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Species Diversity of Bumblebees (Hymenoptera: Apidae) from Different Mountain Regions of Kashmir Himalayas

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Abstract

The species diversity of bumblebees was investigated in three provinces Jammu, Kashmir and Ladakh during 2007-2010. Bumblebee queens, workers and males were collected right from the commencement till to the end of flowering stage in all the three mountain regions. In total, 27 species of bumblebees were collected and identified, of which eleven species were common in the two regions, e.g., Kashmir and Ladakh. A list of species assemblages and abundance is provided in each of the mountain ranges. Species diversity of three regions was determined with Shannon-Weiner diversity index and evenness was calculated with indices of Pielou. The obtained results showed species diversity; evenness and species richness were more observable in Kashmir compared with Ladakh and Jammu. The three sample sites within the Kashmir Himalayas indicate significant differences in species diversity; the Kashmir region had higher species diversity and richness than the other regions. Most species of bumblebees were collected in altitudinal ranges of 3000-4000m. Four species *viz. Bombus cornutus*, *B. parthenius*, *B. miniatus* and *B. morawitizianus* are recorded for the first time from this region, while *B. morawitizianus* turn out to be the first record to the national list.

Key words: Species Diversity; Bumblebees; Kashmir Himalayas.

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1. Introduction

Bumblebees belong to the genus *Bombus* Latreille, 1802 of the family Apidae, order Hymenoptera. Bumblebees rank among the most abundant and conspicuous of flower visitors in alpine, temperate and arctic environment of the northern continents. They are called primitively eusocial and are associated with the high lands and play a key role in the functioning of agricultural ecosystems as pollinators of crops, orchards and wild flowers. Almost all species of bumblebees are generalists in their choice of food plants, visiting any remunerative flowers. Their foraging follows a scramble pattern without either recruitment of nest mates to good food sources. These characteristics of bumblebees

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may account for their abundance in cool environments that have a predictable season of adverse conditions, where flowers are often fairly evenly dispersed. The Kashmir Himalayas, a floristically rich region extending from Pirpanjal, has tremendous variation in altitude, latitude, topography, rainfall and climate. This is responsible for great amount of biodiversity of the region, due to the varied geography, location, climate, rainfall and altitude, the vegetation in the area ranges from tropical deciduous forests to temperate and coniferous forests [1]. Temperature of the valley ranges from -7.8° (winter) to 36.6° (summer), with an average Altitude of 1650m and experiences a sub Mediterranean climate with annual precipitation of about 105cm. Because of extreme diverse physiography, the state shows an equally remarkable diversity in climate in its different regions. In the outer plains and outer hill regions of Jammu division the temperature averages around 30.1°C with a minimum of 11.5°C in winter to a maximum of 40.6°C in summer. In the interior of the middle Himalayan region and its adjoining regions it averages 13.3°C with mean maximum and minimum temperature of 30°C in summer and -2.1°C in winter, respectively.

Bumblebees of Kashmir Himalaya are of particular interest as this narrow corridor of mountain is almost the only major point of contact between the large and divergent bumblebees fauna of Oriental and Palaearctic regions. The fauna of these regions is separated by deserts in central Asia and in China, except for another corridor of contact near Beijing but with relatively few species [2]. Greater Kashmir encompasses almost the entire mountain system that links the high Tibetan (Xizang-Qinghai) plateau in the east with the Hindu Kush, Pamir and Tien Shan mountain ranges to the west and north covering segments of Pir Panjal, Great Himalaya, Zanskar, Ladakh, Karakoram and Hindu Raj ranges which include some of the highest peaks in the world with an altitudinal range of 400-8600m [3].

In Europe distributional patterns of the bumblebees have been linked with climatic factors [4]. High relief of Kashmir provides a broad range of habitats for bumblebees. With respect to climate, Kashmir is summarized into three regions [5]. Sub tropical region of the Jammu foot hills, subjected to summer monsoon; a range beyond Pir Panjal, temperate valley of Kashmir, with most of the rain and snow falling in the months of winter and the rain shadow of the Great Himalaya, an arid alpine region of Zanskar, Ladakh and Karakoram ranges. These three climatic regions differ in their flora influenced by local altitudinal zonation and variation in local exposure [6], contributing towards a broad range of habitats. In comparison with some parts of Himalaya, Kashmir retains relatively large forests yet access to these varied alpine areas is no longer difficult.

There are two hundred and fifty known species of bumblebees present on global basis [7]. The majorities of these species is known as ‘true’ bumblebees, and have a social worker caste which is more or less sterile. In fauna of British India 23 species of Bumblebees were recorded [8] that included some records from the neighbouring countries; as Myanmar, Bhutan, Nepal, etc. Subsequent workers added 149 species to this list, raising the total species number to 172, but due to lot of synonymy as put forth by Williams [9] only 47 species stand as valid. Genus *Bombus* is at present represented by

47 species from India out of which 26 species are reported from Kashmir alone [10]. Earlier, bumblebee studies from Kashmir Himalaya are based merely on a couple of hundred specimens. The first important collection of bumblebees from Kashmir was made by Col and Nurse in 1901. A complete inventory of this material was never published, although it provided the specimens that have since been described as the types of many nominal taxa [11-15]. Other important collections were carried out by Jacobson in Kashmir and Ladakh during 1912 [16] and by Meinertzhagen in Ladakh during 1925[17]. A preliminary list of the fauna of Kashmir was compiled by Skorikov [18] and discussed the fauna of the entire Himalaya, though his work based on different concepts of the species than what it is present. The only recent revision of some part of the large Himalayan fauna has been conducted by Tkalcu [15, 19] and included description of 73 bumblebees from Nepal. Although there are many elements in common between the faunas of Nepal and Kashmir, 16 species that are known from Kashmir are not represented in this collection. Recently he has described several new taxa from the region. The only key that has been intended to cover any part of the Himalayan fauna is that published by Bingham [8].The only commendable job on the bumblebees from Kashmir Himalaya is done by Williams [10], where he reported 29 species of bumblebees including some from Pakistan-administered Kashmir.

With the immense economic importance of these anthophilous insects and their association with entomophilous flowering plants, their species diversity and altitudinal distribution has already been well studied in many countries. Some important works have already been reported by several authors [10-13, 16, 20-22, 29-31]. They not only enlisted these insects, but provided comprehensive account on their associations with the host plants.

The earlier records show that genus Bombus was represented by 26 species from Kashmir Himalaya and 47 species from India as a whole [9, 10]. It is only under the present study that another species *viz. B. morawitizianus* has been inducted into this list thus raising the total to 48. Thus the main aim of this study was to evaluate the species richness and diversity of bumblebees in three different mountains regions of Kashmir Himalayas having the altitudional distribution ranging from 1000-5500m amsl.

2. Material and Methods

During 2007-10, thirty five major and fifteen minor collection cum survey tours were conducted in various localities situated in the state of Jammu and Kashmir. These include: Anantnag, Baramulla, Bandipora, Budgam, Kupwara, Pulwama, Srinagar, Ganderbal, Shopian, Kulgam, Kargil, Leh, Rajori, Poonch, Udhampur, Doda, Kishtiwar and Ramban, which are located at an elevation ranging from 1000m to 5500m amsl. These localities were systematically explored, every year twice or thrice (April to July for queens and August to October for workers and males) for the collection of all the three castes of every species. Attention was paid to the areas above 2000m. Altitude of each site was measured with digital altimeter. Sampling was conducted at sites dominated by the most

representative vegetation types of the region.

Bumblebees were collected with sweeping hand net made up of nylon cloth and latter killed with ethyl acetate. Some collection was also made with the help of malaise trap. Most of the collections were available from open areas rather than closed ones. The collection was based mainly on random sampling methods, covering different agro-ecosystem(s). In addition to collection their live photography was done with Olympus camera equipped with different macro lenses. During the study it was found that bumblebee collection with sweeping hand net was found more effective than malaise trap, the latter does not work at high altitude because of very high wind velocity accompanied with intermittent rains.

2.1. *Killing and setting techniques*

The collected insect material was first sorted out in the field and latter brought to the laboratory for further identification and analysis. For the collection of these insects, special transparent killing jars were designed, so as to preserve the colour of the pubescence. As the colour of the pubescence in bumblebees holds great importance in identification of species, so its proper care was taken during the collection period. Keeping in view the delicacy and grace of pubescence, insects killed in the killing jar were continuously shifted to other jar of same size so as to protect the pubescence. After coming to the laboratory, the specimens were pinned with the help of entomological pins of different sizes, keeping in view the size of specimen. After stretching the specimens were appended with data label containing the important information regarding its locality, altitude, date of collection and name of the collector. Later on, stretched specimens were transferred to the storage boxes, poisoned with ethyl acetate soaked cotton and napthalene powder filled in the side grooves of boxes. All the identified specimens have been deposited in the Department of Zoology, Punjabi University, Patiala for future references.

2.2. *Identification*

While dealing with bumblebee taxonomy in general, the following taxonomic characters were found trust worthy, stable and unambiguous *viz.*, colour of the pubescence, ocello-ocular area, inter ocellar distance, length of malar space, sculpturing of the labrum, length of antennal segments 3, 4 and 5, mandibular teeth number, 7th tergum & sternum in females, shape of mesobasitarsus and corbicular area on metabasitarsus and different parts of male genitalia. Two major keys which were helpful and repeatedly consulted in this connection were by Bingham and Williams [8, 10].

2.3. *Species diversity index*

Species diversity index of bumblebees was calculated after completing the identification of bumblebees. Species diversity index (H) was calculated with Shannon-wiener function [23] as:

$$H = \sum P_i (\ln P_i)$$

where $P_i = N_i/N$, N_i = total number of individuals in a species, N = total number of individuals in all species.

Evenness (j) was calculated to estimate the equitability component of diversity using the formula [24]:

$$j = H/\log_{10}S$$

Richness was computed by using formula [25]:

$$ma = S\text{-}1/\log_{10}N,$$ where S = total number of species collected.

3. Results and Discussion

During the present investigations 27 species of bumblebees, belonging to 10 subgenera of the genus *Bombus* were found in the Kashmir Himalaya within an altitudinal range and are shown in Table 1. Subgenus *Melanobombus* has been found to be represented by maximum number of seven species, followed by *Psithyrus* with five, *Pyrobombus* with four, *Bombus*, *Mendacibombus*, *Subterranobombus* and *Sibiricobombus* with two each while the remaining subgenera such as *Alpigenobombus*, *Megabombus* and *Orientalibombus* have been found to be represented with one species each (Table 2).

Table 1. Total number of bumblebee species recorded from Jammu and Kashmir.

Sl. No.	Name of the species	q	w	m	Total catch
1.	*B. asiaticus* Morawitz, 1875	51	159	146	356
2.	*B. avinoviellus* Skorikov, 1914	2	48	82	132
3.	*B. branickii* Radoszkowski, 1893	1	0	1	2
4.	*B. cornutus* Frison, 1933	0	0	2	2
5.	*B. ferganicus* Radoszkowski, 1893	31	0	78	109
6.	*B. haemorrhoidalis* Smith, 1852	2	2	21	25
7.	*B. himalayanus* Skorikov, 1914.	0	2	0	2
8.	*B. kashmirensis* Friese, 1909	4	12	10	26
9.	*B. keriensis* Morawitz, 1886	4	43	63	110
10.	*B. ladakhensis* Richards, 1928	0	12	0	12
11.	*B. lemniscatus* Skorikov, 1912	0	26	10	36
12.	*B. lepidus* Skorikov, 1912	0	5	3	8
13.	*B. lucorum* Linnaeus, 1761	17	67	84	168
14.	*B. morawitizianus* Popov, 1931	4	0	0	4
15.	*B. melanurus* Lepeleitier, 1836	42	187	203	432

Table 1 (contd.)

16.	*B. miniatus* Bingham, 1897	0	2	2	4
17.	*B. novus* Frison, 1933	2	0	0	2
18.	*B. oberti* Morawitz, 1883	1	0	0	1
19.	*B. parthenius* Richards, 1934	0	2	2	4
20.	*B. personatus* Smith, 1879	0	3	0	3
21.	*B. pyrosoma* Morawitz, 1890	20	0	31	51
22.	*B. rufofasciatus* Smith, 1852	38	155	197	390
23.	*B. semenovianus* Skorikov, 1914	7	32	26	65
24.	*B. simillimus* Smith, 1852	109	200	237	546
25.	*B. subtypicus* Skorikov, 1914	0	40	50	90
26.	*B. trifasciatus* Smith, 1852	42	201	138	381
27.	*B. tunicatus* Smith, 1852	93	251	389	733
Total catch		470	1449	1775	3694

Table 2. Diversity index, richness and evenness of different subgenera of genus *Bombus* from Kashmir Himalaya.

Sl. No.	Subgenus	Total No. of ind. in species	Total No. of species	Species diversity index (H)	Species richness (ma)	Species evenness (j)
1.	*Alpigenobombus*	26	01	0	0	0
2.	*Bombus*	901	02	0.20892	0.338441	0.694017
3.	*Megabombus*	381	01	0	0	0
4.	*Melanobombus*	1178	07	0.56702	1.953669	0.670952
5.	*Mendacibombus*	134	02	0.03369	0.470123	0.111916
6.	*Orientalibombus*	25	01	0	0	0
7.	*Psithyrus*	119	05	0.17392	1.927203	0.248823
8.	*Pyrobombus*	138	04	0.38958	1.401948	0.647078
9.	*Sibiricobombus*	357	02	0.00837	0.391747	0.027805
10.	*Subterranobombus*	435	02	0.01789	0.379005	0.059429

Species diversity index and richness of bumblebees is found to be highest at altitudinal range of 3000-3999m (1.06115 and 7.492262 respectively) followed by 4000-4999m (1.02325 and 5.937445); 2000-2999m (0.97794 and 5.006415); 1000-1999m (0.59786 and 1.7996) and lowest diversity index and richness is found at 5000-5500m (0.28731 and 0.724527). Evenness of bumblebee species is found to be highest at 5000-5500m followed by 1000-1999m (Table 3). Species richness is found highest in subgenus *Melanobombus* (1.927203) followed by *Pyrobombus* (0.38958); *Psithyrus* is next

subgenus in the hierarchy of species richness (1.9272). Evenness is found to be highest in subgenus *Bombus* (0.694017) while its species richness is lowest (0.338441); three subgenera, *Alpigenobombus*, *Megabombus* and *Orientalibombus* represent only one species each. Lowest species diversity was found in case off subgenus *Sibiricobombus* (0.00837) (Table 2).

Table 3. Species diversity index, richness and evenness of bumblebee species collected from different altitudes of Kashmir Himalaya.

Altitude (amsl)	Total No. of species collected	No. of ind. in all species	Species diversity index (H)	Species richness (ma)	Species evenness (j)
0 - 999	0	0	0	0	0
1000 - 1999	05	167	0.59786	1.7996	0.855344
2000 - 2999	17	1570	0.97794	5.006415	0.794783
3000 - 3999	25	1597	1.06115	7.492262	0.759081
4000 - 4999	16	336	1.02325	5.937445	0.849791
5000 - 5500	02	24	0.28731	0.724527	0.954423

The species abundance recorded from Kashmir Himalaya is in the following order: *B. tunicatus* (733); *B. simillimus* (546); *B. melanurus* (432); *B. rufofasciatus* (390); *B. trifasciatus* (381); *B. asiaticus* (356); *B. lucorum* (168); *B. avinoviellus* (132) ; *B. kerie nsis* (110); *B. ferganicus* (109) and *B. subtypicus* (90). Least abundant species is *B. obe rti* (1); *B. branickii; B. cornutus; B. himalayanus; B. novus* are represented by 2 individuals each*; B. personatus* by 3; *B. parthenius; B. morawitizianus; B. miniatus* by 4; *B. lep idus* by 8 and *B. ladakhensis* by 12. The other scarce species recorded include *B. haemo rrhoidalis* (25); *B. kashmirensis* (26); *B. lemniscatus* (36); *B. semeovianus* (65) and *B. pyrosoma* (51). *B. morawitizianus* (4), which is first record from India was found only once in Gurez valley (Table 1).

Species composition and distributional patterns of Bumblebees varies with altitude. Preference to a specific altitude (1000-5500m), with different mean elevations is observed for each species. Highest diversity is found at 3000–3999m with 25 species and 1597 individuals, followed by 2000m-2999m with 17 species and 1570 individuals; 4000m-4999m with 16 species and 336 individuals; 5000-5500m is found to inhabit only 2 species (Table 4). These findings are in accordance with the fact that elevation is the main environmental gradient for turnover of species and number of individuals [9, 10]. As far as the species diversity and abundance of bumblebees from three principal zones of Jammu and Kashmir is concerned, valley of Kashmir contributes maximum to both,

followed by Ladakh and Jammu, respectively (Table 5), this is attributed to the variation in altitude, topography, climate and flora. Bumblebees with different colour patterns tend to be associated with different elevational zones, entirely black coloured pile on the thoracic dorsum is most frequent at 1000-2000m; at 2000-3000m pale coloured pattern of thoracic dorsum predominates; above 3000m colour pattern of the thoracic dorsum is strongly banded and in the sub alpine and alpine zones much paler pile is observed. Increasingly, light pile confers an advantage by increasing reflectance of incident solar radiations in habitats with brighter sun light and the less shade at the higher elevation.

Table 4. Distribution of No. of individuals and species by elevation zone within Kashmir Himalaya.

Sl. No	Altitude, amsl	1000-1999	2000-2999	3000-3999	4000-4999	5000-5500
1.	Individuals	167	1570	1597	336	24
2.	Species	5	17	25	16	2

Table 5. Species diversity index, richness and evenness of bumblebees from Jammu-Kashmir Himalaya.

Region	No. of species	No. of individuals in all the species	Species diversity index (H)	Species richness (ma)	Species evenness (j)
Jammu	03	69	0.47373	1.087637	0.992892
Kashmir	19	2826	0.99286	5.215619	0.776428
Ladakh	17	799	0.91191	5.5124	0.74112

It is high time to record the diversity, distribution (altitudinal stratification) and population densities of these anthophilous insects. It is rather more important to gather information on association of these insects with the entomophilous flowering plants (particularly the medicinal plants) occurring up to the permanent snow line. It is also important to underline some commercially important bumblebees so that their pollination potential may be exploited to increase the yield of some regional cash crops such as peas, mustard, clover, alfalfa; some vegetables such as brinjal, onion, reddish, tomato, bottle and bitter gourd; some fruit trees including pear, peach, cherry, apricot, almond; variety of citrus plants and numerous medicinal plants. Studies on the pollination biology along with other insect plant associations in the higher reaches of Himalaya can go a long way in protecting and preserving the rarest type of vegetation gene-pool.

It is further suggested that this work may be extended to the remote high altitude areas of entire India, which may be thoroughly screened, so that the actual position of these insects can be brought to light. It is very likely that 18 bumble bee species so far recorded purely from the neighbouring countries (Pakistan, Afghanistan, Bhutan, Nepal, Tibet and

Myanmar) may be found from Indian faunistic limits. Another major problem with these insects is that in spite of the presence of host plants; the same species may not remain confined to the same place every year. Since, they are very strong fliers so they keep on shifting their colonial sites every year. So while making the complete survey of these insects, Zanskar and Gurez range in Kashmir Himalayan belt and South Indian hills must be taken into consideration with special attention to Nilgiri and Kodakanal hills. More recently, concerns over the dramatic declines of some bumblebee species have led research to focus on trying to understand why some species appear to be both rarer and more susceptible to environmental change than others. Based on studies of forage use by UK bumblebee species, Goulson *et al.* [26, 27] argue that the rare species tend to be long tongued and have narrower diets, with a very large proportion of the pollen they collect being from Fabaceae. These species are associated with Fabaceae-rich unimproved grasslands, a habitat which has been largely eradicated. In contrast the common species tend to have broad foraging preferences and readily encompass non-native garden plants and mass-flowering crops in their diets [28].

The present study not only demonstrates the importance of different habitats but also provide quantitative evidence in the form of species richness, evenness, and characterization of species diversity and abundance of common bumblebee species portraying their role in pollination. Baseline data generated will serve for the future investigations of bumblebees at habitat level and consequently devising conservation strategies at landscape level.

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