmir Valley. Doctorial thesis submitted to Department of Entomology, SKUAST-K, and Kashmir, India. pp: 4-148

Dar S.A., Maihnaz N; Mir G.M and Parry M.A. (2017b) Plum *P.domestica* pollinator /visitor abundance and diversity in hilly orchards of Temperate Kashmir, India. Conference venue change for TASARD, 2017, Feb 20 22, 2017 to NAAScomplex, New Delhi.

Dar S.A., Maihnaz N; Mir G.M; Parry M.A., Yaqob M and Khrusheed R. (2017c). Threats of anthropogenic pressure on insect pollinators. Conference venue change for TASARD, 2017, Feb 20 22, 2017 to NAAS complex, New Delhi.

Dar S.A., Mir S.H and Mir G.M (2017d). Nesting behaviour of *Andrena cineraria* (Hymenoptera: Andrenidae) in landscapes of Kashmir Valley. (Abstract No.3198).National Conference on 'Climate Change and Agricultural Production-Adapting Crops to Increased Climate Variability and Uncertainty' scheduled to be held on 6-8th April, 2017 at Bihar Agricultural University, Sabour, Bhagalpur, Bihar (Accepted).

Gallai N., Salles J., Settele J and Vaissière B.E. (2009). *Economic valuation of the vulnerability of world agriculture confronted to pollinator decline*. Ecological Economics 68: 810-821

Garibaldi L.A. (2013) *Wild pollinators enhance fruit set of crops regardless of honey bee abundance*. Science 339:1608-1611.

Gathmann A and Tscharntke T. (2002). Foraging ranges of solitary bees. Journal of Animal Ecology 71:757-764.

Goulson D., Lye, G and Darvill B (2008). Decline and Conservation of Bumble Bees. Annual Review of Entomology53(1):191-208.

Goulson D., Lye, G.C and Darvill B. (2008) *Decline and conservation of bumble bees*. Annual Review of Entomology 53:191-208.

Hopfenmuller S., Steffan-Dewenter I and Holzschuh A. (2014) Trait-Specific Responses of Wild Bee Communities to Landscape Composition, Configuration and Local Factors. PLoS ONE 9(8): e104439, doi: 10.1371

Jauker F., Bondarenko B., Becker H.C and Steffan-Dewenter I. (2012). Pollination efûciency of wild bees and hover ûies provided to oilseed rape. Agriculture Forestry and Entomology 14:81-87.

Klein A.M, Vaissiere B.E., Cane J.H., Steffan-Dewenter

I., Cunningham S.A., Kremen C and Tscharntke T. (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of Royal Society of London B 274:303-313.

Kremen C., Williams N.M., Aizen M.A and Ricketts T.H. (2007). Pollination and other ecosystem services provided by mobile organisms: a conceptual framework for the effects of land-use change, Ecological Letters 10: 299-314

Krewenka K, Holzschuh A., Tscharntke T and Dormann C. F. (2011) Landscape elements as potential barriers and corridors for bees, wasps and parasitoids. Biological Conservation 144:1816-1825.

Kueûer D., Hudgens B., Haddad N.M., Thurgate N. (2010). The conûicting role of matrix habitats as conduits and barriers for dispersal. Ecology 91: 944-950.

Meiners J. M. (2016) Biodiversity, Community Dynamics, and Novel Foraging Behaviors of a Rich Native Bee Fauna Across Habitats at Pinnacles National Park, California. All Graduate Theses and Dissertations. pp: 48-77.

Monkman D. (2013) Hedgerows are nature's ally in farm fields. pp: 1-4

Morandin L.A and Kremen C. (2013). Hedgerow restoration promotes pollinator populations and exports native bees to adjacent fields. Ecological Applications 23(4):829-39.

Murray T.E., Fitzpatrick U., Byrne A and Paxton R.J. (2012) Local scale factors structure wild bee communities in protected areas. Journal of Applied Ecology 49:998-1008.

Ockinger E., Lindborg R., Sjodin N.E and Bommarco R. (2012) Landscape matrix modifies richness of plants and insects in grassland fragments. Ecography 35 (3):259-267.

Ollerton J., Erenler H., Edwards M and Crockett R. (2014) *Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes*. Nature 346: 1360-1362

Potts S.G. (2010) *Global pollinator declines: trends, impacts and drivers*. Trends in Ecological Evolution 25:345-353

Pyke G.H., Inouye D.W and Thomson J.D (2011) Activity and abundance of bumble bees near Crested Butte, Colorado: diel, seasonal, and elevation effects. Ecological Entomology 36: 511-521.

Samnegard U. (2016) The impact of forest on pest damage, pollinators, and pollination services in Ethiopian agricultural landscape. Thesis submitted to department of ecology, environment and plant science, Stockholm University, Ethiopia. ISBN: 978-91-7649-354-0.

Schauff M.E. (1986) Collecting and preserving insects and mites: Tools and techniques. Systematic Entomology Laboratory, USDA National Museum of Natural History, Washington, D.C. 20560: 168.

Stoate C., Báldi A., Beja P., Boatman N., Herzon I. and Van Doorn A. (2009) Ecological impacts of early 21st century agricultural change in Europe-A review. Journal of Environment Management 91:22-46.

Sydenham M.A., Moe S.R., Stanescu-Yadav D.N., Totland O. and Eldegard K. (2016) The effects of habitat management on the species, phylogenetic and functional diversity of bees are modified by the environmental context. Ecological Evolution 6(4):961-73.

Sydenham M.A.K., Eldegard K and Totland Q. (2014) Spatio-temporal variation in species assemblages in field edges seasonally distinct responses of solitary bees to local habitat characteristics and landscape conditions. Biodiversity Conservation 23: 2393-2414.

Venturini E.M., Drummond F.A., Hoshide A.K., Dibble, A.C. and Stack L.B. (2017). Pollination reservoirs for wild bee habitat enhancement in cropping systems: A review. Journal of Agroecology and sustainable Food Syaytems, Tylor and Francis 41 (2): 101-142.

Westrich P. (1996) Habitat requirements of Central European bees and the problems of partial habitats. The Conservation of Bees (eds A. Matheson, S.L. Buchmann, C. O'Toole, P. Westrich & I. H. Williams), Academic Press, London. pp: 1-16.

Winfree R., Aguilar R., Vazquez D.P and Aizen M.A. (2009) *A meta-analysis of bees' responses to anthropogenic disturbance*. Ecology 90:2068–2076.

Woodcock B., Isaac N.B., Bullock J.M., Roy D.B., Garthwaite D.G., Crowe A and Pywell R.F. (2016) Impacts of neonicotinoid use on long-term population changes in wild bees in England. Nature- Communications 7: Article number :12459, doi:10.1038/ncomms12459.

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