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Potential habitat value for wild bees in Kashmir valley

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ABSTRACT

The declines in honeybee populations in Indian have highlighted the importance of native bee conservation, and the need for research on the ecological requirements of native bees in various landscapes. In this study, we investigated the value of hedgerows as foraging habitat for native bees in mosaics of small scale agriculture and natural vegetation in the landscapes of Kashmir division. In the spring of 2013-14 we surveyed bees and flowers in four habitats: hedgerows, agricultural fields, grasslands, and native woodland. We investigated that how hedgerows varied compare to other available habitats in bee abundance and species richness; species composition in hedgerows compare to species composition in agricultural fields and woodland. We found that hedgerows were attractive foraging habitat for native bees, especially in early spring and summer. Cumulative species richness was highest in hedgerows, although cumulative species richness did not significantly differ among fields, hedgerows, and woodland. While 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 that were otherwise uncommon in the landscape, including some species that are potentially valuable pollinators of stone fruit crops such as peach, plum and cherry.

Keywords : Bees, ecology, habitat, hedgerows, wild

Recently UN science report warns of bees which are in the period of decline and there are going to be increasing consequences of their loss (Potts, 2016). Habitat loss and fragmentation in agricultural landscapes lead to severe declines of abundance and richness of many insect species in the isolated semi-natural habitats (Krewenka *et al*., 2011). The problem of habitat loss has been characterised as a “pollinator health crisis” where health refers to pollinator species diversity and abundance (Goulson *et al*., 2015; Maddox, 2016) and the pollination from these bees is most valuable ecological service provided by wildlife (Hall et al., 2016). Agricultural landscapes are increasingly important settings for biological conservation, especially for the conservation of important pollinators such as native bees of helictidae family (Jauker *et al.,* 2012; Klein *et al*., 2007). Bees (Hymenoptera: Apoidea) are the dominant providers of pollination services in both natural and agricultural ecosystems (Colla and Ratti, 2010). Field research with a range of crops suggests that maintaining abundant and diverse native bee communities can provide insurance against the loss of pollination services in the face of reduced honeybee populations (Winfree *et al*., 2007). The potential of native bees to act as an alternative pollinators for crops is one reason to focus on their conservation near the farmland and other landscaps. Effective conservation of these native bee populations depends on understanding how the ecological requirements of wild bees can be met in agricultural landscapes (Jauker *et al*., 2012). Agricultural land can be insufficient to provide all of the resources necessary to sustain resident bee populations, e.g., pollen, nectar, floral oils, nest sites, nesting materials, and stable sites for overwintering (Kremen *et al.*, 2007). Intensively managed agricultural landscapes tend to lack species-rich floras and continuity of floral resources (Corbet, 1995). The urban landscape offers a potential habitat or refuge to many different species (Samnegard, 2016). Wild bees are amongst those seeking a safe haven in our back gardens, roadside verges, industrial sites and hedgerows. It was found that between 13-40 per cent of wild bee species were found living in urban settings (Cornelissen 2012). Barrier effects of hedgerows are also known to restrict movement of some invertebrate species (Kuefler et al., 2010).One means of preserving resources for wild bees in agricultural landscapes is maintaining patches of semi-natural vegetation within the agricultural matrix (Westrich, 1996) for pollination as bees have complex habitat requirements. Not only do some bees have very specific demands for certain floral resources, they also require specific structures to build their nests. Hedgerows are important as for as construction of nesting structures are concerned. Pollen sources are often distributed over different habitats (Westrich 1996). Therefore, most bee species rely on several partial habitats to cover all needs, and these habitats have to lie within the flight range of the bee species, which is a usually limited (Gathmann and Tscharntke 2002) and demand the hedgerows close to the agricultural areas. Here, we investigate the use of

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hedgerows by wild bee communities in mixed landscapes of native vegetation and small-scale agriculture in Kashmir. The study areas are two corridors in south-eastern Kashmir, noted for their high diversity of bees and flowering plants. Hedgerows are common features on the small farms of both study areas.

MATERIALS AND METHODS

Study area

Kashmir division of State Jammu and Kashmir is located in North-eastern of India. Geographically it 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 5,550m on North-east dip down to about 2,770m 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 research was conducted in the Budgam and Pulwama situated at the heights of 5400 and 1570 meters from mean sea level (MSL). Higher altitudes of Kashmir (India) region are the centres of diversity, especially Budgam and Pulwama (Fig. 1), support diverse invertebrate faunas and species-rich floras. The two drainages have almost very similar plant communities. The dry uplands support a divers types of desert vegetation community.

This region of N-S receives 25–35 per cent of its precipitation during the winter and early spring months, and 50-60 per cent in the monsoon period. The agricultural landscapes of both the Upper experimental plots of both Budgam and Pulwama districts are characterized by relatively small fields, less than 3 ha, and a mosaic pattern of habitat types. Fields are frequently separated by hedgerows, having abundance of native shrubs, herbs and mulberry plantations and other social forestry plants.

The matrix of field and hedgerow is interspersed with areas where various forest trees have been allowed to regenerate. In the areas of Kashmir Valley, agricultural land occurs in two distinct clusters. We surveyed hedgerows and other agricultural habitats on 10 locations, five along the south and five on the North. The agricultural clusters of the study areas are largely made up of contiguous farms. In order to minimize any effect of farm-to-farm variation, we standardized farms for available habitat types and management practices – including crops grown and pesticide/herbicide use. Fields were planted with crops like maize, oats, Brassica; however, large areas in both experimental sites are under paddy and considerable area is maintained as irrigated pastures of mixed grasses and forbs for cattle. On each farm, various types of social forest trees were used to graze cattle for at least part of the year. There was no aerial application of pesticide or herbicide on any farm; spot-application of herbicide was used to suppress woody seedlings in fields. In district Budgam walnut and almond orchards and in Pulwama the apple orchards were also surveyed for the bee species richness and abundance.

We surveyed bees and flowers in four habitat types and established 15 transects in each category of landscape. Each transect consisted of a 2 m by 40 m rectangular plot, the maximum length of transects being constrained by the length of hedgerows on some farms. We placed transects randomly along hedgerows and placed a second transect in the approximate centre of

the adjacent field, running parallel to the longest dimension of the field. We placed a third transect in a randomly chosen site in the nearest woodlot. The minimum distance between hedgerow and woodlot transects was 100 m. The minimum distance between hedgerow and field transects was somewhat smaller (75 m). We identified potential native woodland sites based on the presence of the dominant native perennial grass and/or the absence of economic shrubs. For practicality of sampling, once one transect was placed randomly within suitable woodland habitat, a second transect was placed 200 m away. This was the minimum distance among native woodland transects. Woodland transects were located between 400 and 600 m from the nearest agricultural field.

Bee sample collection

We used timed periods of observation and hand-netting to sample bee assemblages. Surveys were completed between 9:30 am and 4:00 pm, and were only conducted in clear weather. Afternoon surveys were also done but usually not feasible because of reliable afternoon cloud cover and rain in Kashmir during the monsoon season of 2013-14. Depending on the survey year, two or three observers were used. Observers alternated the transects they surveyed, and the order in which transects at a given site were surveyed, in subsequent sampling periods. In each survey, the observer spent 30 min in the 20-35 m transect area, catching insect specimens and recording the flower species, if any, visited by each bee. 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 30 min total observation time was divided into five 6-min periods (one for each 7 m subplot) in order to spread observer attention across the transect area. Data from the four subplots were combined to make one sample per transect. We attempted to catch every bee detected, even if not caught photographs were taken while foraging. Voucher specimens were deposited in pollinator lab of entomology, SKUAST-K, Srinager. The three sampling periods corresponded to the pre-monsoon, early monsoon, and late monsoon seasons. Flowering plant phonologies were surveyed from the lowest elevation sites in each round. The highest elevations were visited last within each round.

Data analysis

Bee species richness

In order to compare species richness among habitats with almost equal sampling intensity we estimated total species richness for each habitat using Manitab and O. P. Sherom softwares were also used to determine the significance among the species pertaining to the respective specific orders. The diversity and abundance of the bees captured from each habitat and comparisons between particular pairs of habitats were made using the Student's t-test. We compared mean species richness and abundance among habitats using one-way ANOVA. Separate ANOVA's were performed for each sampling period, so that statistical comparisons of species richness and abundance were only made among observations made in the same sampling periods (between and within the group, Fig.1 below).

We chose the Bray–Curtis index to quantify dissimilarity among bee assemblages.

RESULTS AND DISCUSSION

Total species richness

Altogether, we collected 731 individuals of 20 bee species in 9 genera and five families. Sampling intensity varied among habitats, with a range of n = 65 to 135 samples (one sample equals one survey of one transect during one sampling period in 1 year). Therefore, to compare species richness among habitats, we randomly subsampled 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. Overall, 90 per cent of the species recorded were common across different landscapes. In addition all of the species were recorded near by the stone fruit orchards. When cumulative species richness was plotted against number of surveys in each habitat, hedge rows near orchards had the highest estimated species richness for a given level of sampling effort. Estimated species richness in fields, hedgerows, and native woodland differ significantly. Estimated species richness in woodlots was significantly lower than in the other three habitats. However, the because flowering commences later at higher elevation, abundances of workers and males are also shifted later; therefore elevational comparisons play an important role in species richness (Pyke *et al.*, 2011). While observed species richness was highest in hedge rows near orchards, further the jackknife estimates of actual species richness were highest for hedgerows near orchards (J 1st order: 19 species, 2nd order: 20 species).

During the present investigations the *Lassioglossum* genus was the most abundant flower visitor, representing 45 to 48 per cent of all individuals collected. Foragers of this species recorded at the study sites belong to wild colonies. The *Lasioglossum marginatum* was the most abundant species and foraging apparently takes place within a radius of 100 m from the nesting site. On stone fruit flowers in orchards of experimental locations, the per cent relative abundance of insect pollinators species were significantly highest of 5.0±0.67 in 2013 (P $\leq$ t=4.87, t. stat. =2.79, p.value <0.01) and comparatively lowest 3.0±0.35 pollinators/m^2/10 min.

in 2014 ($P \leq$ t= 9.75, t. stat= 2.04, p.value < 0.01) with pooled relative abundance of 4.0±0.51 pollinators/m^2/ 10 min. (F. ratio 0.94; CV, 17.84; SE, 0.87; $CD_{(0.05)}$= 0.49; Pearson's correlation= 0.90, T-test=4.73, p.value < 0.001). The average relative abundance percentage of helictidae bees visiting the peach flowers was statistically significant and were in the order of abundance, *Lassioglossum margintaum*, *L nursei, L. himalayans*, *L. regolatum, L. sublaterale, L leucozoni* and *L. polyctor* with 4.0±0.51, 3.54±0.34, 3.27±0.41, 3.0±0.21, 1.5±0.18, 1.5±0.31 and 1.89±0.10 pollinators/ m^2/10 min, respectively. However, the relative abundance of *Halictus constructus* from genus Helictus of family Helictidae was comparatively minimum only of 2.28±0.11 pollinators/ m^2/10 min. The species *viz*, *Andrena patella*, *Andrena flordula*, *Andrena cineraria* and *Andrena bicolor* of family andrena have relative abundance of 1.78±0.14, 1.56±0.16, 0.33±0.09 and 0.89±0.09 pollinators/m^2/10 min, respectively. In family Apidae the species *Xylocopa valga* and *Xylocopa violaceae* have the abundance of 1.17±0.19 and 1.04±0.11 pollinators/sq. meter/10 min, respectively. Among the family megachilidae only two species *Megachile rotundata* and *Anthedium consolatum* were reported having the significant relative abundance of 0.95±0.06 and 0.94±0.39 pollinators/m^2/10 min, respectively.

Species composition and relative abundance

There was broad overlap in species composition in the cumulative bee faunas of fields, hedgerows (orchards), woodlots, and native woodland. The majority of the hedgerow bee fauna was shared either with other on-farm habitats or with native woodland. Excluding singletons and using data only from 2013 to 2014 field seasons, 61 per cent of species in hedgerows also occurred in fields, 48 per cent also occurred in woodlots, and 71 per cent were found in native woodland. Only 7.33 per cent were found exclusively in hedgerows. Likewise, fields, woodlots, and woodland shared the majority of the species present there with other habitats – and had small proportions of 'unique' species. We also compared bee assemblages at the transect level – summing the abundances of bee species occurring on a given transect in the pre, early, and late monsoon over 2 years. Not surprisingly, the strongest difference was between fields and each of the hedgerows (orchards), woodlots and native woodland. Hedgerows were significantly more similar to woodlots and native woodland than to assemblages in agricultural fields. In general, there was high variability in bee assemblage composition among transects within habitats and wide overlap in composition among habitats. This variability was reflected in the low effect size scores for differences among habitats.

Spatial autocorrelation in bee species composition

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 of bees by sampling period

Bee abundance was highly variable among transects within habitats, and patterns of abundance were variable across years. There were some consistent patterns, however. In each year, 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.

Pre-monsoon species richness was highest in hedgerows in 2013. This same trend was apparent, but not statistically significant, in 2014. During the year 2014, the valley Kashmir was hit by floods and various foraging habits were effected so bee assemblage and abundance were low. Fields tended to have the most species per transect during the early monsoon, a time when bee abundance and species richness was depressed in most habitats. Woodlots had the lowest mean species richness in most sampling periods. Pollen specialists foraged in each of the habitat types we surveyed, but habitats varied in specialist species richness. Cumulatively, hedgerows attracted a relatively large number of specialists – more than both fields and native woodland. With equivalent sampling effort, hedge rows had the highest number of specialist species as in order; hedgerows >fields>native woodlands >woodlots.

Anthropogenic landscape elements, such as roadsides, hedgerows, edges, and power line clearings, can be managed to provide important habitats for wild bees. Hedgerows acted as net exporters of bees into adjacent fields (Sydenham *et al*., 2016, Coulter, 2016) and also had enough be populations. Within-farm habitat restoration such as hedgerow creation may be essential for enhancing native pollinator abundance and diversity, and for pollination services to adjacent crops (Morandin and Kremen, 2012). Semi natural grasslands, such as

Table1: Relative abundance of insect pollinators of stone fruit crops in Kashmir valley.

Sl. No	Pollinator Species	2013	2014	pooled
1	*Lassioglossum marganatum*	5	3	4
2	*L. regolatum*	4	2	3
3	*L. himalayense*	4.33	2.22	3.27
4	*L. sublaterale*	1.67	1.33	1.5
5	*L. leucozonium*	1.67	1.33	1.5
6	*L. nursei*	4.78	2.33	3.54
7	*L. polyctor*	2	1.78	1.89
8	*Halictus constructus*	1.33	1	1.16
9	*Sphecodes tantalus*	0.67	0.33	0.5
10	*Andrena patella*	2	1.56	1.78
11	*A. flordula*	2.34	0.78	1.56
12	*A. cineraria*	0.44	0.22	0.33
13	A. bicolor	1.35	0.44	0.89
14	A. barbilabris	1	0.22	0.61
15	*Amegilla cingulate*	0.45	0.33	0.39
16	*Megachile rotundata*	1.11	0.78	0.95
17	*Anthedium consolatum*	0.89	1	0.94
18	*Xylocopa valga*	1.33	1	1.17
19	*X. violacea*	1.07	1	1.04
20	*Bombus sp.*	0.11	0	0.05

One way ANOVA of species abundance

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.372424	1	4.3724	3.9148	0.0055	4.1131
Within Groups	40.20803	36	1.1168	-	-	-
Total	44.58046	37		-	-	-

F-Test Two-Sample for Variances (across the two year)

Mean	1.712632	1.034211
Variance	1.739343	0.494437
Observations	19	19
Df	18	18
F	3.517826	-
P(F<=f) one-tail	0.005342	-
F Critical one-tail	2.217197	-

calcareous grasslands, provide important habitats for bees (Murray *et al*. 2012), but are often lost due to changes in land use, particularly reduced livestock grazing (Stoate *et al*. 2009). However, other anthropogenic landscape elements, such as power line clearings (Russell *et al*. 2005), hedgerows (Morandin and Kremen 2013), and orchard field edges (Sydenham *et al*. 2014), may also provide important habitats for bees in the agricultural landscape matrix. In the mixed farm and natural landscapes of our study areas along the Budgam and Pulwama, it is clear that hedgerows contribute to available foraging habitat for local native bee populations. Net surveys showed that diverse assemblages of bees are finding nectar and pollen resources in hedgerows; a total of 20 bee species from 9 genera and five families were observed visiting flowers in hedgerow transects. Because of the extreme temporal variability in native bee faunas, it is important to look at habitat use by season, not just in sum. In our study areas, hedgerows were arguably the best foraging habitat for bees. Hedgerows tended to attract more diverse bee assemblages than fields, woodlots or native woodland during the 2013-14.The flower resources of the dominant tree and native woodland-associated shrubs drove this pattern, attracting the 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 may have been due to underlying low variability in species richness among transects in both hedgerows and fields. Hedgerows bloom and so provide food for insects (Minarro and Prida 2013). Research has shown that native wild plants, shrubs and trees within hedgerows provide important foraging resources for wild bees and managed honey bees (Minarro and Prida 2013, Morandin and Kremen 2013).Both agricultural fields and hedgerows were better foraging habitat, in terms of bee abundance and species richness, than either woodlots or native woodland during the pre-monsoon. Fields attracted bees in higher or comparable numbers to hedgerows during the pre-monsoon in 2013 year, and in later sampling periods. These findings differ somewhat from the European literature, in that hedges and fields were equally attractive to wild bees for at least some seasons. Croxton *et al*. (2002) found that bumblebees in agricultural habitats find much higher numbers foraging in the herbaceous understories of hedgerows than in adjacent fields. While as, pasture and hay crop fields in our study sites, commonly supported perennial and annual flowering weeds in addition to grasses and hay crops. Clearly, irrigation extends the period of available forage in fields beyond that of natural habitats, where available flower resources are tied to seasonal rains. This expanded blooming period could boost the total bee species richness observed in fields. In a study of bee communities in a landscape of forested heath, agriculture, and suburban development in New Jersey, Winfree et al. (2007) also found greater total species richness in agricultural habitats than in native forest. However, the pattern of bee species richness were found opposite to the one we observed. In most of the early and late flowering periods, the proportion of woodland transects with no flowers was relatively high.

Healthy hedgerows are home to a rich plant community, and provide crucial bee habitat (Monkman, 2013). For example, hedgerow shrubs such as cherries, plants of family rosacea, dogwoods, hawthorns 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. For the most part, hedgerows appeared to offer additional resources for native bee species that were also using other agricultural and natural habitats in the landscape. Excluding singletons, hedgerows shared 87 per cent of their bee species with at least one other habitat. The dispersed pattern of bee species distribution among hedgerows and other available habitats was evident in most sampling periods and in the cumulative bee faunas in each habitat. Winfree et al. (2007) found a similar pattern of wide overlap in the bee faunas of agriculture and native forest in their New Jersey study area. As in our data, a relatively small proportion of species occurring in agricultural or forest habitat was unique to one habitat type (Winfree et al., 2007). One explanation for the wide overlap in bee faunas among habitats in our study areas is the close proximity of multiple habitat types in the landscapes we studied. Depending on the bee species studied and methodology used, typical bee foraging distances are estimated at 150 m to more than 1.5 km. In our study areas, 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. The generalized foraging behaviour of many bee species may also explain their wide distribution among available habitats on and off farms. Solitary bees commonly use multiple habitats to gather the resources they require, commuting between nest sites and foraging habitats, and tracking patchy, ephemeral floral resources (Westrich, 1996; Cane, 2001).

In intensive industrially farmed fields there was low field diversity (lack of hedgerows), and bee abundance and diversity were lowest (Allsopp *et al*., 2014). While hedgerows shared the majority of their bee fauna with other habitats, resources in hedgerows did attract some native bee species that were otherwise uncommon in the landscape. Some of these bee species were apparently responding to unique floral resources in hedgerows. The most abundant examples were three species of genus lassioglossum (*L. marganatum, L. nursi, L. himalayans*). Hedgerows attracted these native bees in significantly greater numbers and with significantly greater frequency than either agricultural fields or woodland. Andrena species was only rarely found in habitat other than hedgerows, and *A. cinera* was only caught in hedgerows. Helictid species preferentially visited the flowers of a native shrub, fruit plants and agricultural crops. 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 (*e.g.*, Lasioglossum, Bombus, and Xylocopa spp.).

In intensive farmed fields there was low field diversity (lack of hedgerows), and bee abundance and diversity were lowest. While hedgerows shared the majority of their bee fauna with other habitats, resources in hedgerows did attract some native bee species that were otherwise uncommon in the landscape. Some of these bee species were apparently responding to unique floral resources in hedgerows. The most abundant examples were three species of genus lassioglossum (*L. marganatum, L. nursi, L. himalayans*) were found near to the hedgerows. Hedgerows attracted these native bees in significantly greater numbers and with significantly greater frequency than either agricultural fields or woodland. Andrena species was only rarely found in habitat other than hedgerows, and *A. cinera* was only caught in hedgerows. The declines in honeybee populations in Indian have highlighted the importance of native bee conservation, and the need for research on the ecological requirements of native bees in various landscapes. In this study, we investigated the value of hedgerows as foraging habitat for native bees in mosaics of small scale agriculture and natural vegetation in the landscapes. Hedgerows varied compare to other available habitats in bee abundance and species richness;

compare to species composition in agricultural fields and woodland. We found that hedgerows were attractive foraging habitat for native bees, especially in early spring and summer. Cumulative species richness was highest in hedgerows, although cumulative species richness did not significantly differ among fields, hedgerows, and woodland.

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