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Research Article

SEASONAL TROPHIC NICHE BREADTH AND OVERLAP IN A GUILD OF SIX MOST FREQUENT BEE SPECIES IN BAHAWALPUR, PAKISTAN

Farwa Mustafa[1], Asif Sajjad*[1], Asif-ur-Rehman[2], Muhammad Arshad ullah[3], Hafiza Sehrish Bashir[1], Shameen Ehsaan[1]

[1]*Department of Entomology, The Islamia University of Bahawalpur, Pakistan*
[2]*Mango Research Institute Multan, Pakistan*
[3]*Natural Resources Division, Pakistan Agriculture Research Council Islamabad, Pakistan*
**Corresponding author: asifbinsajjad@gmail.com*

ABSTRACT

Agonistic relationships in plant-pollinator assemblages are poorly understood as compared to mutualistic relationships. We estimated the floral resource competition in terms of seasonal trophic niche breadth and overlap among the guild of six most frequent bee species i.e., *Ceratina smaragdula*, *Lasioglossum* sp., *Ceylalictus* sp., *Halictus* sp., *Apis dorsata* and *Apis florea* in Bahawalpur (Punjab), Pakistan. The species exhibiting the maximum niche breadth had the minimum abundance in spring and summer seasons. The niche breadth of two solitary bees i.e., *Lasioglossum* sp. and *C. smaragdula* was higher than the social *A. florae* but they were much less abundant. *Ceratina smaragdula* showed the maximum pair-wise niche overlap with *A. florea* and *Halictus* sp. in spring and with *Ceylalictus* sp. in summer. *Apis florea* and *A. dorsata* had the maximum pair-wise niche overlap in both the autumn and winter seasons. No significant pair-wise niche overlap and interspecific competition was observed among all the six species in any season. This shows that pollination system in arid Bahawalpur is stable and less prone to competition and species loss.

Keywords: plant-pollinator, solitary bees, social bees, abundance, seasons
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1. INTRODUCTION

The ecological niche refers to a species' place within an ecosystem and the conditions that are necessary for its persistence i.e., how it meets the demand of shelter, food, reproduction and survival, as well as what role it performs in its environment. The function of a species' niche can be described as its way of life, which is based on the resources it has, the entire range of biological and abiotic conditions it inhabits, and the interactions it needs or is capable of creating (Polechová and Storch, 2008).

The concept of niche represents range of environment and resources required by a species to survive. There are two kinds of positions a species can hold in an ecosystem: fundamental niche and realized niche. When an organism has access to all the natural elements of the environment without having to compete for them, it's called a fundamental niche. On the other hand, if there's competition for resources between organisms, it's called realized niche (Wharton and Kriticos, 2008).

Niche overlap refers to the way an organism or population responds to the resources available to it and the competition between them for those resources (Nosil and Sandoval, 2008). Niche overlap also determines intensity of competition (intraspecific and interspecific) and which species and how many species can live together sharing same resources (Abrams *et* *al.*, 1980). The population with a lower degree of niche overlap tends to have a more stable environment compared to the one with a high degree of competition (Badali and Zilman, 2020).

Niche overlap in bees primarily involves the use of floral resources and division of these resources among them (Goulson and Darvill, 2004) e.g., niche overlap will be high for more similar floral resources. The two primary elements that influence niche overlap are the environmental response to the species and the species response to the environment (Barônio and Torezan-Silingardi, 2017). Communities of bees are more affected by environmental factors than competition among communities (Aguiar *et al*., 2017).

Niche breadth is defined as degree of likeliness between what resources an individual uses and what resources are available to that individual (Feinsinger and poole 1981). Species coexistence, biodiversity and pollination are also represented by niche breadth. In order to enhance pollination, it is mandatory to have higher diversity of pollinator species in that area (Blüthgen and Klein, 2011). Andena *et al*., (2012) reported that in temperate regions the network of bees shows a nested structure i.e., specialist species typically make use of the resources available to generalist species when there is strong intra-specific and weak inter-specific competitions in an ecosystem. Many factors effect niche overlap and niche breadth of bees like availability of floral resources, limited flight range and weather factors (Blüthgen and Klein, 2011).

In the present study, we measured trophic niche overlap and breadth among two social bees and four solitary bees at Baghdad-ul-Jadeed campus of The Islamia University of Bahawalpur. We also measured how the species belonging to the guild of bees distribute their foraging activities and to what extant overlapping in trophic niche occur across the seasons.

2. Materials and Methods

2.1. Study Area

Current study was carried out from January to December in 2019 at Baghdad-ul-Jadeed campus (29°22'38"N 71°45'46"E) of The Islamia University of Bahawalpur, Punjab, Pakistan. The campus is characterized by a range of topographies, including naturally occurring desert, planted forests, agricultural area, ornamental grassland, roadways, and buildings. This region experiences an arid climate with lengthy hot summers and brief frigid winters. The mean daily minimum and maximum temperatures are 18.8 °C and 33.5 °C in winter and summer, respectively and the average annual rainfall is 83-218 mm (Ahmad et al., 2019). There are four unique seasons in this locale: spring (March to May), summer (June to September), pre-winter or autumn (October to November) and winter (December to February). In the region about 60% of the plants species bloom during spring season (Sajjad et al., 2010).

2.2. Sampling

Since the types of inflorescences varied from species to species, we identified floral units for each species and recorded observations on these units each time. The floral abundance was determined by tagging 15 plants per species and counting the total floral units at intervals of 2 weeks. Fortnightly surveys were carried out for recording bee visitation. Each survey consisted of random walks during which 15 plants of each species (at flowering stage) were randomly selected. Each plant was observed for one minute in its floral units for any bee visit. For agricultural crops, 15 plants were randomly selected from the margins of the field. In this way each plant Species was observed for a total of 15 minutes in a survey. The surveys were carried out in clear and bright days; rainy or over casted days were circumvented. Plants of a particular species were chosen at least 50

Table 1. Year-long cumulative breadth of trophic niches (*H′*), richness of visited plants (S_{pl}), number of individuals in each bee species N_{ind}), and niche overlap (NO) index values between pairs of six bee species

	H′	$\mathbf{S_{pl}}$	$\boldsymbol{N}_{\mathbf{ind}}$	***Lasioglossum* sp.**	***Ceylalictus* Sp.**	***Halictus* Sp.**	***Apis dorsata***	***Apis florea***
Ceratina smaragdula	16.7	41	159	0.27	0.40	0.26	0.10	0.22
Lasioglossum sp.	9.3	21	80		0.04	0.20	0.03	0.06
Ceylalictus sp.	5.5	18	70			0.80	0.26	0.70
Halictus sp.	6.6	16	67				0.23	0.70
Apis dorsata	18.1	36	477					0.47
Apis florea	12.5	38	454					

meters apart in order to avoid the phenomenon of floral constancy i.e., the tendency of bees to visit single plant species even in the presence of many other plant species at flowering stage in a particular area (Gruter *et al*., 2011).

2.3. Statistical analysis

Six bee species were selected for the analysis of trophic niche overlap and niche breadth represented by 18 or more individuals in the total sample. Trophic overlap among the bee species was calculated by the Pianka's diversity index for each pair of replicated samples for each month and the differences between pairs of values were also calculated (Pianka, 1974).

$Ojk = Okj = [\mathbf{S}\ (p_{ij} \text{ x } p_{ik})] / (\mathbf{S}\ p_{ij}^2 \text{ x } p_{ik}^2)^{0.5}$

Where p_{ij} and p_{ik} are the proportion of the 'I' resource used by the 'j' and 'k' paired categories in each treatment. Non-parametric Kruskal Wallis test was used to calculate the significant difference between mean of ranks of Pianka index values of six bee species among the four seasons. Shannon (1948) index (H′0−Σpk×ln pk) was used to calculate the niche breadth. Pianka index ranges from 0.0 (no overlap) to 1.0 (complete overlap). Shannon Wiener index can range from 0 to infinity, it can also standardize on a 0-1 scale (Colwell and Futuyma, 1971).

To see if niche overlap diverged significantly from random distribution (without overlap), null model -based on 5000 interactions using RA3 algorithm- was applied to randomize data regarding floral utilization by each bee species. RA3 algorithm is an option provided in EcoSim program (Gotelli and Entsminger 2003) which creates "pseudo-communities" by using Monte Carlo resampling method (Joern and Lawlor 1980; Winemiller and Pianka 1990). The random communities obtained were statistically compared with the observed data. The statistical significance of observed overlap with that of obtained by null model was evaluated at alpha 0.05.

In this analysis, the interspecific competition is supposed to occur when the observed mean overlap is significantly lower than that expected overlap. In case if observed overlap exceeds expected overlap, species might face abiotic limitations which ultimately provokes homogenization pattern among species (Albrecht and Gotelli 2001).

Table 2. Breadth of trophic niches (*H′*), richness of visited plants (S_{pl}), number of individuals in each bee species N_{ind}), and niche overlap (NO) index values between pairs of native bee species during summer

	H′	$\mathbf{S_{pl}}$	$\boldsymbol{N}_{\mathbf{ind}}$	***Lasioglossum* sp.**	***Ceylalictus* Sp.**	***Halictus* Sp.**	***Apis dorsata***	***Apis florea***
Ceratina smaragdula	8.7	20	77	0.26	0.73	0.00	0.14	0.33
Lasioglossum sp.	9.2	11	30		0.21	0.00	0.27	0.32
Ceylalictus sp.	6.2	11	35			0.00	0.10	0.29
Halictus sp.	0.0	0	0				0.00	0.00
Apis dorsata	4.7	11	33					0.34
Apis florea	4.7	8	71					

Table 3. Breadth of trophic niches (H'), richness of visited plants (S_{pl}), number of individuals in each bee species N_{ind}), and niche overlap (NO) index values between pairs of native bee species during spring

	H′	S_{pl}	N_{ind}	*Lasioglossum* sp.	*Ceylalictus* Sp.	*Halictus* Sp.	*Apis dorsata*	*Apis florea*
Ceratina smaragdula	19.4	27	73	0.28	0.20	0.33	0.13	0.26
Lasioglossum sp.	4.0	12	44		0.00	0.13	0.01	0.01
Ceylalictus sp.	2.1	9	35			0.81	0.28	0.82
Halictus sp.	6.1	15	64				0.22	0.71
Apis dorsata	13.5	22	400					0.44
Apis florea	7.6	28	309					

3. Results

A total of 1304 individuals of six bee species were recorded in two families i.e., Apidae (*A. dorsata* and *A. florea*) and Halictidae (*C. smaragdula*, *Lasioglossum* sp., *Ceylalictus* sp., *Halictus* sp.) on 82 flowering plants species. *Apis dorsata* and *A. florea* comprised the maximum proportion of total abundance i.e. 36.57% and 34.50%, respectively whereas *Halictus* sp. and *Ceylalictus* sp. comprised the minimum proportion of total abundance i.e. 5.13% and 5.36%, respectively.

Table 4. Breadth of trophic niches (H'), richness of visited plants (S_{pl}), number of individuals in each bee species N_{ind}), and niche overlap (NO) index values between pairs of native bee species during autumn

	H′	S_{pl}	N_{ind}	*Lasioglossum* sp.	*Ceylalictus* Sp.	*Halictus* Sp.	*Apis dorsata*	*Apis florea*
Ceratina smaragdula	4.0	4	4	0.22	0.00	0.00	0.45	0.58
Lasioglossum sp.	1.8	2	3		0.00	0.00	0.00	0.52
Ceylalictus sp.	0.0	0	0			0.00	0.00	0.00
Halictus sp.	1.0	1	3				0.00	0.00
Apis dorsata	2.8	4	22					0.74
Apis florea	3.0	3	3					

The seasonal data showed that the maximum number of bee species (6) were recorded in spring season followed by summer (5), autumn (5), and winter (4) seasons. The abundance of bees was maximum (925 individuals) during spring season followed by summer (246), winter (98) and autumn (35). *Ceratina smaragdula* remained active throughout the year. *Apis dorsata* and *A. florea* were not recorded during May and December, respectively. *Lasioglossum* sp. was not observed during February and December. *Ceylalictus* sp. was recorded from April to August while *Halictus* sp. was observed only in April, May and then October. *Halictus* sp. and *Ceylalictus* sp. were not recorded in summer and autumn, respectively while both were also not recorded in winter (Table 1).

In the summer season, the maximum niche breadth (9.2) was recorded for *Lasioglossum* sp. followed by *C. smaragdula* (7.8) and the minimum for *A. dorsata* and *A. florea* (4.7 each). Although *Lasioglossum* sp. had the highest niche breadth, it comprised the minimum number of individuals (i.e., 30). *Apis florae,* on the other hand, had the minimum niche breath but showed much higher abundance (i.e., 71 individuals). The highest pair-wise niche overlap (0.73) was recorded between *Ceylalictus* sp. and *C. smaragdula* and minimum (0.10) between *A. dorsata* and *Ceylalictus* sp. (Table 02).

In spring season, the highest niche breadth (19.4) was recorded for *C. smaragdula* followed by *A. dorsata* (13.5) and the minimum (2.1) for *Ceylalictus* sp. The abundance of *C. smaragdula* was also greater than *Ceylalictus* sp. *Apis dorsata* and *A. florea* had intermediate and low levels of niche breadths i.e., 13.5 and 7.6,

Table 5. Breadth of trophic niches (*H′*), richness of visited plants (S_{pl}), number of individuals in each bee species N_{ind}), and niche overlap (NO) index values between pairs of native bee species during winter

	H′	S_{pl}	N ind	*Lasioglossum* sp.	*Ceylalictus* Sp.	*Halictus* Sp.	*Apis dorsata*	*Apis florea*
Ceratina smaragdula	2.3	3	5	0.13	0.00	0.00	0.00	0.04
Lasioglossum sp.	1.8	2	3		0.00	0.00	0.00	0.00
Ceylalictus sp.	0.0	0	0			0.00	0.00	0.00
Halictus sp.	0.0	0	0				0.00	0.00
Apis dorsata	2.7	4	22					0.36
Apis florea	3.7	6	71					

respectively but both exhibited highest abundance i.e., 400 and 309 individuals, respectively. *Ceylalictus* sp. exhibited the highest pair-wise niche overlaps with *A. florea* (0.82) and *Halictus* sp. (0.81) (Table 3).

In winter season, *A. florea* exhibited the highest tropic niche breadth (3.7) and abundance (71 individuals) and *Lasioglossum* sp. had the lowest tropic niche breadth (1.8) and abundance (3 individuals). Only three interactions were recorded in winter. *Apis florea* showed the highest niche overlap (0.36) with *A. dorsata* (Table 5).

Table 6. Results of Kruskal-Wallis test for Niche overlap among seasons

	Ceratina smaragdula	*Lasioglossum* sp.	*Ceylalictus* sp.	*Halictus* sp.	*Apis dorsata*
Lasioglossum sp.	Spring 0.251 Summer 0.139 Autumn 0.000 Winter 0.259				
Ceylalictus sp.	Spring 4.500 Summer 4.500 Autumn 8.500 Winter 9.625	Spring 5.500 Summer 5.500 Autumn 5.500 Winter 10.375			
Halictus sp.	Spring 5.500 Summer 5.500 Autumn 7.800 Winter 9.667	Spring 6.000 Summer 6.00 Autumn 6.000 Winter 8.000	Spring 5.500 Summer 5.500 Autumn 5.500 Winter 9.500		
Apis dorsata	Spring 3.500 Summer 6.333 Autumn 8.506 Winter 9.167	Spring 5.000 Summer 5.000 Autumn 6.667 Winter 10.250	Spring 5.000 Summer 5.000 Autumn 7.667 Winter 9.500	Spring 6.000 Summer 6.000 Autumn 6.000 Winter 8.000	
Apis florea	Spring 3.500 Summer 6.333 Autumn 8.375 Winter 9.333	Spring 5.667 Summer 6.667 Autumn 7.500 Winter 8.000	Spring 5.000 Summer 5.000 Autumn 7.000 Winter 9.000	Spring 5.500 Summer 5.500 Autumn 5.500 Winter 9.500	Spring 0.182 Summer 0.416 Autumn 0.546 Winter 0.388

In autumn season, very low tropic niche breadth and abundance was recorded. The maximum tropic niche breadth (4.0) was recorded for *C. smaragdula* and minimum (1.0) for *Halictus* sp. Only 4 individuals of *C. smaragdula* and 3 individuals of *Halictus* sp. were recorded. *Apis dorsata* had also very low niche breadth but had relatively high abundance i.e., 22 individuals. Only five interactions of niche overlap were found in autumn season. *Apis florea* showed the highest pair-wise niche overlap (0.74) with *A. dorsata* (Table 04).

The nonparametric Kruskal-Wallis test suggested no significant niche overlap among the bee species across four seasons (Table 6). Since the observed overlap among six bee species was significantly higher than the expected overlap, no interspecific competition was suspected among the bees in any of the four seasons (Table 7).

Table 7. Probability test of null models (RA3) between the mean observed and expected trophic niche overlap for six bee species in four seasons (p-value = pobs averages observed; pesq = p-value of expected average).

Season	Mean observed	Mean estimate	p-observed >p-expected
spring	0.30847	0.08575	0.00000
summer	0.12621	0.07775	0.05000
autumn	0.12106	0.02655	0.00800
winter	0.29991	0.09270	0.00000

4. Discussion

These results indicate that *A. dorsata* and *A. florea* comprised the maximum proportion of total pollinators' abundance i.e. 36.57% and 34.50%, respectively whereas *Halictus* sp. and *Ceylalictus* sp. comprised the minimum proportion of total abundance i.e. 5.13% and 5.36%, respectively. *Apis florea* and *A. dorsata* are the key floral visitors in sub-tropical region Punjab (Ali *et al*., 2017). Both are social bees, they have open nest and found in very large colonies and trees provide ideal nesting locations (Punchihewa *et al*., 1985). They have long foraging rage (beyond 400m), and can fly large distance to find nectars (Bashir *et al*., 2019). They have high adaptability towards harsh conditions i.e. migrate in case of low nectar flow and pest attack. Both are important pollinators of wild and crop plants and show positive correlation with the floral resources (El-Niweiri *et al*., 2019).

Halictus sp. and *Ceylalictus* sp. are solitary bees or found in very small groups of 2-8 individuals. As they have small foraging range, reduction in floral diversity has direct impact on abundance of these bees Koeniger, (2019). Another reason of their low abundance is the destruction of their nests during farming practices mainly digging of soil.

We observed marked fluctuations in the abundance of different bee species throughout the year. *Ceratina smaragdula* showed peak abundance in June, *Lasioglossum* sp. in July and November, *Ceylalictus* sp. in June to August and *Halictus* sp. in May and October. *Apis dorsata* and *A. florea* remained active throughout the year except in May and December, respectively. Change in season effects blooming activity of flowers which effects pollination and foraging activity of bees. Ali *et al*., (2017) noticed the maximum abundance of bees in spring (early March to late May) followed by a gradual decrease until December in forest ecosystems of Perowal (Central Agriculture Zone, southern Punjab, Pakistan).

When biotic and abiotic environments change, bee behavior changes dramatically i.e., decrease in plantation or area, limited flight range of bees and habitat characteristics (weather, seasons, floral resources) etc. (Vitale *et al*., 2020). Habitat characteristics (weather and temperature) directly influence abundance, richness and foraging activities of bees. The diversity of bees depends on proximity of nesting and floral resources within the flight limit of bees (solitary bees flight limit 150-750m) (Cane, 2005).

We did not find trophic niche overlap within and between solitary (*C. smaragdula*, *Lasioglossum* sp., *Ceylalictus* sp. and *Halictus* sp.) and social bee (*A. dorsata* and *A. florea*) species in any month of year. A previous study in temperate New Zealand (Iwasaki *et al*., 2018) suggests that introduced social bees (i.e. *Apis mellifera* and *Bombus*) and solitary native bees (i.e. Colletidae and Halictidae) exhibit no significant competition in terms of niche overlap (Iwasak *et al*., 2018). Steffan-Dewenter and Tscharntke, (2000) also observed no interspecific competition in terms of niche overlap between solitary and social bees in continental climate of Germany. On the other hand, Wilms et al., (1996) observed significant competition between introduced *A. mellifera* and native stingless bees in terms of niche overlap in Neotropical Brazil (Wilms *et al*., 1996).

The niche overlap may vary with type of climate and available flora. In Neotropical regions, environmental conditions do not fluctuate significantly across the year and remain favorable for plant growth due to proper availability of water and warmth. Rainfall 100 inches (2500 mm) of rain falls annually. On the other hand, in temperate regions, climate range from mild to warm summer to cool to cold winters. Reason being the type and availability of floral resources also differ (Zanette *et al*., 2005).

The difference in type and availability of floral host plants and floral abundance leads to difference in niche overlap among pollinators. Badali and Zilman, (2020) reported that species having largely distinct niches exhibit less competition and result in stable mixed population. On the other hand, species having narrow niches exhibit strong interactions and competition and results in rapid extinction of some species (e.g., specialized ones) and fixation of others (Badali and Zilman, 2020). More the diversity of flora less will be the chances of competition of floral resources. However, so far, the studies from sub-tropical and arid regions are lacking in this regard.

5. Conclusion

In the present study, we did not find significant niche overlap among all the six focused bee species in any part of the year. This shows that arid southern part of Punjab, Pakistan is more stable and less prone to competition and species loss. Future studies should focus the impact of anthropogenic land use on inter-specific competition of insect pollinators.

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