Assemblage of pollinator communities in four widely isolated nature reserves of southern Punjab, Pakistan

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1. Introduction

Insect pollinators, including moths, flies, bees, beetles, butterflies, and wasps, play an important role in most terrestrial ecosystems, and deliver a key ecosystem service of pollination that is vital for the maintenance of agricultural crops and wild plant communities (Buchmann and Nabham, 1996). Pollination services might be affected by a range of recent and projected environmental changes, such as habitat loss due to intensification in agriculture and climate change (Bartomeus et al., 2013).

Understanding the identity, diversity, and abundance of pollinators is a first step towards devising a conservation strategy for crop pollination, as these have important implications on reproductive interactions among plant species (Garratt et al., 2014; Moeller, 2005). The identity, diversity, and abundance of pollinators vary across landscape scales and time, and any change in these traits may lead to pollen limitation (Gomez et al., 2010). Bees (Hymenoptera: Apoidea: Apiformes) constitute the most important pollinator group worldwide (Ali et al., 2016; Michener, 2000). Bees occur in a wide range of bio-geographical regions and habitat types, where both sufficient floral resources and suitable nesting sites and materials are available (Khan et al., 2014; Michener, 2000). The most diverse bee communities can be found in structurally complex and flower-rich semi-natural habitats (Potts et al., 2003).
The ecological process of pollination depends on scales much larger than a single habitat. Therefore, it is important to link spatial patterns of pollinators and subsequent pollination at a landscape scale (Steffan-Dewenter et al., 2002). Climatic conditions and quality of habitat (availability of nesting places and floral resources) are considered as the main drivers of such variations, considering that climate and quality of habitat vary on large scales (Cunningham, 2000; McCall and Primack, 1992). Spatial patterns of pollinator assemblages are of great interest to ecologists. Practically, we must know where species richness is highest and how species assemblages change in space in order to better conserve biodiversity (Ali et al., 2015; Cody, 1986); theoretically, it provides material to test theories of why diversity varies among sites and how species turnover increases with inter-site distance (Condit et al., 2002). Most of these studies have highlighted lack of detailed information on assemblage structures of the pollinators, and have stressed the necessity to unveil assemblage complexity in order to devise effective ecosystem management planning.

Pakistan Agricultural Research Council (PARC) has divided Pakistan into 10 agro-ecological zones, out of which the southern irrigated zone represents the present study area, (PARC, 1980). The climate of the area is arid, sub-tropical with hot summer and mild winter; mean daily maximum and minimum temperature ranges from 38 °C to 50 °C and 8 °C to 12 °C, respectively. This area is one of the hottest areas of the country, and very little is known about the diversity of the flower visiting insects. The current study investigated the diversity of pollinators and explored the diversity of the native pollinators and their assemblage in the area. The purpose of the study was to understand assemblages of insect pollinators in four isolated forest reserves of the southern irrigated zone of Punjab, Pakistan.

2. Materials and methods

2.1. Study location

The experiment was performed in four geographically distinct areas of southern Punjab, i.e., Pirowal, Lal Suhanra, Ghazi Ghat, and Fort Munro. Pirowal Wildlife Park (District Khanewal) is a characteristic alluvial plain forest of southern Punjab. Lal Suhanra National Park (District Bahawalpur) has a semi-desert landscape. Ghazi Ghat game reserve (District Muzaffargarh) is a lower Indus plain and a characteristic wetland forest. Fort Munro is the hilly (6000 feet from sea level) and least disturbed area of southern Punjab.

2.2. Data collection

The study was conducted from February 1 to August 30, 2012. In each forested landscape, all the available plant species at the flowering stage were observed for pollinator visitation on a fortnightly basis. In each location, we chose an experimental (focal) plot of 10 hectares. Ten individuals of each plant species were randomly selected during their anthesis, and each individual plant was observed for 60 s and all the insects visiting the flowers were recorded. As such, there was a total of 10 min of observation per plant species during a single census. The records were taken on sunny days from 08:00 to 11:00 h (local time) in order to increase the sample size. The observations were done on clear days, and rainy or cloudy days were avoided. To avoid the phenomenon of floral constancy (insects that tend to visit single plant species even in the presence of many other flowering plant species in that particular area) (Goulson and Wright, 1998), we selected the plants of a particular species at a considerable distance from each other (>5 m).

2.3. Statistical analysis

To evaluate the community assemblage of pollinators in different forest ecosystems, two traits of assemblage were studied, i.e., abundance (total number of individuals of a particular species) and diversity. Species diversity was measured as species richness, dominance, Simpson index (Simpson, 1949), Shannon-Wiener index (Shannon, 1948), and evenness index (Pielou, 1966). Species richness is the number of insect visitor species in each location, whereas dominance was calculated as the relative abundance of the most abundant visitor species. In order to find any significant differences in mean monthly abundance and richness of three pollinator groups, analysis of variance (ANOVA) was used and means were compared by Least Significant Difference (LSD) test at p = 0.05.

To assess the effectiveness of the pollinator sampling method in each location, individual based refraction curves were used. Rarefaction allows for estimation of the number of species (S) expected in random samples of N individuals taken from a larger collection consisting of N individuals and S species (Gotelli and Entsminger, 2005). Based on the number of the pollinator species and their abundance in each site during the whole study period, rank abundance curves were separately applied for flies, bees, and wasps. Moreover, to see the similarity in four locations based on pollinator abundance, Hierarchical Cluster Analysis was applied using the jaccard similarity index as the input formula (Jaccard, 1912). Statistical analyses were performed using the PAST software (Hammer et al., 2001).

3. Results

The maximum abundance (1354 individuals) of pollinators was recorded at Ghazi Ghat, followed by Pirowal (1331), Lal Suhanra (1197), and Fort Munro (808) (Table 1). The highest species richness (80 species) was observed at Ghazi Ghat, while the lowest (65) was observed at Fort Munro. The highest values of Simpson and evenness indexes were recorded at Fort Munro, while Shannon and dominance indexes were found to be the highest at Ghazi Ghat and Pirowal (Table 1). The rank abundance curves of pollinators showed that there were many species with less abundance and only few species with much higher abundance at four locations (Figs. 1–4).

ANOVA results suggested that abundance of pollinators differed significantly (DF =, P = 0.0074, F = 4.74) among the four locations. Ghazi Ghat had the highest abundance and Lal Suhanra showed the lowest abundance. Similarly, richness also differed significantly

| Table 1 |
| Pollinator species assemblage in four locations. |
| Indexes | Ghazi Ghat | Pirowal | Lal Suhanra | Fort Munro |
| Richness | 84 | 80 | 77 | 65 |
| Abundance | 1354 | 1331 | 1197 | 808 |
| Dominance | 0.055 | 0.054 | 0.051 | 0.049 |
| Simpson | 0.945 | 0.947 | 0.949 | 0.951 |
| Shannon | 3.604 | 3.586 | 3.586 | 3.527 |
| Evenness | 0.438 | 0.451 | 0.469 | 0.524 |
among the locations (DF =, P = 0.0152 F = 4.03) i.e. the maximum at Ghazi Ghat and the minimum at Lal Suhanra (Table 3).

Individual based rarefaction curves of pollinators showed that the sampling efforts were sufficient in all the four locations to represent the maximum number of species (Fig. 5). The hierarchical cluster analysis grouped Ghazi Ghat and Fort Munro into one cluster, while Pirowal and Lal Suhanra were grouped into another cluster, on the basis of similarity in species assemblage (Fig. 6).
Ghazi Ghat: A total of 1354 individuals of 84 species were recorded in 22 families. These included 5 families of bees (Andrenidae, Halictidae, Apidae, Colletidae, and Megachilidae), 9 families of flies (Calliphoridae, Syrphidae, Asilidae, Anthomiidae, Bombyliidae, Tephritidae, Sarcophagidae, Muscidae, and Sepsidae), and 8 families of wasps (Chrysidinae, Crabronidae, Philanthidae, Pompilidae, Scelionidae, Sphecidae, Tiphiidae, and Vespidae). Halictidae, Apidae, and Megachilidae were the families with the highest

Fig. 5. Individual based rarefaction curve showing sampling efforts at four locations by showing the relationship between numbers of species (taxa) and numbers of Pollinator individuals (specimens) collected at all four sites.

Fig. 6. Hierarchical cluster analysis of four study locations based on abundance and richness of pollinator species with Jaccard similarity index as input formula.
species richness, while Sepsidae and Halictidae were the families with the highest numbers of individuals. Species richness was the highest (38 species) for bees and the lowest (21 species) for wasps, although flies had the highest abundance (810 individuals) (Table 2). The most abundant species of bees, flies, and wasps are shown in Fig. 1.

Pirowal: A total of 1354 individuals of 80 species were recorded in 19 families. These included 5 families of bees (Andrenidae, Halictidae, Apidae, Colletidae, and Megachilidae), 7 families of flies (Calliphoridae, Syrphidae, Asilidae, Anthomidae, Bombyliidae, Tephritidae, and Sarcophagidae), and 7 families of wasps (Muscidae, Philanthidae, Pompilidae, Scelionidae, Sphecidae, and Vespidae). Species richness was the highest (29 species) for bees, while it was the lowest (24 species) for flies, although flies had the highest abundance (780 individuals) (Table 2). Halictidae, Apidae, and Syrphidae were the families with the highest species richness while Syrphidae, Anthomidae, and Halictidae were the families with the highest abundance of individuals. The most abundant species of bees, flies, and wasps are shown in Fig. 2.

Lal Suhanra: A total of 1197 individuals of 77 species were recorded in 22 families. These included 5 families of bees (Andrenidae, Halictidae, Apidae, Colletidae, and Megachilidae), 9 families of flies (Calliphoridae, Syrphidae, Asilidae, Anthomidae, Bombyliidae, Tephritidae, and Sarcophagidae), and 8 families of wasps (Muscidae, Phaenodontidae, Philanthidae, Pompilidae, Scelionidae, Sphecidae, and Vespidae). Halictidae, Vespidae, and Apidae were the families with the highest species richness, while Syrphidae, Apidae, and Vespidae were the families richest in number of individuals. Species richness was the highest (31 species) for bees and the lowest (19 species) for flies, although flies had the highest abundance (591 individuals) (Table 2). The most abundant species of bees, flies, and wasps are shown in Fig. 3.

Fort Munro: A total of 808 individuals of 65 species were recorded in 20 families. These included 3 families of bees (Halictidae, Apidae, and Megachilidae), 8 families of flies (Calliphoridae, Syrphidae, Asilidae, Anthomidae, Bombyliidae, Tephritidae, Sarcophagidae, and Muscidae), and 9 families of wasps (Muscidae, Philanthidae, Pompilidae, Scelionidae, Sphecidae, Tiphi- idae, and Vespidae). Apidae, Halictidae, and Vespidae were the families with the highest species richness, while Anthomidae, Halictidae, and Calliphoridae were the families with the highest numbers of individuals. Species richness was the highest (26 species) for bees and the lowest (18 species) for flies, while the flies had the highest abundance (591) (Table 2). The most abundant species of bees, flies, and wasps are shown in Fig. 4.

4. Discussion

The maximum abundance and species-richness of pollinators were observed at Ghazi Ghat, while the lowest abundance and species-richness were observed at Fort Munro. There has been increasing concern on the importance of pollinator diversity in different ecosystems (Buchmann and Nabham, 1996; Kevan et al., 1997; Sajjad et al., 2012). Most studies have stressed the lack of detailed information on pollinator biodiversity and the necessity to know the biodiversity of pollinators in any ecosystem management planning.

Although there is sufficient evidence that plant–pollinator interactions vary spatially (Cane and Payne, 1993; Eckhart, 1992; Fenster and Dudash, 2001), the spatial scale of variation and the ecological factors that determine variation in pollinator communities remain unclear. Diversity and structure of pollinator communities are better predicted by climatic conditions of any area, while climate is reflective of the altitude and latitude. As a consequence, floral evolution and reproductive interactions among plant species occur due to this variation in diversity and structure of pollinator communities (Gomez et al., 2007).

The highest values of Simpson and evenness indexes were recorded at Fort Munro, while Shannon and dominance indexes were found to be the highest at Ghazi Ghat and Pirowal. Simulations suggest that diversity indexes vary independently of species richness under laboratory (Rainey and Travisano, 1998) and field conditions (Wilsey and Potvin, 2000). e.g., evenness indexes (Smith and Wilson 1996). It is widely accepted that diversity can change with key ecological processes such as competition, predation, and succession, each of which can proportionally alter the diversity by effecting evenness without any change in species richness (Wilsey and Potvin, 2000).

The hierarchical cluster analysis grouped Ghazi Ghat and Fort Munro into one cluster, while Pirowal and Lal Suhanra were grouped into another cluster on the basis of similarity in species assemblage. While evaluating similarity between multiple sites, the information on the identity of species shared across sites is not preserved, and, thus, average similarity across the sites does not show to what extent there is a change in shared species between pairs (Basset et al., 2004). The information on similarity in species composition between different sites can be used as a basis for conservation planning (Ferrier, 2002).

Rank abundance curves of pollinators showed that there were many species with less abundance and only few species with higher abundance at all four locations. Similar results were reported by Sajjad et al. (2012) from subtropical forests of southern Punjab of Pakistan. Studying the relative abundance of species in ecological communities provides an opportunity to better understand community structure not only at community level, but also at trophic and taxonomic group levels (Tokeshi, 1993).

Species richness of bees was the highest among all the four locations. On the other hand, although flies were the lowest in species richness, they were the highest in abundance among all four locations. Flies (Diptera) are often neglected but an important group of pollinators. However, their role in sustainable agriculture production has not yet been recognized due to knowledge gaps (Szymank et al., 2008). Flower-visiting flies may be abundant in numbers and diversity, and are found in all habitats. The relative importance of fly and bee pollinators in particular situations may
relate to differences in their basic biology (Kearns, 2001). For example, unlike bees, flies do not need to make continual visits to flowers to provision a brood, and most lack specialized structures for pollen transport.

5. Conclusion

The current study is a first account of pollinator assemblage structure in four widely isolated forest reserves of Punjab, Pakistan. This will provide support for ecosystem management planning, and opens doors for further research to unveil further complexity in pollinator assemblage structure, especially in relation with plant communities.

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