Entomon 43(2): 99-110 (2018)
Article No. ent. 43204

Systematic survey on alpha diversity of anthophilous insect fauna in Binsar Wildlife Sanctuary, Western Himalaya

Manoj Kumar Arya*, Prachi Tamta and Aman Verma

Department of Zoology, D.S.B. Campus, Kumaun University, Nainital 263002 Uttarakhand, India. Email: dr.manojkumar19@rediffmail.com; amannaini92@gmail.com

ABSTRACT: Insects as pollinators or anthophiles are key components for proper functioning and long term sustainability of the agro and forest-ecosystems. Investigations undertaken to determine the status and diversity of insect pollinators in relation to the floristic composition in Binsar Wildlife Sanctuary (BWLS), Uttarakhand, India, revealed a total of 53 species of insects belonging to 18 families under four orders facilitating the pollination process in the entire area of the sanctuary. The species richness and value of Shannon Wiener diversity index (H') was recorded highest for the order Lepidoptera i.e., 33 species and 3.064, followed by Hymenoptera (11 species and 2.233), Diptera (five species and 1.495) and Coleoptera (four species and 1.226), respectively. The members of order Hymenoptera were much more evenly distributed with highest 0.9313 value of Pielou's Evenness Index (J') in comparisons to the other orders throughout the study period. In addition, the three study sites which were selected in the BWLS exhibited a declining trend of pollinators' alpha diversity along increasing altitudes. In the present study several plant species of families Asteraceae, Fabaceae, Rosaceae and Urticaceae constituted important foraging resources for insects throughout the years. Temporal variations in patterns of plant-pollinators interactions get affected by multiple environmental factors and different habitat types of BWLS, were also observed.

KEYWORDS: Altitudes, anthophiles, forest ecosystem, pollination, Western Himalaya.

INTRODUCTION

Despite the existing legal policies and regulations, India is facing a plethora of inter-related challenges such as degrading environmental quality, declining ecosystem services, deforestation, biodiversity loss, human wildlife conflict and climate change (Singh and Bagchi, 2013). The establishment of protected areas ensures not only the conservation of biodiversity but also maintain a wide range of ecosystem services for socio-economic and cultural well being (Stolton *et al*., 2015). However, studies suggest that local floral and faunal extinction, even in the protected areas of many developing countries can occur which is often linked with the anthropogenic pressures on the resources (Brashares, 2003; Pillay *et al*., 2011). Animals, insects in particular that visits flowering plants in order to obtain pollen, nectar, oils or floral

* Author for correspondence

tissues are considered as anthophiles or well known as pollinators (Kevan and Baker, 1983; 1998). Both domesticated and wild pollinator populations of insects are helpful in providing one of the most important ecosystem services of pollination crucial for the maintenance of wild plant communities, agricultural productivity and conservation and sustainability of global biodiversity (Kevan, 2003a; Ashman *et al*., 2004; Klein *et al*., 2007). It has been estimated that pollination of approximately 87% of all flowering plants are affected by animals (Ollerton *et al*., 2011) and moreover, about 80% of wild floral biodiversity is directly dependent on insect pollination for fruit and seed production with bees being the most efficient pollinators among other anthophilous insects (Ashman *et al*., 2004; Potts *et al*., 2010). Internationally, there is a grave concern over the widespread declining trends of pollination services in most of the ecosystems which have been disrupted by the multiple interactive effects such as changes in land use patterns, unusual climatic conditions, various environmental stresses, pesticide applications, spread of pests and pathogens, decreased resource diversity and others (Kevan, 2003a; Carvell *et al*., 2006; Winfree *et al*., 2009; Potts *et al*., 2010; Vanbergen and IPI, 2013). Thus, in the context of this, it becomes essential to evaluate plant-pollinators interactions for monitoring ecosystem functions and disruption (Senapathi *et al*., 2015) as well as for managing habitat for biodiversity (Gilgert and Vaughan, 2011). Many studies on insect pollinators in agricultural ecosystems of the world have been made by various workers which have contributed much to our understandings on pollination of agricultural and horticultural crops (Kevan, 1999; Raju and Reddi, 2000; Kevan, 2003b; Mishra *et al.,* 2004; Joshi and Joshi, 2010; Mattu *et al*., 2012; Raj *et al.*, 2012; Sharma and Mitra, 2012; Ganie *et al*., 2013; Raj and Mattu, 2014; Mattu and Bhagat, 2015; Kapkoti *et al.,* 2016; Khan *et al.,* 2016; Mattu and Bhagat, 2016). However, such studies on pollination services provided by insects in forest ecosystems are few (Campbell and Hanula, 2007; Winfree *et al*., 2007; Thakur and Mattu, 2010; Hussain *et al.,* 2012; Pandey *et al.,* 2013; Arya, 2015; Brunismann *et al.,* 2016). Moreover, pollination services of many wild plants have remained poorly understood (Potts *et al*., 2010). The present study, thus aims to highlight the importance of insect pollinator species of natural ecosystems in relation to their floral plants based on collections and observations in temperate forests of Binsar Wildlife Sanctuary located in the Western Himalayan region.

MATERIALS AND METHODS

(1) General description of the study area

The Himalayas in India account for more than 50 percent of its geographical area under forest cover and comprise 40 percent of species endemic to Indian subcontinent (Pandey *et al.,* 2013). Binsar Wildlife Sanctuary (BWLS) with a geographical area of 47.67 sq. km located between two districts of Uttarakhand state namely Almora and Bageshwar represents one of the oldest protected landscapes the Kumaun Himalayan region. Binsar is a fascinating spot that offers a majestic glimpse of the snow capped Indian Himalayan peaks namely Nanda Devi, Trishul and Panchachuli, presenting a unique experience to its visitors. The geographical location of Binsar Wildlife Sanctuary is $29^{o}\,39' \times 29^{o}\,44'$ N and $79^{o}\,41' \times 79^{o}\,49'$ E and the altitude varies between 1200 to 2500 meters above sea level. The sanctuary has core zone (4 sq. km) and buffer zone (43.67 sq. km). No human activity is allowed in Core Zone (Restricted Zone). Prior to India's independence in 1947, the study area was notified as "Protected Forest'' in 1893 and later upgraded as "Reserve Forest" in 1897. After independence, its status was revived to "Wildlife Sanctuary" by the Government of India in the year 1988. The climatic conditions prevailing in the BWLS range from temperate to sub-temperate type. Binsar represents the characteristic floral element of moist temperate type of vegetation.

For the present study, three study sites were selected in the Binsar Wildlife Sanctuary in a manner that they represented different altitudes and vegetation type (Table 1). A total of 25 species of trees, 34 species of shrubs and 55 species of herbs were recorded from different study sites of the protected area. Fig. 1 shows the graph of relative numbers of plant diversity recorded from different study sites of BWLS and the description of each study site is as under:

Site-1 (**Ayarpani**)**:** This site is located adjacent to the main highway of Almora-Bageshwar. It is about 35 kms north of Almora town in Uttarakhand. It is the entry gate for the sanctuary and because of its proximity to highway, the area nearby it receives high level of disturbances due to tourism, transportation activities and other associated anthropogenic pressures. During the study period, temperature of this study site varied from 9ºC (January) to 29ºC (June), while the relative humidity ranged between 56% (November) to 88% (August).

Site-2 (Binneshwar Mahadev): This site is located near the Binneshwar temple within Binsar Wildlife Sanctuary and approximately 13 kms away from main highway (Almora-Bageshwar). This site receives moderate level of disturbance due to animal grazing, collection of minor and major forest products by neighbouring villagers and tourism. March and April are the months when flowers, especially ruby red *Rhododendron*, are in full bloom. The oak habitat is moderately dense and diverse in comparison to the pine habitat (Site-1). During the study period, temperature of this study site varied between 8.3ºC to 27ºC, while the relative humidity ranged between 57% (November) to 89% (August).

Site-3 (Jhandi Dhar): This study site is perched at an elevation of 2450 meters above mean sea level on the Jhandi Dhar hills, and is one of highest hill tops in the Kumaun region. This part of study area is also known as 'Zero Point' in BWLS providing scenic panoramic view of the Himalayan peaks. This site receives very low level of disturbances. This is highly snow prone area of the sanctuary receiving snow from mid of December till the mid of March. The habitat is denser but less diverse in comparison to the Site-2. During the study period, temperature of this study site varied between 6ºC (January) to 26ºC (June), while the relative humidity ranged between 57.8% (November) to 90% (August).

(2) Taxonomic survey and analysis of anthophilous insect fauna

Multiple samplings were carried out at an interval of 30 days by direct observations on either side of transects mainly during 08:00-11:00 and 03:00-05:00 hours of a day from July, 2013 to June, 2015 in order to assess diversity and abundance of anthophilous insect fauna at three different study sites of BWLS. The collection of species of insects belonging to different orders was made by hand picking, net sweeping and aspirator methods (Gadgkar *et al.*, 1990 and Jonathan, 1990). The collected insects were preserved, identified using insect identification guides and by the scientists in Entomological Division of Forest Research Institute, Dehradun, India and later sorted taxonomically into different families and orders to prepare an inventory of anthophilous insect fauna of BWLS. Status to individual species was assigned as Very Common (VC) when counted in large numbers, Common (C) when observed regularly, Uncommon (UC) when recorded occasionally and Rare (R) when recorded rarely. Lastly, the collected data on pollination was analysed statistically using the program PAST (2005) in order to determine various measures of alpha diversity.

RESULTS AND DISCUSSION

During the present systematic survey on anthophiles of temperate region, a total of 2177 individuals of 53 species under 18 families belonging to four orders of classs Insecta were counted in the activity of pollination across the

Table 1. Characteristic features of the study sites at Binsar Wildlife Sanctuary (BWLS)

Study sites	Altitude (m) above sea level	Geographical Co-ordinates	Dominant plant species
Site-1 Ayarpani —	1757m	N-29°40.255' E-79°42.325'	*Pinus roxburghii*, *Pyrus pashia*, *Myrica esculenta*, *Quercus leucotrichophora*, *Viburnum continifalium*, *Viburnum mullah*, *Eupatorium adenopharum*, *Bergenia ciliate*, *Carex condensata*, *Arisaema propinquum* and *Trifolium repens*.
Site-2 Binneshwar Mahadev	2191m	N-29°41.965' E-79°44.950'	*Quercus semecarpifolia, Quercus floribunda, Aesculus indica, Rhododendron arboreum, Ainsliaea aptera, Artemisia nilagirica, Conyza javanica, Gallium elegens, Bistorta amplexicaulis, Circium arvense, Chrysopogon gryllus and Cynotis vaga.*
Site-3 Jhandi Dhar	2450m	N-29°42.443' E-79°45.254'	*Cedrus deodara, Quercus semecarpifolia, Quercus glauca, Quercus floribunda, Quercus leucotrichophora, Inula cuspidate, Myrsine africana, Rubus paniculatus, Artemisia nilagirica, Arundinella nepalensis, Calamintha umbrosa, Conyza japonica and Cynoglossum dentculatum.*

different study sites of BWLS (Table 2). Of these, maximum number of species belonged to the order Lepidoptera (33 species), followed by Hymenoptera (11 species), Diptera (five species) and Coleoptera (four species), respectively. The order Lepidoptera was found to be most abundant pollinator group with 64.03% of total individuals recorded, followed by Hymenoptera (15.02%), Coleoptera (13.55%) and Diptera (7.4%), respectively (Fig. 2). Such variations in dominance among insect community with Lepidoptera being predominant pollinator group also support to earlier findings from the different ecosystems of Western Himalaya (Joshi and Joshi, 2010; Pandey *et al*., 2013; Arya, 2015). However, studies that were confined to temperate fruit orchards have reported order Hymenoptera and Diptera of prime significance (Mattu *et al*., 2012; Raj *et al*., 2012; Sharma and Mitra, 2012; Ganie *et al*., 2013; Raj and Mattu, 2014; Mattu and Bhagat, 2015; Kapkoti *et al*., 2016). Table 3 shows variation in the pattern of alpha diversity indices among different orders of anthophilous insects during the entire study period. The value of Shannon Wiener Diversity index (H') was calculated as 3.608 for overall samplings of insect assemblage depicting a rich diversity of insect pollinators in the protected area.

Based on observations a highest number of 29 species belonging to different orders were categorized as uncommon during the study period whereas, species of the order Lepidoptera such as *Aglais cashmiriensis* Kollar, *Vanessa indica* Herbst, *Pieris canidia indica* Evans and *Coccinella septumpunctata* Linnaeus of the order Coleoptera were recorded as very common and most abundant species across different study sites. On the other hand, seven species of Lepidoptera, three species of Hymenoptera, two species each of Diptera and Coleoptera were found common. Apart from this, species such as *Acraea issoria anamala* Kollar, *Aulocera padama* Kollar, *Lasiommata schakra schakra* (Kollar), *Pontia daplidice* (Linnaeus) of the order Lepidoptera and *Salius flavus* Fabricius, *Scolia venusta* Smith of the order Hymenoptera were recorded as rare species in the sanctuary.

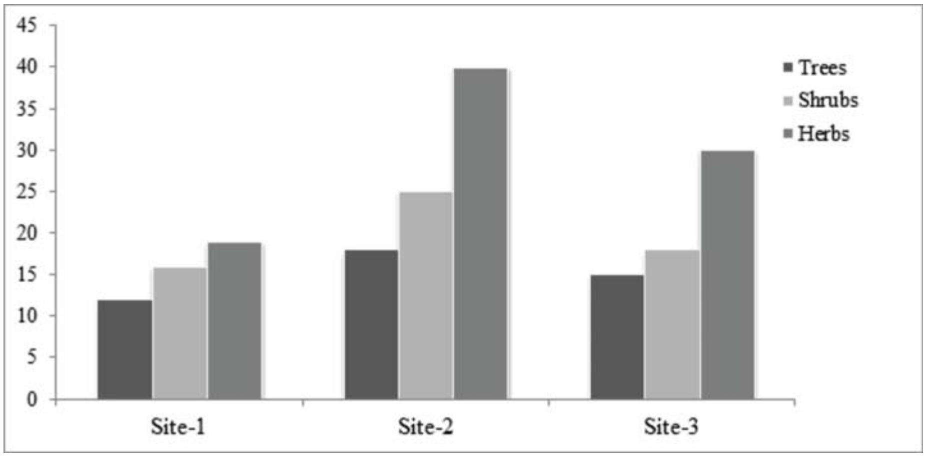

Fig. 1. Graph showing relative numbers of plant diversity recorded from different study sites of BWLS.

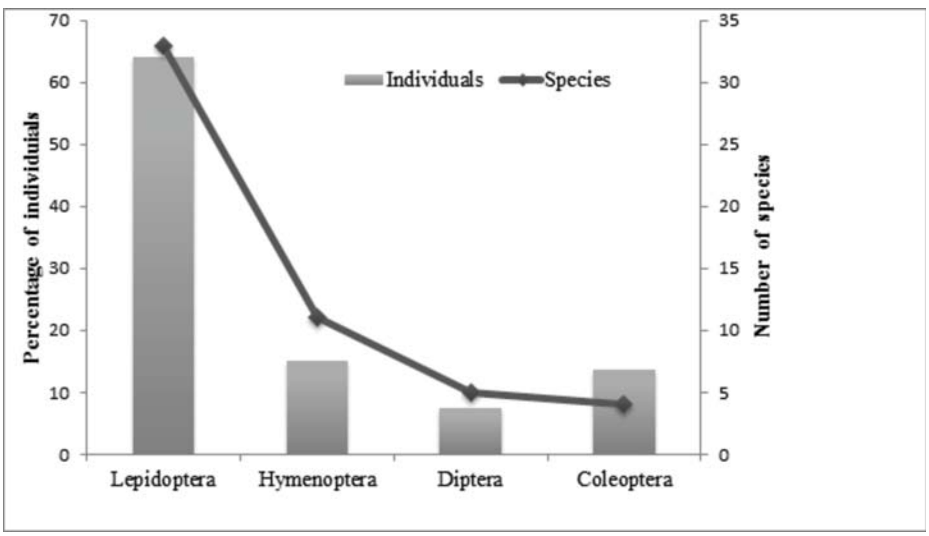

Fig. 2. Graph of species richness and abundance of different insect orders recorded as anthophiles during 2013-15

In the temperate regions the temporal variation in abundance and activity of herbivorous insects varies substantially, as related in response to more dramatic changes in weather conditions such as temperature maxima and minima, sunshine hours and rainfall then in the tropics with moderately constant environment (Wolda, 1988; Nestel *et al*., 1994; Speight *et al*., 1999). During the present study, out of total recorded species, 43 species were found in Site-1, followed by 41 species in Site-2 and 34 species in Site-3, respectively. Data in Table 4 shows the various measures of alpha diversity calculated for insect pollinator's community across different study sites. In general, the values of Shannon Wiener Diversity index (H'), Margalef's Diversity index (D) and Simpson's Dominance index varied significantly across the study sites showing decreasing trends in diversity, species richness and dominance of certain species of insect pollinators in response to variations in altitude (Rahbek, 1995; Malo and Baonza, 2002; Medan *et al*., 2002), habitat types and quality (Steffan-Dewenter and Tscharntke, 1999; Devoto *et al*., 2005; Kovas-Hostyanszki *et al*., 2014). Moreover, the

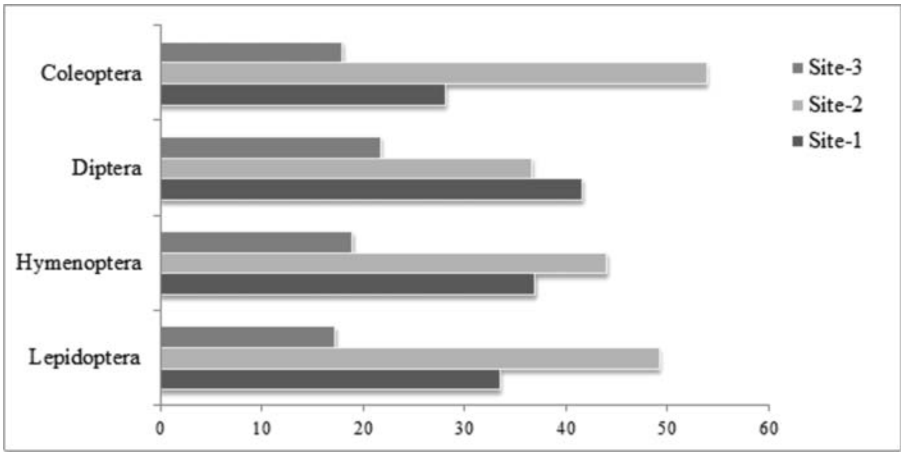

Fig. 3. Graph showing relative percentage composition of individuals of each order at different study sites

percentage of abundance of representative species and Pielou's Evenness index (J') was recorded highest for Site-2 i.e., 48.14% and 0.934, respectively expressing more even distribution of anthophilous insects. This might be attributed to efficient sharing of resources by each species as maximum number of plants was reported from Site-2 as compared to Site-1 and Site-3.

Fig. 3 indicates the relative percentage composition of individuals of each order at different study sites, wherein order Diptera shows a decreasing pattern of abundance with increasing altitudes of study sites. This is in slight contradiction with previous studies which suggests more abundance of flies at higher altitudes (Arroyo *et al*., 1982; Kearns, 1992; Devoto *et al*., 2005). However, the other three orders were abundant at Site -2, followed by Site-1 and least in Site-3, thus favoring the prevalence of more heterogeneous environment at Site-2. Overall, least abundance of insect assemblage at Site-3 might be due to more humid and wetter environment of the region which shows the least diversity of flower visiting taxa (Devoto *et al*., 2005). Out of total recorded species, 43.39% species have been recorded from all study sites in BWLS whereas 20.75% species were found restricted to only a single study site and hence can be considered as unique species. Species like *Scolia venusta* Smith of the order Hymenoptera and *Tabanus orientis* Walker of the order Diptera were reported only in the study Site-1. Species belonging to the order Lepidoptera such as *Danaus chryssippus* (Linnaeus), *Pseudoergolis wedah* (Kollar), *Phalanta phalantha* (Drury), *Anapheis aurata aurata* (Fabricius), *Eurema laeta laeta* Boisduval and those belonging to the order Hymenoptera like *Vespa* sp. and *Xylocopa fenesrata* Fabricius were restricted only to study Site-2. Such habitat specificity can be directly linked with the ecological demands of species such as the availability of host plants, atleast in the case of Lepidoptera (Thomas, 1995; Khan *et al*., 2011).

Patterns of plant-pollinators interactions may vary from species to species, with few species of insects are highly specialized while most of them show high degree of generalization (Faegri and Van-Der-Pijl, 1979). In the present study, members of plant families Asteraceae, Fabaceae, Rosaceae and Urticaceae and more importantly species like *Cirsium verutum*, *Circium arvense*, *Erigeron bonasiensis*, *Trifolium repens*, *Trifolium indicum* and *Pelia scripta* constituted important foraging plants throughout the years. Being predominant, the order Lepidoptera formed potential pollinator group among recorded

Table 2. Distribution pattern and relative abundance of different identified species of class Insecta recorded as anthophiles from BWLS

Sl. No.	Species Composition	Distribution at study areas			Relative Abundance	Status
		Site-1	Site-2	Site-3		
	Order: Lepidoptera					
	Family: Nymphalidae					
1.	*Acraea issoria anamala* Kollar	+	+	-	0.32	R
2.	*Aglais cashmiriensis* Kollar	+	+	+	8.45	VC
3.	*Argyreus hyperbius* Johanssen	+	-	+	0.96	UC
4.	*Aulocera padama* Kollar	-	-	+	0.04	R
5.	*Aulocera swaha swaha* Kollar	+	+	+	2.15	C
6.	*Danaus chryssippus* (Linnaeus)	-	+	-	0.64	UC
7.	*Euploea core* (Cramer)	+	+	-	1.28	UC
8.	*Kallima inachus* Boisduval	+	+	-	0.50	UC
9.	*Lasiommata schakra schakra* (Kollar)	+	+	-	0.32	R
10.	*Pseudoergolis wedah* (Kollar)	-	+	-	0.78	UC
11.	*Phalanta phalantha* (Drury)	-	+	-	1.10	UC
12.	*Sephisa dichroa* (Kollar)	+	-	+	0.50	UC
13.	*Vanessa cardui* Linnaeus	+	+	+	1.05	UC
14.	*Vanessa indica* Herbst	+	+	+	5.51	VC
	Family: Pieridae					
15.	*Anphaeis aurata aurata* (Fabricius)	-	+	-	1.15	UC
16.	*Catopsilia pomona* Linnaeus	+	+	-	4.08	C
17.	*Colias electo fieldi* Menetries	+	-	+	1.98	C
18.	*Eurema brigitta rubella* Wallace	+	+	-	1.83	UC
19.	*Eurema hecabe* Linnaeus	+	+	+	3.50	C
20.	*Eurema laeta laeta* Boisduval	-	+	-	0.82	UC
21.	*Gonepteryx rhamni nepalensis* Linnaeus	+	+	+	2.94	C
22.	*Metaporia agathon* (Gray)	+	+	+	0.91	UC
23.	*Pieris brassicae* Linnaeus	+	+	+	4.40	C
24.	*Pieris canidia indica* Evans	+	+	+	8.13	VC
25.	*Pontia daplidice* (Linnaeus)	-	-	+	0.13	R
	Family: Lycaenidae					
26.	*Heliophorus sena* Kollar	+	+	+	1.83	UC
27.	*Lycaena pavana* (Kollar)	+	-	+	0.78	UC
	Family: Papilionidae					
28.	*Byasa polyeuctes* Doubleday	+	+	+	0.82	UC
29.	*Papilio polyctor* Boisduval	+	+	+	1.42	UC
30.	*Papilio polytes romulus* Linnaeus	+	+	+	2.11	C
	Family: Arctiidae					
31.	*Ceryx imaon* Cramer	+	+	-	1.60	UC
	Family: Noctuidae					
32.	*Calpe ophideroides* Guen.	+	-	+	0.64	UC

	Family: Sphingidae					
33.	*Macroglossum* sp.	+	-	+	1.24	UC
	Order: Hymenoptera					
	Family: Apidae					
34.	*Anthophora confusa* Smith	+	-	+	0.96	UC
35.	*Apis laboriosa* Smith	+	+	-	1.28	UC
36.	*Bombus haemorrhoidalis* Smith	+	+	-	2.52	C
37.	*Bremus* sp.	+	+	+	1.42	UC
38.	*Crocisa ramosa* Lepeletier	+	+	+	1.93	C
39.	*Coelioxy* sp.	+	+	+	1.10	UC
	Family: Scoliidae					
40.	*Compsomeris asiatica himalaya* Bar.	+	+	+	3.07	C
41.	*Scolia venusta* Smith	+	-	-	0.42	R
	Family: Pompilidae					
42.	*Salius flavus* Fabricius	-	+	+	0.42	R
	Family: Vespidae					
43.	*Vespa* sp.	-	+	-	1.10	UC
	Family: Xylocopidae					
44.	*Xylocopa fenestrata* Fabricius	-	+	-	0.78	UC
	Order: Diptera					
	Family: Tabanidae					
45.	*Pangonia longirostris* Hardwicke	+	+	-	2.06	C
46.	*Philoliche* sp.	+	-	+	0.55	UC
47.	*Tabanus orientis* Walker	+	-	-	0.82	UC
	Family: Syrphidae					
48.	*Syrphus fulvifacies* Brunetti	+	+	+	2.25	C
	Family: Tipulidae					
49.	*Tipula himalayensis* Brunetti	+	+	+	1.70	UC
	Order: Coleoptera					
	Family: Chrysomelidae					
50.	*Altica himensis* Shukla	+	+	+	4.18	C
	Family: Coccinelidae					
51.	*Coccinella septumpunctata* Linnaeus	+	+	+	5.60	VC
	Family: Meloidae					
52.	*Mylabris cichorii* Linnaeus	+	+	+	2.98	C
53.	*Mylabris* sp.	+	+	+	0.78	UC

anthophiles during the present study. Species like *Aulocera swaha swaha* Kollar, *Vanessa cardui* Linnaeus, *Pieris canidia indica* Evans and *Byasa polyeuctes* Doubleday were foraging on *Aesculus indica* (Indian horse-chestnut) while species such as *Aglais cashmiriensis* Kollar, *Vanessa indica* Herbst, *Eurema hecabe* Linnaeus, *Colias electo fieldi* Menetries and *Papilio polytes romulus* Linnaeus were found frequent on plant species like *Cirsium verutum*, *Circium arvense*, *Eupatorium adenopharum*, *Gallium rotundifolium* and *Urtica dioca*. Species such as *Aulocera padama* Kollar, *Anphaeis aurata aurata* (Fabricius) and

Table 3. Variation in the pattern of alpha diversity among different orders of anthophilous insects in the BWLS

Diversity Indices	Lepidoptera	Hymenoptera	Diptera	Coleoptera	Total
Simpson	0.9361	0.8778	0.7584	0.6819	0.9639
Shannon	3.064	2.233	1.495	1.226	3.608
Margalef	4.42	1.727	0.7872	0.5275	6.766
Pielou/ Equitability	0.8764	0.9313	0.9288	0.8841	0.9088

Table 4. Variation in the diversity indices values of insects as calculated for different study sites in the BWLS

Diversity Indices	Site-1	Site-2	Site-3
Simpson	0.9626	0.9625	0.9457
Shannon	3.488	3.469	3.179
Margalef	6.36	5.752	5.529
Pielou/ Equitability	0.9274	0.9341	0.9016

Gonepteryx rhamni nepalensis Linnaeus were found nectaring on plant species namely, *Pyracantha crenulata*, *Anaphalis contorta* and *Salvia* sp., respectively. Species belonging to family Lycaenidae such as *Heliophorus sena* Kollar and *Lycaena pavana* (Kollar) were reported on *Fragaria daltoniana*, *Indigofera dosua*, *I. heterantha*, *Anaphalis cinnamonea* and *Circium arvense*. *Macroglossum* sp. of family Sphingidae was collected on *Arisaema propinquum* and moreover, family Sphingidae constitutes a major class of pollinator in many parts of the world (Frankie *et al*., 1983; Opler, 1983). Among Hymenoptera, members of the family Apidae are highly adapted and diverse anthophiles structurally, behaviorally and taxonomically (Kevan, 2003a). During the present study, *Bombus haemorrhoidalis* Smith, *Bremus* sp. and *Coelioxy* sp. were found on plants like *Berberis asiatica*, *Calamintha umbrosa*, *Digitalis purpurea*, *Inula cuspidate*, *Oxalis corniculata*, *Pyracantha crenulata*, *Rubus ellipticus*, *Rubus lasiocarpus*, *Rubus paniculatus*, *Bistorta amplexicaulis* and *Verbena officinalis* whereas species namely, *Anthophora cuspida* Smith and *Apis laboriosa* Smith were counted on plant species like *Lyonia ovalifolia*, *Pyrus pashia* and *Rhododendron arboretum*. Members of family Scoliidae, Pompilidae, Vespidae and Xylocopidae were collected on plants belonging majorly to families Araceae, Asteraceae, Geraniaceae and Fabaceae. In addition, species of *Xylocopa* are considered as important and most generalized pollinators in the natural ecosystems of the world (Raju and Reddi, 2000; Chamorro *et al*., 2012; Senapathi *et al*., 2015). In the present study, species like *Syrphus fulvifacies* of family Syrphidae belonging to the order Diptera were recorded on *Erigeron bonasiensis* and *Myrsine semiserrata* while species of the families Tabanidae and Tipulidae were found on *Berberis asiatica*, *Daphne papyracea*, *Deutzia staminea*, *Erythrina arborescens*, *Hypericum hookerianum*, *Inula cuspidate*, *Rubus ellipticus*, *Arisaema tortuosum*, *Bistorta amplexicaulis*, *Roscoea procera*, *Pyrus pashia* and *Sonchus oleraceus*. Similarly, species belonging to the order Coleoptera such as *Altica himensis* Shukla, *Coccinella septumpunctata* Linnaeus, *Mylabris cichorii* Linnaeus and *Mylabris* sp. were counted on

Circium arvense, *Cirsium verutum*, *Erigeron bonasiensis*, *Erythrina arborescens*, *Gallium elegans*, *Gallium rotundifolium*, *Geranium nepalense*, *Potentilla fulgens* and *Urtica dioca*.

The present study is the first of this type of study in the area of BWLS that might serve as a baseline data for future plant-pollinators relationships in the region. Our results suggest that rich assemblage of insects like butterflies, bees, wasps, flies and beetles constituted one among the primary groups of pollinators of biologically diverse wild plants with few species highly restricted to particular study sites. These species can be used to monitor environmental and climatic changes as they show a high degree of specialization and are critical to healthy and sustainable ecosystems. Moreover, the differences in the subsequent interactions of plant-pollinators may depend on several intrinsic and extrinsic factors that prevailed in the different habitats during the entire study period.

ACKNOWLEDGEMENTS

Authors would like to thank Divisional Forest Officer, Almora Forest Division and Range Officer, Binsar Wildlife Sanctuary of Uttarakhand Forest Department for providing us necessary permission required for the present study. We are also grateful to scientists of Forest Research Institute, Dehradun for their cooperation in identification of insect species.

REFERENCES

Arroyo M.T.K., Primack R. and Armesto J. (1982) Community studies in pollination ecology in the high temperate Andes of central Chile. I. Pollination Mechanisms and Altitudinal Variation. American Journal of Botany 69(1): 82-97.

Arya M.K. (2015) Observations on trophic levels of different groups of insect population vis a vis insect pollinators in a protected forest ecosystem in Western Himalayas. Journal of Experimental Zoology India 18(1): 271-277.

Ashman T.L., Knight T.M., Steets J.A., Amarasekare P., Burd M., Campbell D.R., Dudash M.R., Johnston M.O., Mazer S.J., Mitchell R.J., Morgan M.T. and Wilson W.G. (2004) Pollen limitation of plant reproduction: ecological and evolutionary causes and consequences. Ecology 85: 2408-2421.

Brashares J.S. (2003) Correlates of extinction in West Africa. Conservation Biology 17: 734-743.

Brunismann A.G., De Souza M.M., Pires E.P., Coelho E.L. and Milani L. R. (2016) Social wasps (Hymenoptera: Vespidae) in deciduous seasonal forest in Southeastern Brazil. Journal of Entomology and Zoology studies 4(4): 447-452.

Campbell J.W. and Hanula J.L. (2007) Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. Journal of Insect Conservation 11: 399-408.

Carvell C., Roy D.B., Smart S.M., Pywell R.F., Preston C.D. and Goulson D. (2006) Declines in forage availability for bumblebees at a national scale. Biological Conservation 132: 481-489.

Chamorro S., Heleno R., Olesen J.M., McMullen C.K. and Traveset A. (2012) Pollination patterns and plant breeding systems in the Galapagos: a review. Annals of Botany 110: 1489- 1501.

Devoto M., Medan D. and Montaldo N.H. (2005) Patterns of interaction between plants and pollinators along an environmental gradient. Oikos 109: 461-472.

Faegri K. and Van-der-pijl L. (1979) The principles of pollination ecology. Third edition, Pergamon Oxford. 244 pp.

Frankie G.W., Opler P.A. and Bawa K.S. (1983) Characteristics & organization of large bee pollination system in Costa Rica dry forest. In: Handbook of experimental pollination biology, New York, U.S.A. pp. 411- 447.

Gadgakar R., Chandrashaekara K. and Nair P. (1990) Insect species diversity in the tropics: sampling method and case study. Journal of Bombay Natural History Society 87(3): 337-353.

Ganie M. A., Pal A. K. and Ahmad N. (2013) Native insect pollinators in apple orchards under different management practices in the Kashmir Valley. Turkish Journal of Agriculture- Food Science and Technology 1(1): 29-36.

Gilgert W. and Vaughan M. (2011) The value of pollinators and pollinator habitat to Rangelands: Connections among pollinators, insects, plant communities, fish and wildlife. Rangelands, Society for Range Management. pp. 14-19.

Hussain A., Khan M. R., Gaffar A., Alia H. and Jamil A. (2012) The hymenopterous pollinators of Himalayan foothills of Pakistan (distributional diversity). African Journal of Biotechnology 11(28): 7263-7269.

Jonathan J. K. (1990) Collection and preservation of animals (Hymenoptera). Zoological Survey of India, Calcutta. pp 147-150.

Joshi P. C. and Joshi N. C. (2010) Secondary productivity of entomofauna in fruit orchards of district Nainital, Uttarakhand, India. Journal of Environment and Biosciences 24(1): 13-17.

Kapkoti B., Joshi R. K. and Rawal R. S. (2016) Variation in the abundance and diversity of insects in apple orchards of Kumaun, Western Himalaya, India. Current Science 110(3): 438- 443.

Kearns C. A. (1992) Anthophilous fly distribution across an elevation gradient. The American Midland Naturalist 127: 172- 182.

Kevan P. G. (1999) Pollinator as bioindicators of the state of the environment: species, activity and diversity. Agriculture, Ecosystems and Environment 74: 373- 393.

Kevan P. G. (2003a) The global decline of pollination services. Biodiversity 4(4): 3- 8.

Kevan P. G. (2003b) Pollination for the 21st Century; integrating pollinator and plant interdependence. In: for Nonnative crops, whence Pollinators of the future Cane (Eds.)., Thomas Say Publication of the Entomological Society of America, Lanham, Maryland, U.S.A. pp. 181- 204.

Kevan P. G. and Baker H. G. (1983) Insect as flower visitor and pollinators. Annual Review of Entomology 28: 407- 453.

Kevan P. G. and Baker H. G. (1998) Insects on flowers. In: Ecological Entomology, A. P. (Ed.). New York: Wiley. pp. 553- 584.

Khan A. R., Khan A. B., Mukhtar M. K. and Ramzan M. (2016) Estimation of abundance, distribution pattern and diversity of cash crop hymenopteran pollinators (Super family: Apoidae; Vespoidae) from irrigated areas of district Bhakkar and Layyah, Punjab, Pakistan. Journal of Entomology and Zoology Studies 4(5): 994- 998.

Khan Z. H., Raina R. H., Dar M. A. and Ramamurthy V.V. (2011) Diversity and distribution of Butterflies from Kashmir Himalayas. Journal of Insect Science 24(1): 45- 55.

Klein A. M., Vaissiere B. E., Cane J. H., Steffan-Dwenter I., Cunnigham S. A., Kremen C. and Tscharntke T. (2007) Importance of pollinators in changing landscapes for world crops. Biological Sciences , Proceedings of the Royal Society B, London 274: 303- 313.

Kovas-Hostyanszki A., Korosi A., Orci K. M., Batary P. and Baldi A. (2014) Set – aside promotes insect and plant diversity in a Central European country. Agriculture, Ecosystems and Environment 141: 296- 301.

Malo J. E. and Baonza J. (2002) Are there predictable clines in plant-pollinator interactions along altitudinal gradients? The example of *Cytisus scoparius* (L.) Link in the Sierra de Guadarrana (Central Spain). Diversity and Distributions 8: 365- 371.

Mattu V. K. and Bhagat T. (2015) Effects of changing landscapes on diversity, distribution and relative abundance of insect pollinators on apple crop in Northwest Himalayas. International Journal of Science and Research 4(5): 1762- 1767.

Mattu V. K. and Bhagat T. (2016) Foraging strategies of honey bees in pollinating apple flowers and its variation with altitude in Kullu hills of Western Himalaya, India. Journal of Entomology and Zoology Studies 4(1): 164- 169.

Mattu V. K., Raj H. and Mattu N. (2012) Pollinator diversity and relative abundance studies on apple crop in Shimla Hills, Himachal Pradesh. HP University Journal 1(2): 130- 135.

Medan D., Montaldo N. H., Devoto M., Mantese A., Vasellati V., Roitman G. G. and Bartoloni N. H. (2002) Plant- pollinator relationships at two altitudes in the Andes of Mendoza, Argentina. Arctic, Antarctic and Alpine Research 34(3): 233-241.

Mishra R. M., Gupta P. and Yadav G. P. (2004) Intensity and diversity of flower of flower–visiting insects in relation to plant density of *Zizyphus mauritiana* Lamk. Tropical Ecology 45(2): 263- 270.

Nestel D., Dickschen F. and Alteiri M. A. (1994) Seasonal and spatial population loads of a tropical insect: the case of the coffee leaf miner in Mexico. Ecological Entomology 19: 159- 167.

Ollerton J., Winfree R. and Tarrant S. (2011) How many flowering plants are pollinated by animals? Oikos 120: 321- 326.

Opler P. A. (1983) Nectar production in Tropical Ecosystem. In: Biology of Nectaries, Columbia University Press, New York, U.S.A. pp. 30- 79.

Pandey P., Joshi P. C. and Kaushal B. R. (2013) Role of insects in sustaining a forest ecosystem in

Western Himalaya, India. Journal of Applied Biosciences 39(1): 1- 22.

Pillay R., Johnsingh A. J. T., Raghunath R. and Madhusudan M. D. (2011) Patterns of spatiotemporal change in large mammal distribution and abundance in the southern Western Ghats, India. Biological Conservation 144: 1567-1576.

Potts S. G., Biesmeijer J. C., Kremen C., Neumann P., Schweiger O. and Kunin W. E. (2010) Global pollinator declines: trends, impacts and drivers. Trends in Ecology and Evolution 25: 345- 353.

Rahbek C. (1995) The elevational gradient of species richness: a uniform pattern? Ecography 18: 200-205.

Raj H. and Mattu V. K. (2014) Diversity and distribution of insect pollinators on various temperate fruit crops of Himachal Pradesh, India. International Journal of Science and Nature 5(4): 626- 631.

Raj H., Mattu V. K. and Thakur M. L. (2012) Pollinator diversity and relative abundance of insect visitors on crop in Shimla Hills of Western Himalayas, India. International Journal of Science and Nature 3(3): 507-513.

Raju A. J. S. and Reddi C. S. (2000) Foraging behavior of carpenter bees, genus *Xylocopa*: Hymenoptera, and the pollination of some Indian plants. Journal of Bombay Natural History Society 93(3): 381- 389.

Senapathi D., Biesmeijer J. C., Breeze T. D., Kleijn D., Potts S. G. and Carvalheiro L. G. (2015) Pollinator conservation – the difference between managing for pollination services and preserving pollinator diversity. Current Opinion in Insect Science 12: 93- 101.

Sharma R. M. and Mitra B. (2012) A preliminary study on insect pollinators of temperate fruit crops in Himachal Pradesh. Records of the Zoological Survey of India 111(3): 103- 110.

Singh N. J. and Bagchi S. (2013) Applied ecology in India: scope of science and policy to meet contemporary environmental and socio-ecological challenges. Journal of Applied Ecology 50: 4- 14.

Speight M. R., Hunter M. D. and Watt A. D. (1999) Ecology of insects, concepts and applications. Blackwell Science, Oxford. 350 pp.

Steffan-Dewenter I. and Tscharntke T. (1999) Effects of habitat isolation on pollinator communities and seed set. Oecologia 121: 432- 440.

Stolton S., Dudley N., Avcioglu C. B., Hunter D., Ivanic K., Kanga E., Kettunen M., Kumagai Y., Maxted N., Senior J., Wong M., Keenleyside K., Mulrooney D. and Waithaka J. (2015) Values and benefits of protected areas. In: Protected Area Governance and Management, I. Pulsford (Eds.), ANU Press, Canberra, Australia. pp. 145- 168.

Thakur M. S. and Mattu V. K. (2010) The role of Butterfly as flower visitor and pollinators in Shiwalik Hills of Western Himalayas. Asian Journal of Experimental Biological Sciences 1(4): 822- 825.

Thomas J. A. (1995) The ecology and conservation of Maculinea arion and other European species of large blue butterfly. In: Ecology and Conservation of Butterflies, A. S. Pullin (Eds.), London: Chapman and Hall. pp. 180- 210.

Vanbergen A. and IPI (International Pollinator Initiative) (2013) Threats to an ecosystem service: pressures on pollinators. Frontiers in Ecology and the Environment 11: 251- 259.

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

Winfree R., Griswold T. and Kremen C. (2007) Effect of human disturbance on bee communities in a forested ecosystem. Conservation Biology 21(1): 213- 223.

Winfree R., Williams N. M., Gaines H., Ascher J. S. and Kremen C. (2008) Wild bee pollinators provide the majority of crop visitation across land-use gradients in New Jersey and Pennsylvania, USA. Journal of Applied Ecology 45: 793- 802.

Wolda H. (1988) Insect seasonality: why? Annual Review of Ecology and Systematics 19: 1-18.

(Received 19 March 2018; revised ms accepted 31 May 2018; published 08 June 2018)