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Seasonal patterns in the diversity of *Apis* and non-*Apis* bees in an agro-ecosystem: A case study from eastern dry zone of Karnataka

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ABSTRACT

A study has been taken up to investigate seasonal patterns in the diversity of bee fauna in different landscape elements of GKVK farming system, Bangalore. The study was carried out over a period of one year from August, 2009 to October, 2010. During sampling, a total of 2030 bees were collected which belong to 20 genera and 65 species. In this paper, the temporal variation in abundance of bee species is examined and compared the patterns in different species. The study concluded that there was a trend towards increased bee abundance and richness during winter with increased flowering with a subsequent decline over the course of the summer season. The assessment of diversity of any taxon at a given temporal or spatial scale is important for its conservation and management.

KEY WORDS: Agroecosystem, *Apis*, Halictids, Megachilids, Non-*Apis* bees

INTRODUCTION

Apoidea has an important role as pollinating agents in the ecosystem. Among the pollinator groups, honey bees have been considered a priority group. In addition to honey bees, non-*Apis* bees have been recognized for their vigorous and quite rapid pollination in many crops. In recent years, the use of many non-*Apis* species of bees has opened a new era in pollination studies (Heemert *et al.*, 1990; Tuell *et al.*, 2009). Moreover, their populations and diversity also serve as bioindicators of the state of many environments (Tscharntke *et al.*, 1998; Keven, 1999; Steffan-Dewenter *et al.*, 2002; Tylianakis *et al.*, 2004). They are the best indicators of overall species richness in agroecosystems, together with Coleoptera and Heteroptera (Duelli and Obrist, 1998).

Both, bee abundance and species richness were subject to marked seasonal variations in any habitat. Temporally, bee communities can vary widely on an annual, seasonal and even diurnal basis. Temporal variation can be the combined result of life history traits and environmental factors (Oertli, 2005). These Apiformes as a whole tend to be mostly diurnal, with daily activities greatly influenced by such factors as temperature, illumination thresholds, wind and precipitation (Cane *et al.*, 2006). Several studies examined the community structure of bee populations living on one site but only few studies have attempted to show the bee population fluctuation across seasons and the years (Oertli *et al.*, 2005). These seasonal variations in bee population are attributed mainly to host plant phenology.

Plant Phenology and Seasonality in Bees: Bee species have distinct phenologies (Wcislo and Cane, 1996). Bee abundance positively relates to the number of flowering plant species (Williams *et al.*, 2001; Kleijn and Langevelde, 2006; Kearns and Oliveras, 2009). Solitary bees have shorter life cycles than social bee species. Several studies have shown that a limited period of activity of many species of solitary bees (one or two months during the year), often corresponds with the flowering of their host plants. For this reason, solitary species can only benefit from flowering crops when the bloom falls into their active period (Westphal *et al.*, 2008). According to Wolfe and Barrett (1988) temporal changes in the pollinator (bee) fauna occurs over a time and highest densities correspond to the peak flowering seasons. Oertli *et al.*, 2005 have shown that changes in the season have a marked effect on the ecological patterns shown by a bee assemblage. Differences among species in the pattern of temporal variation in abundance could have important implications for comparisons of the diversity and faunal composition of species assemblages between natural and agro-ecosystem in different seasons. The information about the status of non-*Apis* bee population fluctuation, the impact of the changes in farming practice and agricultural management on the bee species richness and abundance is very scanty. In light of these challenges an attempt has been made to study the seasonal dynamics of *Apis* and non-*Apis* bees.

MATERIALS AND METHODS

The present study was aimed to understand seasonal patterns of *Apis* and non- *Apis* bee fauna of agroecosystems in GKVK campus, Bangalore. The study was carried out over a period of one year from August, 2009 to October, 2010. The campus is located at 12°58' latitude North and 77°35' longitude East at an altitude of 930 meters above sea level. All the laboratory work was carried out in Department of Entomology, University of Agricultural Sciences, GKVK campus, Bangalore, Karnataka, India.

Climate: GKVK campus comes under the Eastern dry zone of Karnataka. It has three seasons. Summers characterized by warm, sunny dry weather that occurs from March to June, whereas winters are cool and dry from November to February. The rainfall in GKVK is bimodal with an average precipitation of 80 cm. The highest amount of rainfall is received between July-August (monsoon), the second rainy season occurs in September-October (post-monsoon) although some amount of rains also received during summer (Pre-monsoon).

Sampling Methods: For assessing seasonal patterns, bee fauna was sampled using sweep nets and 'Bee pan traps.' The collection was made year around from August, 2009 to July, 2010 with sweep-net and from November, 2009 to October, 2010 using bee pan traps for three days each month. Bees were collected with sweep nets only if warm temperatures and bright sunshine persist. Bees were collected by direct netting on flowering plants between 10-12 am on the same day of the 'Bee pan traps' collection. Bee pan traps were set out in the field for three days during last week of each month. To evaluate differences and changes in bee diversity throughout the sampling period at GKVK, the occurrence and abundance of number of individuals of bee genera and species were catalogued for each month.

RESULTS AND DISCUSSION

The study investigated the seasonal patterns of the ecologically important bee pollinators in agro-ecosystem at GKVK campus using monthly surveys. In total, 2030 bees representing 65 species belonging to three bee families (Apidae, Halictidae and Megachilidae) were recorded.

Sweep net sampling

Sweep-net method is indispensable sampling method for surveying bee community as it has number of advantages. The monthly changes in the occurrence pattern were determined based on the net collection and visual observation. A total of 336 individual bees representing three families, 19 genera and 48 species were collected by sweep-netting. Sweep-net collections were made exhaustively on the flowering plants during August, September, November and December months. During the later months, only 'new' entries of bees were collected in sweeps and other common genera and species collected earlier were identified in the field to species and released back. The purpose was to collect only representative samples, of the bee fauna of GKVK, Bangalore. For further analysis, the sweep net sampling data was used by scoring for 'presence' and 'absence' of each species during the sampling bout.

The monthly collection of bees indicated a variation in their occurrence over the study period from August, 2009 to July, 2010. Both abundance and species richness of bees was observed to vary across calendar months. In general, bees were found to be abundant during August, September, October, November, December, January and February (monsoon and winter months) of 2009 and 2010 and less abundant during March, April, May June and July in 2010. Seasonal occurrence and their abundance of all bee species caught in Sweep-nets are mentioned in the Table 1. The species, *Halictus* sp. 1, *Amegilla confusa* (Smith), *Amegilla zonata* (L.), *Ceratina binghami* Cockerell, *Apis cerana* F., *Apis florae* F. and *Apis dorsata* F. were more common and abundant in all the sampling months. The species, *Nomia westwoodi* Gribodo, *Nomia iridescens* Smith, *Megachile lanata* F. , *Megachile anthracina* Smith, *Xylocopa latipes* (Drury), *Xylocopa aestuans* L., *Xylocopa* sp. 3, *Ceratina hieroglyphica* Smith, *Ceratina smaragdula* (F.), *Amegilla bicincta*, *Amegilla violacea* (Lepeletier), *Thyreus* sp. 1, *Thyreus* sp. 2, *Thyreus* sp. 3 were encountered throughout the study period.

The bee species, *Steganomus* sp., *Liptriches* sp. 1, *Sphecodes* sp., *Lassioglossum* sp. 8, *Lithurgus* sp., *Anthidiellum* sp., *Megachile hera* Bingham, *Megachile* sp. *3*, *Coelioxys capitata* Smith, *Coelioxys confusa*, *Coelioxys basalis* Smith, *Braunsapis* sp., *Xylocopa* sp. 5, *Amegilla* sp were least common and encountered only during one, two or three months. The species, *Nomioides* sp., *Lassioglossum* sp. 3, *Lassioglossum* sp. 4, *Euaspis edentata*, *Megachile disjuncta*, *Megachile* sp. 1, *Megachile* sp. 2, *Xylocopa* sp. 1, *Xylocopa* sp. 2, *Xylocopa* sp. 4, *Xylocopa* sp. 5 occurred in winter months and decreased later in summer. The megachilids were active from September, 2009 to January, 2010 and their numbers decreased drastically in summer months.

Net collections yielded a richer bee fauna in the late rainy and winter months when many of the plant were at peak flowering stage and less in the late summer when flowering of the many plants in the campus ceased. However, many polylectic bee species were found throughout the study period. Honeybees were most abundant throughout the study period along with *Amegilla, Xylocopa and Ceratina* found in all the seasons.

Bee pan trap sampling

'Bee pan traps' served the purpose of sampling for bees without biasing the collection towards large, active or visually attractive bees and also controlled for variation in sampling effort and time. Bees collected in 'bee pan traps' belonged to the families Halictidae, Megachilidae and Apidae, as was the case with bees collected by sweep-net sampling on flowers and vegetation. Interestingly, however, the generic and species composition was very different from that of the sweep-net. Over all the sampling months the "bee pan traps" yielded 1694 bees representing three families, 13 genera and 33 species.

Table 1: Seasonal occurrence and abundance of bee species sampled through Sweep-nets. Based on the observation from August (2009) to July (2010) at GKVK campus. Absent (-), Present (*), Moderately abundant (**) and Abundant (***)

Family: Apidae

Species	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July
Apis florea	***	***	***	***	***	***	***	***	***	***	***	***
Apis cerana	***	***	***	***	***	***	***	***	***	***	***	***
Apis dorsata	***	***	***	***	***	***	***	***	***	***	***	***
Trigona sp.	***	***	***	***	***	***	***	***	***	***	***	***
Ceratina binghami	***	***	***	***	***	***	***	**	**	**	**	**
Ceratina hieroglyphica	**	**	**	**	**	**	**	*	*	*	*	*
Ceratina smaragdula	*	*	*	*	*	*	*	*	*	*	*	*
Amegilla confusa	**	**	**	**	**	**	**	**	**	**	**	*
Amegilla zonata	**	**	**	**	**	**	**	**	**	**	**	**
Amegilla violacea	-	-	**	**	**	**	**	**	**	*	*	*
Amegilla bicincta	-	-	-	**	**	**	**	**	*	*	*	*
Amegilla sp.	-	-	-	-	-	-	-	-	*	-	-	-
Xylocopa sp. 3	**	**	**	**	**	**	**	**	**	**	**	**
Xylocopa latipes	?	*	**	**	**	**	*	*	*	*	*	*
Xylocopa aestuans	?	*	*	*	*	*	*	*	*	*	*	*
Xylocopa ruficornis	?	?	?	*	*	*	*	*	*	*	*	*
Xylocopa sp. 2	?	?	?	*	*	*	*	*	*	*	*	*
Xylocopa sp. 1	?	?	?	*	*	*	*	*	*	*	?	?
Xylocopa sp. 4	?	?	?	*	*	*	*	*	*	*	?	?
Xylocopa sp. 5	-	-	-	-	-	-	*	-	-	-	-	-
Xylocopa rufescens	-	-	-	-	-	-	-	-	*	-	-	*
Braunsapis sp.	-	-	-	-	-	-	-	-	-	*	-	-

Family: Megachilidae

Species	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July
Megachile lanata	*	*	**	***	***	***	**	**	*	*	*	*
Megachile anthracina	?	*	*	*	*	*	*	*	*	*	*	*
Euaspis edentata	?	*	*	*	*	-	-	-	-	-	*	-
Megachile disjuncta	-	-	**	**	*	*	*	-	-	-	-	-
Megachile sp. 1	-	-	**	**	*	*	*	-	-	-	-	-
Megachile sp. 2	-	-	*	*	*	*	*	-	-	-	-	-
Megachile sp. 3	-	-	-	*	-	-	-	-	-	-	-	-
Coelioxys confusa	-	-	*	*	*	-	-	-	-	-	-	-
Coelioxys capitata	-	-	*	*	*	-	-	-	-	-	-	-
Coelioxys basalis	-	-	*	*	*	-	-	-	-	-	-	-
Megachile sp. 3	-	-	-	*	-	-	-	-	-	-	-	-
Megachile hera	-	-	-	-	-	-	-	-	*	*	-	-
Anthidiellum sp?	-	-	-	-	-	-	-	-	*	-	-	-
Lithurgus sp.	-	-	-	-	-	-	-	-	*	-	-	-

Family: Halictidae

Species	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apr	May	June	July
Halictus sp. 1	***	***	***	***	***	***	***	**	**	**	**	**
Nomia irridescens	**	**	**	**	**	**	**	**	**	**	**	**
Nomia westwoodi	**	**	**	**	**	**	**	**	**	**	**	**
Nomioides sp.	*	*	*	*	*	*	*	*	*	*	*	*
Lassioglossum sp. 3	?	?	?	*	*	*	*	*	*	*	*	*
Lassioglossum sp. 4	**	**	**	**	**	**	**	**	*	*	*	*
Lassioglossum sp. 8	-	-	*	*	-	-	-	-	-	-	-	-
Steganomus sp.	*	-	-	-	-	-	-	-	-	*	*	*
Sphecodes sp.	-	-	*	-	-	-	-	-	-	-	-	-
Lipotriches sp. 1	-	-	-	-	-	-	-	-	*	-	-	-

Question mark against *Megachile anthracina, Lassioglossum* sp. 3, *Xylocopa* sp. and *Euaspis edentata* from August to October indicates doubtful identification and hence their activity during these months could not be conclusively ascertained.

Temporal turnover of the genera and species in the bee pan traps

The bees (mainly oligolectic) tend to be seasonally restricted and coincide with the flowering of the host plant. The total number of genera and individuals collected in bee pan traps during each sampling month were counted to assess seasonal changes in diversity and abundance. Most species were collected during the months of November (20 species) followed by January (16 species), February (16 species) and June (15 species), December (14 species) and April (14 species). Least numbers of species were encountered in the month of March followed by August. The similar pattern was observed for the genera also, with the highest number being encountered during February (10 genera) followed by the November and June (9 genera each). However, there was no apparent variation in the generic composition between the sampling months (Fig. 1).

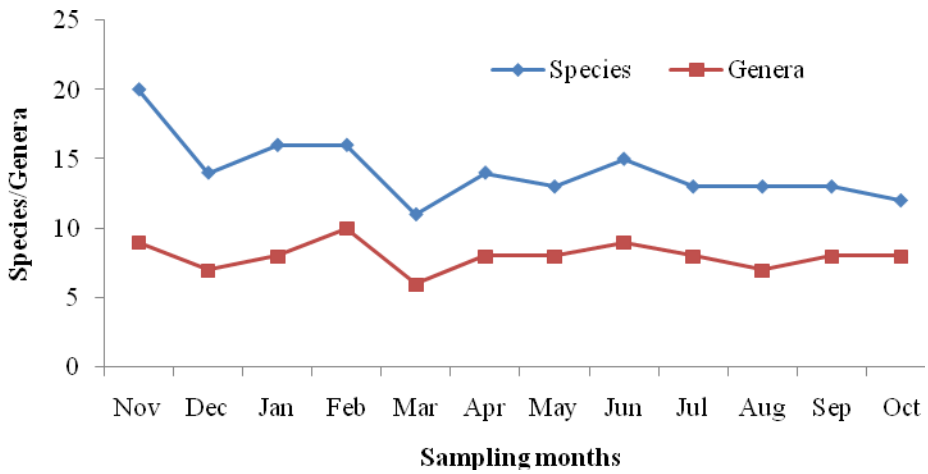

Fig. 1. Monthly changes in generic and species composition of bees in Bee pan traps during the successive sampling months from November (2009) to October (2010). Pooled data from three consecutive days (3hours/day) of sampling during each sampling month.

Halictidae was more abundant and dominant than others in all the seasons followed by Apidae and the family Megachilidae was caught with a very less frequency. The highest abundance or the number of individual bees captured in bee pan traps was in January, with 383 bees being captured, and accounting for 25.90 per cent of the total individuals. This was followed by February which accounted for 274 individuals accounting for 19.00 per cent of the total catches. In general, the bee catches with respect to genera, species and individuals peaked during the first four months of sampling from November (2009) to February (2010) i. e., during winter and decreased during the summer months.

Monthly changes in the abundance of the six most dominant species

There was remarkable monthly variation in abundance of the six most dominant species of bees captured in the 'bee pan traps'. Halictidae and Apidae were more abundant and dominant than others in bee pan traps and the species richness was noticed to vary between months as mentioned earlier. In addition, some bee species appeared to have very restricted flight activity period and these were trapped in bee pan traps only in one or two months.

The monthly variation in the abundance bee species for the six most common and abundant species of bee in bee pan traps was plotted against time to discern seasonal changes (Fig 2). Different species of Halictids peaked during different months. Among species belonging to the genus *Lassioglossum*, *Lassioglossum* sp 2 was abundant during November (2009). *Lassioglossum* sp. 3 and *Lassioglossum* sp. 4 exhibited a similar pattern and peaked during January. *Halictus* sp. 1 was most abundant in January and February (2010), while *Halictus* sp. 3 was abundant during February and March (2010). *Ceratina binghami* which was the only abundant species in the genus *Ceratina* showed a quite a different pattern of activity with a peak in January, and was most active in the winter months and decreased during the summer months. Among the *Apis* species only *Apis florea* was present in the in 'bee pan traps'. The results suggest that in general the most dominant species were all active during post rainy and winter months.

Similar to sweep-net method, the bee species diversity in 'bee pan traps' also peaked during November followed by December, January, February. The species diversity was high during winter when temperatures was fairly low (21^{o} C) which also coincided with peak blooming season of the many flowering plants. But, in general bees are known to be active during the warmer months. The variations in the occurrence of the species during different seasons may be due to the activity spans of the species mainly solitary bees. The lower numbers of species were found during the summer months was possibly due to high temperature (27^{o} C) which may have resulted in the bees being active outside the sampling period, i.e., early morning and late afternoon. In fact 'bee bowl' captures are known to be strongly influenced by the activity level of bees at different times of the day.

CONCLUSION

Bee diversity in the GKVK campus was more in the late rainy and winter months when many of the plants were at peak flowering stage and less in the late summer when flowering of the many plants in the campus ceased. There appeared to be a strong association between seasonal turnover in the composition of the bee community and that of the flowering community. *Apis* sp. and Halictids were most abundant and dominant in all the seasons whereas most of the Megachilids were seasonally bound and were found active during October to January months. In contrast, by June again the generic and species count increased may be because of the planting of many flowering plants in campus, and such habitats can continue to provide floral resources. In conclusion, the study clearly indicates that bees require microhabitats with diversity of flowering plants and availability of nesting sites. While more detailed studies need to be taken up the time of sampling to effectively capture the daily variations in the activity of bees. All these findings underline the importance of season-long and year around sampling.

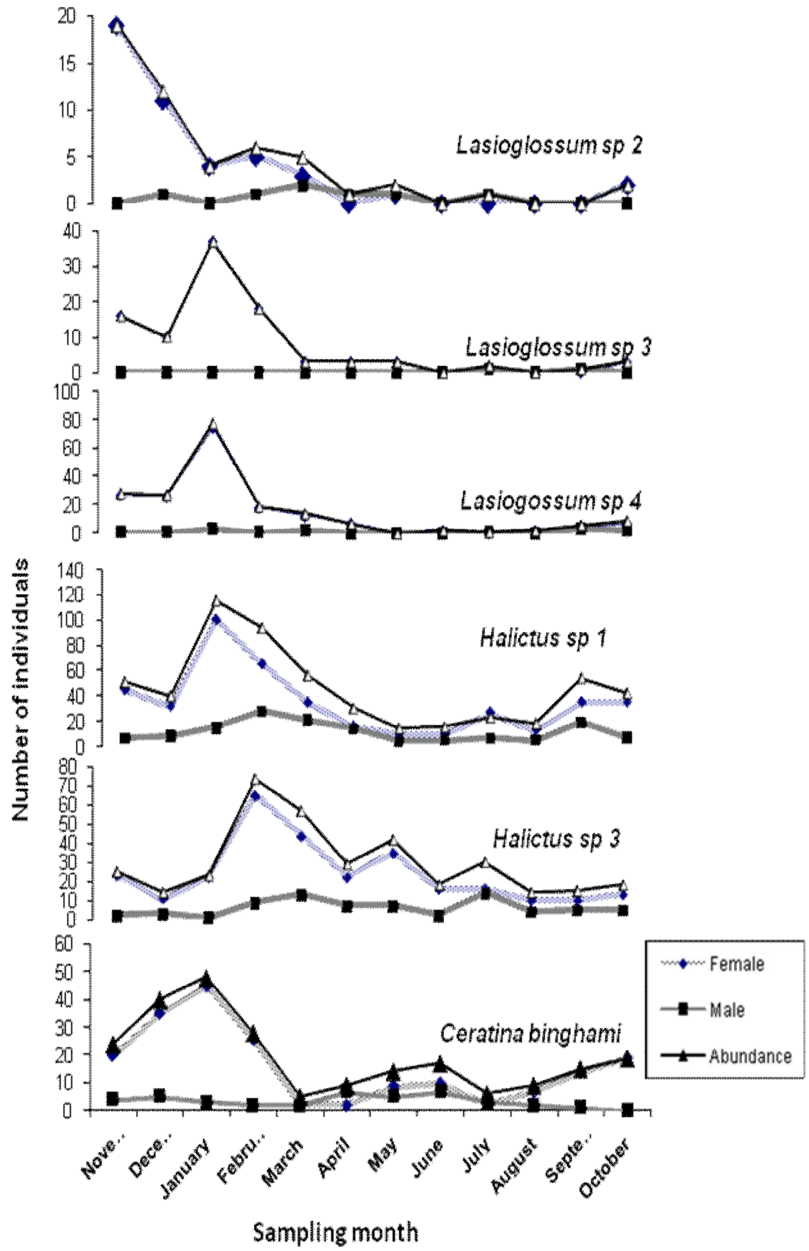

Fig. 2. Seasonal patterns in the abundance of dominant bee species catches in 'bee pan traps' at GKVK campus from November (2009) to October (2010).

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