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Full Length Article

Diversity of Bumblebees (Bombini, Apidae: Hymenoptera) in Northern Pakistan

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ABSTRACT

In agricultural habitat 10 bumblebee species were recorded; 68.62% of which were dominated by five species viz., *B. asiaticus, B. melanurus, B. rufofasciatus, B. semenovianus* and *B. tunicatus*. However, in non-agricultural habitat 13 bumblebee species were recorded and more than 50% bumblebees were dominated by four species viz., *B. asiaticus, B. avinoviellus, B. biroi* and *B. haemorrhoidalis*. Significant variations were observed in the species richness at non-agricultural habitat but none in case of abundance at habitat level. Generally maximum species richness was recorded at Darkot. © 2011 Friends Science Publishers

Key Words: Diversity; Bumblebees; Bombini, Pakistan

INTRODUCTION

Northern Pakistan is endowed with a great variety of flora and fauna owing to its diverse array of altitude, rainfall and climate. It is among the regions where the earth's biological wealth is most distinctive and rich (Malcolm *et al.,* 2002). Pollinators play a pivotal role in flowering plant reproduction and fruit set for agricultural and wild plant communities (Buchmann & Nabhan, 1996; Accorti, 2000; Al-Ghzaw *et al.,* 2003; Eardley *et al.,* 2006*;* Fontaine *et al.,* 2006; Klein *et al.,* 2007). In many plant species a decline in pollination quantity and quality result in a decline of seed set (Kwak *et al*., 1998; Steffan Dewenter & Tscharntke, 1999; Tomimatsu & Ohara, 2002) and or inbreeding (Kwak *et al*., 1998; Velterop, 2000; Luijten, 2001; Mustajärvi *et al*., 2001) and bumblebees provide a vital ecological service in this regard (Sabir *et al.,* 2007).

Bumblebees are efficient pollinator (Abak *et al.,* 2000; Semida, & Elbanna, 2006) and able to forage in adverse weather conditions, which are not suited to honeybees and solitary bees (Allen-Wardell *et al*., 1998). In recent years, many bumblebee (*Bombus*) species have shown sharp declines in their abundance in many parts of the globe (Rasmont, 1995; Buchmann & Nabhan, 1996; Westrich, 1996; Kevan & Phillips, 2001) especially in the last 50 years (Goulson *et al.,* 2005).

Among 5700 species of floral resources of Pakistan, there are almost 400 endemic species and around 1000 species of vascular plants, which are known to occur in Northern mountain regions of Pakistan (Khan *et al*., 2009). But unluckily we are still in dark keeping in view their important pollinators like bumblebees. Owing to already scarce information, knowing bumblebees is thus extremely important to improve the pollination of our cultivated crops and to restore native plants (Sabir *et al.,* 2008). So the main aim of this study was to evaluate the species richness and diversity of bumblebees in two different habitats viz., agricultural and non-agricultural in Northern Pakistan at spatial scale.

MATERIALS AND METHODS

Study area: Present study focuses on Northern Pakistan (Fig. 1) comprising six sites from Gilgit-Baltistan (former Northern Areas) and two from Azad Jammu and Kashmir. The field work was conducted from March through September during 2006 and 2007.

Bumblebees monitoring in different habitats: The observations on the bumblebees were carried out in each habitat viz, agricultural (crop area) and non-agricultural (non-crop, forest area), on two consecutive days i.e., on day first in agricultural habitat (AH) and on day second in non-agricultural habitat (NAH). In both habitats, bumblebees were captured within the search area of 100 m radius and counted during the bloom of the target crop/plant for one hour. Bumblebees were searched for and caught as soon as they landed on or right after leaving the flowers with entomological hand net despite other methods for sampling (Dafni, 1992), because hand net is an easy handling method. The observation turns were six (0700- 0800, 0900- 1000, 1100- 1200, 1300- 1400, 1500- 1600 & 1700- 1800 h) to insure that the equal sampling effort was exerted in each

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study area. The same species/individuals of bumblebees caught were released following identification (Carvell *et al.*, 2004) at the end of each day; however, the new one species/individuals were killed in a killer chamber (cyanide killing bottle) and stored in individual paper bags.

Preservation and identification of the captured specimens: The collected specimens were preserved and properly labeled in collection boxes. The collected specimens were identified up to the species level with the help of available literature (Williams, 1991; Williams, 1998; Williams *et al.*, 2008).

Diversity indices: Species richness (the number of species) and abundance (number of individuals) of insects were summed for each site to get the mean observations of both years. Four measures of diversity statistics were calculated as:

S = Richness = Species richness (the number of species in a sample unit).

H' = Shannon diversity (Shannon & Weaver, 1949).

$$H' = -\sum_{i}^{s} pi \log pi \quad \text{--------} \; 1$$

Where $p_{i=}$ Importance probability (Greig-Smith, 1983).

E = evenness (equitability) (Pielou, 1969).

$$E = \frac{H'}{\ln} \quad \text{--------------} \; 2$$

Where ln is natural log.

D = Simpson's index of diversity for an infinite population (Simpson, 1949). This is the complement of Simpson's original index.

$$D = 1 - \sum_{i}^{s} pi^{2} \quad \text{---------} \; 3$$

The distribution maps were prepared on the basis of the respective coordinates of the sampling sites by using Arc View.

RESULTS

Diversity and abundance of bumblebees in Northern Pakistan: In AH 2836 individuals comprising 22.74% (n = 645) queen, 49.44% (n = 1402) worker & 27.82% (n = 789) male (Fig. 2a) of 10 bumblebee species from eight sub genera were recorded (Fig. 3a). Of which 57.62% individuals belong to three sub genera (Fig. 3a) viz., *Melanobombus* Dalla Torre, *Sibiricobombus* Vogt and *Bombus* s.str. Similarly, 68.62% bumblebees were dominated by five species (Fig. 3b) viz., *B. asiaticus, B. melanurus, B. rufofasciatus, B. semenovianus* and *B. tunicatus*. The most common species, which encountered abundantly was *B. asiaticus.* On the other hand, in NAH, 2860 individuals comprising 20.73% (n = 593) queen, 55.03 (n = 1574) worker and 24.23% (n = 24.23) male (Fig. 2b) of 13 bumblebee species from eight sub genera were recorded (Fig. 3c). Of which more than 58% individuals belong to three sub genera viz., *Mendacibombus* Skorikov, *Pyrobombus* Dalla Torre and *Sibiricobombus* Vogt. Similarly, more than 50% bumblebees were dominated by four species (Fig. 3d) viz., *B. asiaticus, B. avinoviellus, B. biroi* and *B. haemorrhoidalis*. The most common species, which encountered abundantly was *B. asiaticus,* while the less common was found to be *B. tunicatus*. However, two

Fig. 1: Distribution of sampling sites in Northern Pakistan

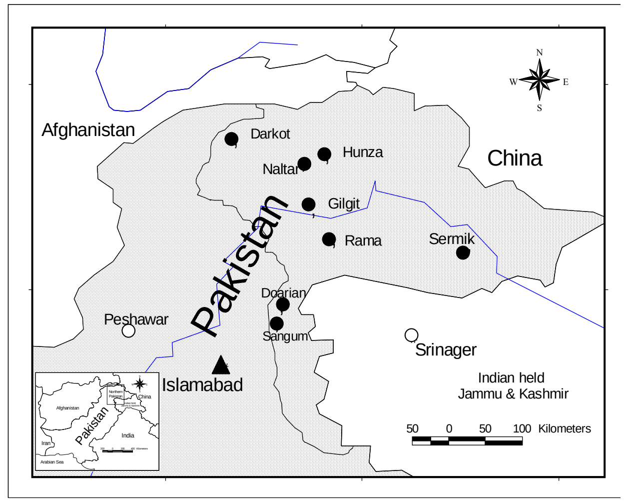


Fig. 2: Bumblebees abundance (Mean ± SE) of genus *Bombus* with all castes and sexes in agricultural (a) and non-agricultural habitat (b) of Northern Pakistan

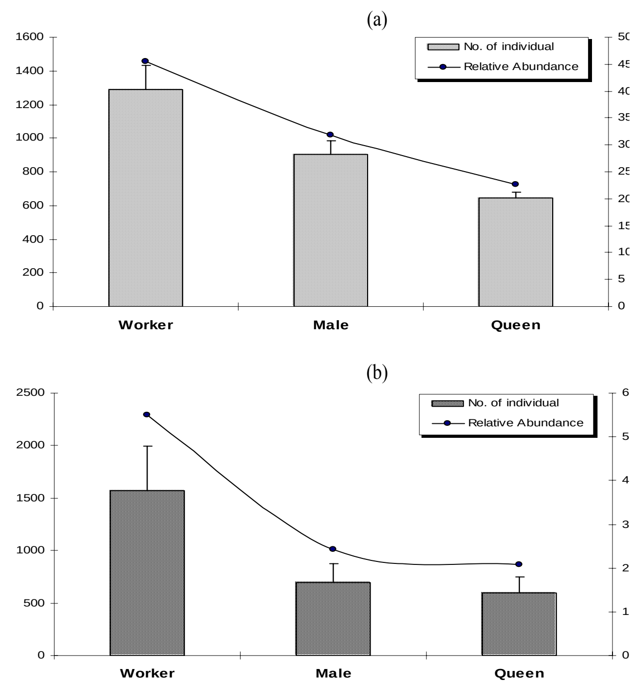
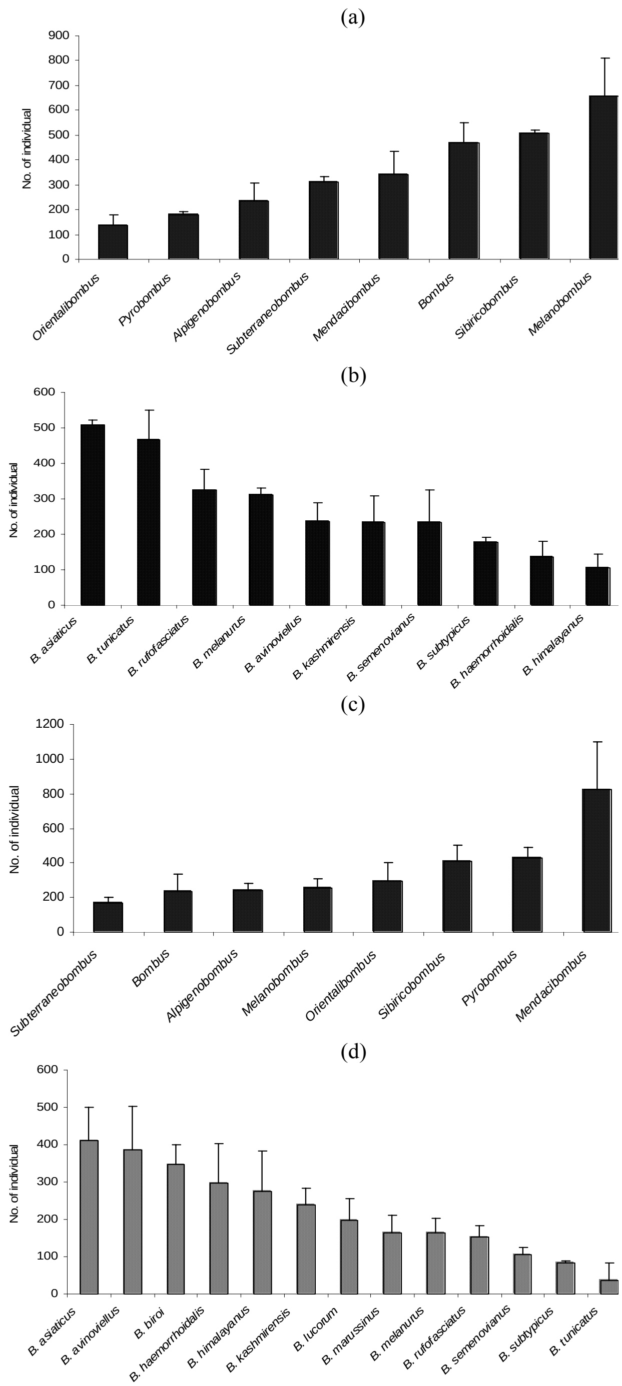


Fig. 3: Relative abundance (mean ± SE) of bumblebees sub genera (a,c) and species (b,d) in agricultural and non-agricultural habitat



species viz., *B. marussinus* and *B. melanurus* showed similar abundance pattern.

On the other hand, distribution patterns in AH revealed that the occurrence of bumblebee species ranged from 2 (Rama) to 8 (Darkot) in the sampling sites at habitat level with a one species (*B. tunicatus*) that was observed at all sites except Sangum (Fig. 4j) followed by *B. asiaticus kashmirensis* (Fig. 4e) from Darkot, Doarian, Hunza and Sangum, *B. melanurus* (Fig. 4f) from Darkot, Gilgit, Rama and Sermik, *B. rufofasciatus* (Fig. 4g) from Darkot, Doarian, Hunza and Sangum, *B. semenovianus* (Fig. 4h) from Darkot, Gilgit, Hunza and Naltar and *B. subtypicus* (Fig. 4i) from Darkot, Naltar, Rama and Sermik. Among the species, two species (*B. haemorrhoidalis* & *B. himalayanus*) were scarcely observed (Fig. 4c d), both occurring in two sites (Doarian, Sangum) and (Darkot, Naltar), respectively.

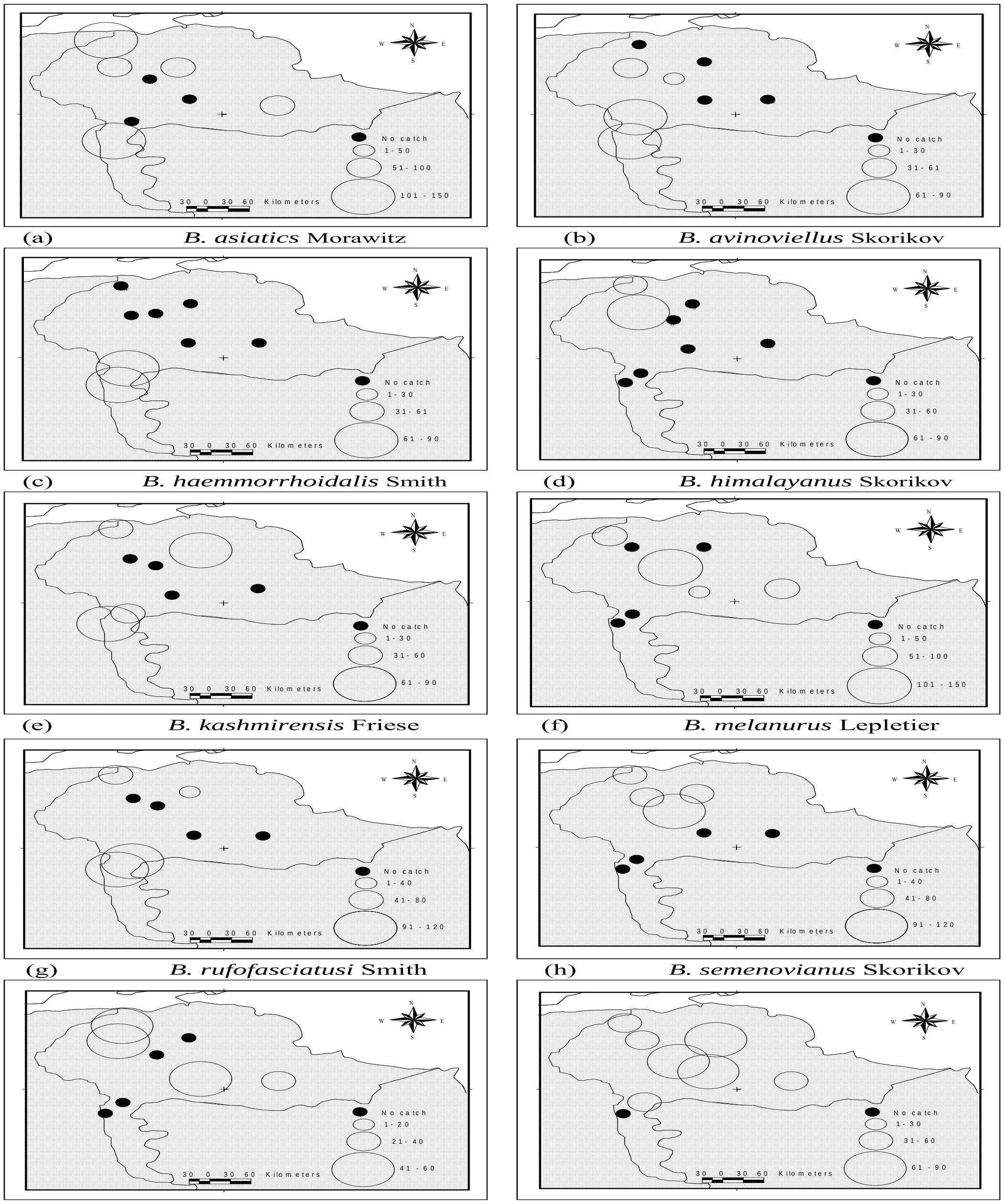
Similarly, distribution patterns in NAH revealed that the occurrence of maximum bumblebee species ranged from 1 to 8 in the sampling sites at habitat level with only one species (*B. tunicatus*) that was observed at all sites viz., Darkot, Doarian, Gilgit, Hunza, Naltar, Rama, Sangum and Sermik (Fig. 5m) followed by *B. asiaticus* (Fig. 5a) from all sites except one sampling site (Rama) and *B. melanurus* (Fig. 5i) from all sites except Doarian and Sangum, however, only one species (*B. biroi*) was recorded from Darkot only (Fig. 5c).

Overall pattern of variations in distribution of bumblebees: A conspicuous variation in bumblebees' abundance was observed spatially in both habitats except at Darkot and Gilgit (Fig. 6a). Generally, it is evident that there was relatively less variations in abundance of bumblebees at habitat level viz., agricultural (n=2836) and non-agricultural (n=2860) habitat (Fig. 6e).

Maximum species richness was studied at Darkot (8) followed by Naltar (6), Sangam, Doarian, Hunza (5), Gilgit, Sermik (4) and Rama (3) in AH and a similar pattern in species richness was observed in NAH also viz., Darkot (11), Naltar (9), Sangum, Doarian, Hunza (7), Gilgit (6) Sermik and Rama with only difference that there was no variation in species occurrence (4) at Sermik in both the habitats (Fig. 6b). Ten species viz., *B. asiaticus, B. avinoviellus, B. haemorrhoidalis, B. himalayanus, B. kashmirensis, B. melanurus, B. rufofasciatus, B. semenovianus, B. subtypicus* and *B. tunicatus* were dominant in both habitats, however, *B. biroi, B. lucorum* and *B. marussinus* were scarce and only encountered in NAH.

Highest species evenness (0.984) in AH was recorded at Naltar (Fig. 6e), Simpson's and Shannon diversity indices (2.022 & 0.860) at Darkot (Fig. 6c, d) with species richness (8) at Darkot (Fig. 6b) viz., *B. asiaticus, B. himalayanus, B. kashmirensis, B. melanurus, B. rufofasciatus, B. semenovianus, B. subtypicus* and *B. tunicatus* out of 10 species. Similarly, in NAH highest species evenness (0.983) was recorded at Rama (Fig. 6e), Simpson's and Shannon (2.230 & 0.876) diversity indices (Fig. 6c d) and species richness (11) all at Darkot (Fig. 6b) viz., *B. asiaticus, B. biroi, B. himalayanus, B. kashmirensis, B. lucorum, B. marussinus, B. melanurus, B. rufofasciatus, B. semenovianus, B. subtypicus* and *B. tunicatus* out of 13 species. It was further investigated that as a whole more species evenness was observed in AH (0.96) than in NAH contrary to highest Simpson's and Shannon diversity indices

Fig. 4: Distribution of bumblebee species on the basis of their abundance in agricultural habitat of Northern Pakistan



(a) *B. asiatics* Morawitz
(b) *B. avinoviellus* Skorikov
(c) *B. haemmorrhoidalis* Smith
(d) *B. himalayanus* Skorikov
(e) *B. kashmirensis* Friese
(f) *B. melanurus* Lepletier
(g) *B. rufofasciatusi* Smith
(h) *B. semenovianus* Skorikov
(i) *B. subtypicus* Skorikov
(j) *B. tunicatus* Smith

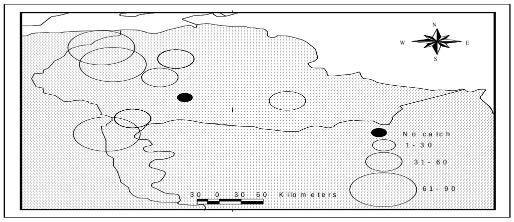
(1.77 & 0.81) in NAH than in AH (Fig. 6f) at habitat level.

DISCUSSION

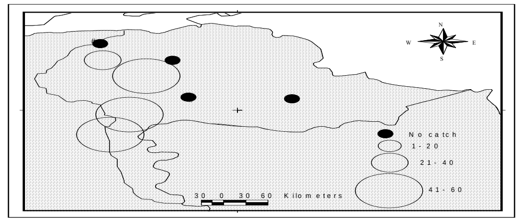
The results suggest that the abundance and distribution of bumblebees varies in both habitats (AH & NAH). Generally distribution pattern of bumblebees in present findings is in line with that of Suhail *et al.* (2009) in ecosystem of Northern Pakistan. They investigated the fauna only in geographical context despite at habitat level. Similarly, bumblebee species in present findings were more or less studied by different authors taxonomically (Morawitz, 1880; Bingham, 1897; 1914; Skorikov, 1931; Frison, 1935; Reinig, 1940; Krüger, 1943; Richards, 1951; Tkalců, 1989; Williams, 1991; Suhail, 2009) from Pakistan as a whole and to some extent from other parts of Northern Pakistan but not at habitat level as bumblebees require different habitats for foraging, nesting and hibernation (Colla & Packer, 2008).

In present study the difference in abundance and distribution of bumblebees between two habitats (AH &

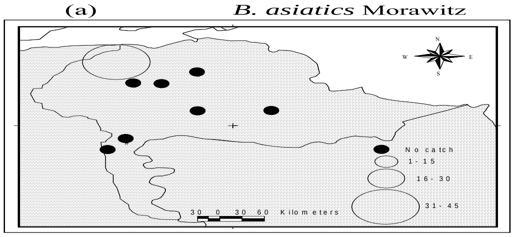
Fig. 5: Distribution of bumblebee species on the basis of their abundance in non-agricultural habitat of Northern Pakistan



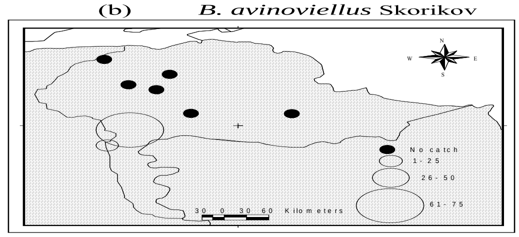
(a) *B. asiatics* Morawitz



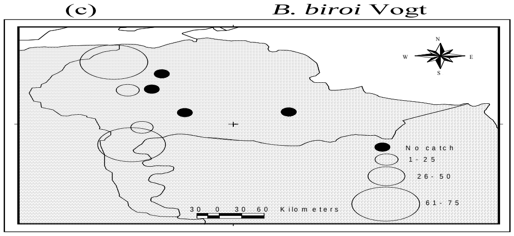
(b) *B. avinoviellus* Skorikov



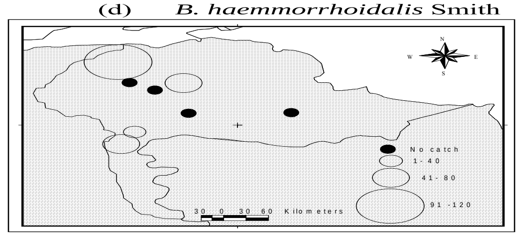
(c) *B. biroi* Vogt



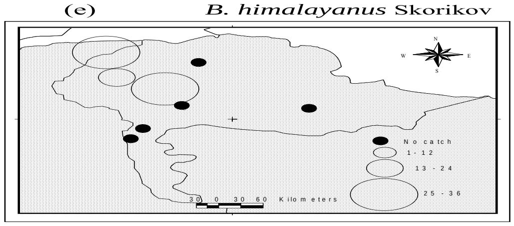
(d) *B. haemmorrhoidalis* Smith



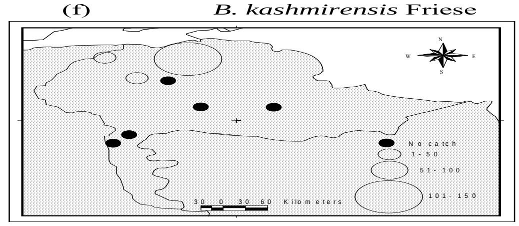
(e) *B. himalayanus* Skorikov



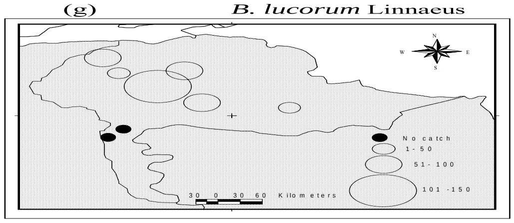
(f) *B. kashmirensis* Friese



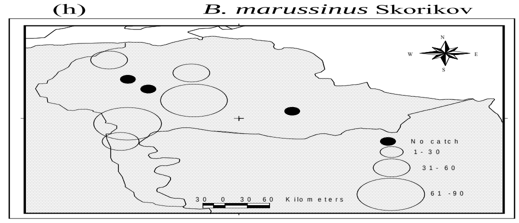
(g) *B. lucorum* Linnaeus



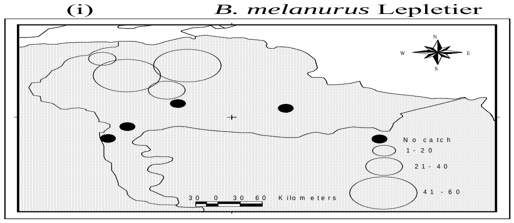
(h) *B. marussinus* Skorikov



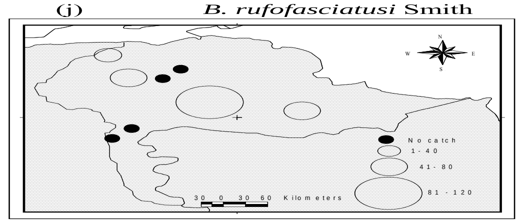
(i) *B. melanurus* Lepletier



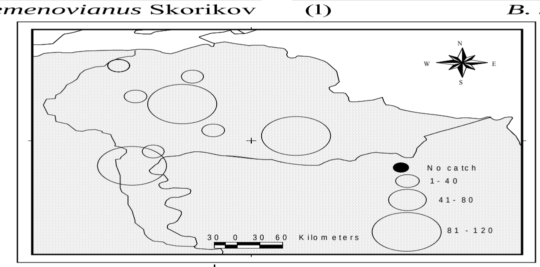
(j) *B. rufofasciatusi* Smith



(k) *B. semenovianus* Skorikov

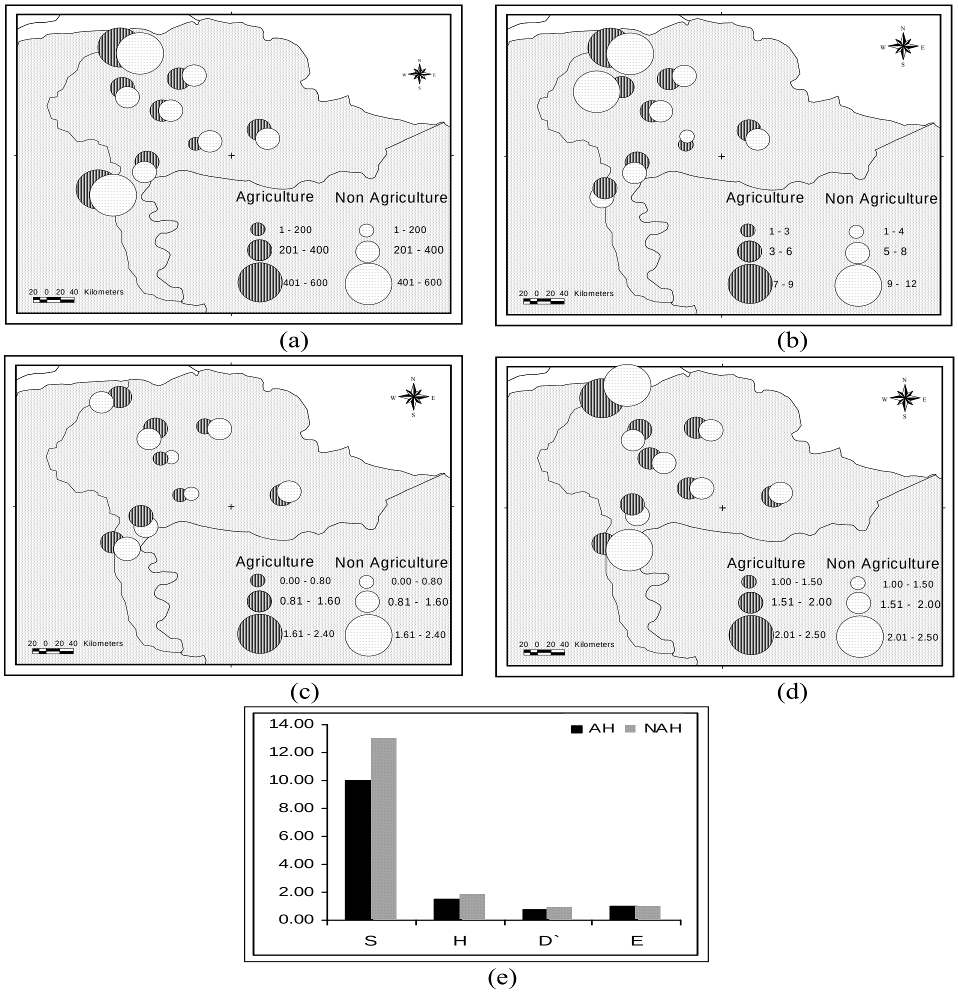


(l) *B. subtypicus* Skorikov



(m) *B. tunicatus* Smith

Fig. 6: Bumblebees' abundance (a), species richness (b), Simpson's (c) and Shannon diversity indices (d) and cumulative diversity indices at habitat level (e) in Northern Pakistan



NAH) was because of the fact that agricultural habitats are continuously in alteration owing to agronomic practices resulting in destruction of their nests (Pywell *et al.,* 2005). That's why bumblebee nests are more on NAH viz., grasslands (Bäckman & Tiainen, 2002; Westphal *et al.,* 2003), field boundaries, forest edges (Kells & Goulson, 2003), set asides, grasslands, ditches, field margins, grassy banks, roadsides, interfaces and hedgerows (Westrich, 1990; Free, 1993; Von Hagen, 1994). These are more or less undisturbed and protected nesting habitats for reproduction and overwintering (Bäckman & Tiainen, 2002; Quaranta *et al.,* 2004; Pywell *et al.,* 2005) as compared to agricultural habitats. Such areas serve as 'refuge habitats' and have positive effect on faunal diversity. Studies in Poland revealed that the diversity in wild bee fauna in crop area was positively correlated with their contact to such refuge habitats (Banaszak & Cierzniak, 1994; Banaszak, 1996).

Similarly, Sepp *et al.* (2004) also observed no significant difference in evenness of intensively and less intensively used agricultural areas. However, Schwenninger (1992) registered higher evenness in agricultural landscape possibly owing to more forage availability in AH. In contrary, relatively higher species richness in NAH was because of the diversity of resources, which provide food in low abundance but over a long period (Walther-Hellwig & Frankl, 2000; Mänd *et al.,* 2002; Pywell *et al.,* 2004; Quaranta *et al.,* 2004). Sepp *et al.* (2004) also recorded more bumblebee species in area with <45% arable land than area with >65% arable land. Being biodiversity refuge and habitat corridors (Tscharntke *et al.,* 2002), non-agricultural habitats supply pollen and nectar resources continuously throughout the spring and summer months (Steffan-Dewenter & Tscharntke, 1999). That's why these habitats are critical for the species richness and abundance of bumblebee communities in an agro-ecosystem (Mänd *et al.,* 2002). Similarly, restoring foraging resources through agri-environment schemes can enhance bumblebees subsequently attracting more large numbers of foraging bumblebees especially in intensively managed agricultural landscapes (Heard *et al.,* 2007). Furthermore, variations in species richness in present studies might be attributable to high habitat diversity also (Obeso, 1992).

In conclusion, the present study has not only demonstrated the value of different habitats but also provided the quantitative evidence in the form of species richness, evenness, characterization of species diversity (Shannon diversity index) and abundance of common species (Simpson's diversity index) portraying their role in different habitats (AH & NAH). Recently, *Bombus* species have shown sharp decline in their abundance in many parts of the globe especially in the last 50 years, which is intensifying day by day as the loss of any bumblebee species may result in cascading impacts on native fauna and flora. Thus, the present findings also provided a baseline study for the future investigation of bumblebees at habitat level and consequently devising conservation strategies at landscape level.

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REFERENCES

Abak, K., A.O. Ozdogan, H.Y. Dasgan, K. Derin and O. Kaftanoglu, 2000. Effectiveness of bumble bees as pollinators for eggplants grown in unheated greenhouses. *Acta Hortic*., 514: 197–203

Accorti, M., 2000. Impollinatori, economia e gestione delle risorse, *In*: Pinzauti, M. (ed.), *Api e impollinazione, Regione Toscana*, pp: 219–231. *Dipartimento Sviluppo economico*, Firenze, Italy

Al-Ghzaw, A.A., S.T. Zaittoun, I. Makadmeh and A.M. Al-Tawaha, 2003. The Impact of Wild Bees on the Pollination of Eight Okra Genotypes under Semi-arid Mediterranian Conditions. *Int. J. Agric. Biol*., 5: 408–410

Allen-Wardell, G., P. Bernhardt, R. Bitner, A. Burquez, S. Buchmann, J. Cane, A.P. Cox, V. Dalton, P. Feinsinger, M. Ingram, D. Inouye, C.E. Jones, K. Kennedy, P. Kevan, H. Koopowitz, R.M. llin, S. Medellin-Morales, G.P. Nabhan, B. Pavlik, V. Tepedino, P. Torchio and S. Walker, 1998. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conserv. Biol*., 12: 8–17

Bäckman, J.C. and J. Tiainen, 2002. Habitat quality of field margins in a Finnish farmland area for bumblebees (Hymenoptera: *Bombus* & *Psithyrus*). *Agric*. *Ecosys. Environ*., 89: 53–68

Banaszak, J. and T. Cierzniak, 1994. The effect of neighbouring environments and the acreage of the winter rapeseed plantation on the diversity and density of Apoidea (Hymenoptera). Zesz. Nau. WSP W Bydgoszczy. *Stud. Przyrodnicze*, 10: 25–38

Banaszak, J., 1996: Ecological bases of conservation of wild bees. In: Matheson, A., S.L. Buchmann, C. O'toole, P. Westrich, I.H. Williams (eds.), *The Conservation of Bees*, pp: 55–62. Academic Press, London, UK

Bingham, C.T., 1897. *The Fauna of British India, Including Ceylon and Burma, Hymenoptera*, Vol. I. Wasps and bees. London, UK

Buchmann, S.L. and G.P. Nabhan, 1996. *The Forgotten Pollinators*. Island Press, Washington, DC

Carvell, C., W.R. Meek, R.F. Pywell and M. Nowakowski, 2004. The response of foraging bumblebees to successional change in newly created arable field margins. *Biol. Conserv*., 118: 327–339

Colla S.R. and L. Packer, 2008. Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. *Biodivers, Conserv*., 17: 1379–1391

Dafni, A., 1992. *Pollination Ecology, A Practical Approach*. Irl Press at Oxford University Press, New York

Eardley, C., D. Roth, J. Clarke, S. Buchmann and B. Gemmill, 2006. *Pollinators and Pollination, a Resource Book for Policy and Practice*, p: 77. African Pollinator Initiative

Fontaine, C., I. Dajoz, J. Meriguet and M. Loreau, 2006. Functional Diversity of Plant–Pollinator Interaction Webs Enhances the Persistence of Plant Communities. *PLoS Biol*., 4: 129–135

Free, J.B., 1993: *Insect Pollination of Crops.* Academic Press, London, UK

Frison, T.H., 1935. Records, notes and descriptions ol *Bremus* from Asia (Bremidae: Hymenoptera). *Record Indian Museum*., 37: 339–363

Goulson, D., M.E. Hanley, B. Darvill, J.S. Ellis and M.E. Knight, 2005. Causes of rarity in bumblebees. *Biol. Conserv*., 122: 1–8

Greig-Smith, P., 1983. *Quantitative Plant Ecology*. University of California Press, Berkeley, California

Heard, M.S., C. Carvell1, N.L. Carreck, P. Rothery1, J.L. Osborne and A.F.G. Bourke, 2007. Landscape context not patch size determines bumble-bee density on flower mixtures sown for agri-environment schemes. *Biol. Lett*., 3: 638–641

Kells, A.R. and D. Goulson, 2003. Preferred nesting sites of bumblebee queens (Hymenoptera: Apidae) in agroecosystems in the UK. *Biol. Conserv*., 109: 165–174

Kevan, P.G. and T.P. Phillips, 2001. The economic impacts of pollinator declines: an approach to assessing the consequences. *Conserv. Ecol*., 5: 8

Khan, K., Alamgeer, A. Erum, B. Ahmad, M. Akram, M.A. Aarshad, Junaid and U. Saleem, 2009. Ethnobotanical Studies from Northern Areas of Pakistan. *Pharmacol. Online Newslett*., 1: 328–354

Klein, A., B.E. Vaissie, J.H. Cane, I. Steffan-Dewenter, S.A. Cunningham, C. Kremen and T. Tscharntke, 2007. Importance of pollinators in changing landscapes for world crops. *Proc. Royal Soc*., 274: 303–313

Krüger, E., 1943. Őber die Genitalanhänge einiger Männchen der Untergattung *Pratobombus* O. *Vogt Zeitschrift Für Morphologie Und Ökologie Der Tiere*., 39: 527–545

Kwak, M.M., O. Velterop and J. Van Andel, 1998. Pollen and gene flow in fragmented habitats. *Appl. Veg. Sci*., 1: 37–54

Luijten, S.H., 2001. Reproduction and genetics of fragmented plant populations. *Ph. D Thesis*, University of Amsterdam, the Netherlands

Malcolm, J.R. Liu, C. Miller, L.B. Allnutt and T. Hansen, 2002. *Habitats at Risk: Global Warming and Species Loss in Terrestrial Ecosystems*, p: 40. WWF Fund for Nature, Gland, Switzerland

Mänd, M., R. Mänd and I.H. Williams, 2002. Bumblebees in the agricultural landscape of Estonia. *Agric. Ecosyst. Environ*., 89: 69–76

Morawitz, F., 1880. Ein Beitrag zur Bienen-Fauna Mittel-Asiens. *Izvéstiya Imperatorskoi Akiademii Nauk*, 26: 337–379

Mustajärvi, K., P. Siikamäki, S. Rytkönen and A. Lammi, 2001. Consequences of plant population size and density for plant-pollinator interactions and plant performance. *J. Ecol*., 89: 80–87

Obeso, J.R., 1992. Geographic distribution and community structure of bumblebees in the northern Iberian peninsula. *Oecologia,* 89: 244–252

Pielou, E.C., 1969. *An Introduction to Mathematical Ecology*, p: 326. John Wiley, New York

Pywell, R.F., E.A. Warman, C. Carvell, T.H. Sparks, L.V. Dicks, D. Bennett, A. Wright, C.N.R. Critchley and A. Sherwood, 2005. Providing foraging resources for bumblebees in intensively farmed landscapes. *Biol. Conserv*., 121: 479–494

Pywell, R.F., J.M. Bullock, K.J. Walker, S.J. Coulson, S.J. Gregory and M.J. Stevenson, 2004. Facilitating grassland diversification using the hemiparasitic plant *Rhinanthus minor*. *J. Appl. Ecol*., 41: 880–887

Quaranta, M., S. Ambroselli, P. Barro, S. Bella, A. Carini, G. Celli, P. Cogoi, L. Comba, R. Comoli, A. Felicioli, I. Floris, F. Intoppa, S. Longo, S. Maini, A.G. Manino, P. Mazzeo, E. Medrzycki, L. Nardi, N. Niccolini, Palmieri, A. Patetta, C. Piatti, M.G. Piazza, M. Pinzauti, M. Porporato, C. Porrini, G.R. D'albore, F. Romagnoli, L. Ruiu, A. Satta, P. Zandigiacomo, 2004. Wild bees in agroecosystems and seminatural landscapes. 1997- 2000 collection period in Italy. *Bull. Insectol*., 57: 11–61

Rasmont, P., 1995. How to restore the apoid diversity in Belgium and France? Wrong and right ways or the end of protection paradigm! *In*: Banaszak, J. (ed.), *Changes in Fauna of Wild Bees in Europe*, pp: 53–64. Pedagogical University, Bydgoszcz

Reinig, W.F., 1940. Beitrage zur Kenntnis der Hummelfauna von Afghanistan. (Hym., Apid.). (Ergebnisse dcr Reise von H. und E. Kotzsch in den Hindukusch im Jahre 1936). *Deutsche Entomol. Zeitschrift*., 1940: 224–235

Richards, O.W., 1951. The 3rd Danish expedition to Central Asia. Zoological results 5. Bombidae (Insccta) from Afghanistan. *Videnskabelige Meddelelser fra Dansk naturhistorisk Forening i KjØbenhavn,* 113: 191–199

Sabir, A.M., A. Suhail, A. Rafi, S. Ahmad, M. Saleem and K. Mahmood, 2008. Bumblebees belonging to Genus *Bombus* (Bombini: Apidae: Hymenoptera) of Northern Pakistan. *28th Pakistan Congr. Zool. (Intern.)*, p: 74. Government College University, Faisalabad, Pakistan

Sabir, A.M., A. Suhail, M.A. Rafi, K. Mahmood and S. Ahmed, 2007. Foraging activity of bumblebees (*Bombus* Latr.) in relation to floral resources in agricultural and semi-natural landscape. *Int. Conf. Biological Resources of Pakistan: Problems, success and future perspectives*" at University of Arid Agriculture, Rawalpindi, Pakistan, p: 25

Schwenninger, H.R., 1992. Untersuchungen zum Einuû der BewirtschaftungsintensitaÈ t auf das Vorkommen von Insektenarten in der Agrarlandschaft, dargestellt am Beispiel der Wildbienen (Hymenoptera: Apoidea). *Zool. J. Syst*., 119: 543–561

Semida, F. and S. Elbanna, 2006. Impact of Introduced Honey Bees on Native Bees at St. Katherine Protectorate, South Sinai, Egypt. *Int. J. Agric. Biol*., 8: 191–194

Sepp, K., M. Mikkb, M. Mändc and J. Truu, 2004. Bumblebee communities as an indicator for landscape monitoring in the agri-environmental programme. Landscap. *Urban Plann*., 67: 173–183

Shannon, C.E. and W. Weaver, 1949. *The Mathematical Theory of Communication*. University of Illinois, Urbana, Illinois

Simpson, E.H., 1949. Measurement of diversity. *Naturalist*, 163: 688

Skorikov, A.S., 1931. Die Hummelfauna Turkestans und ihre Beziehungen zur zentralasiatischen Fauna (Hymenoptera, Bombidae). *Abhandlungen Der Pamir-Expedition*, 8: 175–247

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

Suhail, A., A.M. Sabir, M.A. Rafi, A. Qadir and M. Asghar, 2009. Geographic Distributional Patterns of the Genus *Bombus* (Bombini, Apidae: Hymenoptera) in northern Pakistan. *BioDiControl*, 2: 1–9

Tkalců, B., 1989. Neue Taxa asiatischer Hummeln (Hymenoptera, Apoidea). *Acta Entomol. Bohemoslovaca*, 86: 39–60

Tomimatsu, H. and M. Ohara, 2002. Effects of forest fragmentation on seed production of the understory herb Trillium camschatcense. *Conserv. Biol*., 16: 1277–1285

Tscharntke, T., I. Steffan-Dewenter, A. Kruess and C. Thies, 2002. Contribution of small habitat fragments to conservation of insect communities of grassland–cropland landscapes. *Ecol. Appl*., 12: 354–363

Velterop, O., 2000. Effects of fragmentation on pollen and gene flow in insect pollinated plant populations. *Ph. D Thesis*, University of Groningen, The Netherlands

Von Hagen, E., 1994. *Hummeln Bestimmen*. Ansiedeln, Vermehren, SchuÈ tzen. Naturbuch-Verlag, Augsburg

Walther-Hellwig, K. and R. Frankl, 2000. Foraging habitats and foraging distances of bumblebees, *Bombus* spp. (Hym., Apidae), in an agricultural landscape. *J. Appl. Entomol*., 124: 299–306

Westphal, C., I. Steffan-Dewenter and T. Tscharntke, 2003. Mass flowering crops enhance pollinator densities at a landscape scale. *Ecol. Lett*., 6: 961–965

Westrich, P., 1996. The problems of partial habitats. *In*: Matheson, A., S.L. Buchmann, C. Toole, P. Westrich and I.H. Williams, (eds.), *The Conservation of Bees*. Linnean Society Symposium Series, Vol. 18. Academic Press, London

Westrich, P., 1990. *Die Wildbienen Baden-WuÈ Rttembergs* (1 & 2). Ulmer, Stuttgart, Germany

Williams, N.M. and J.D. Thomson, 1998. Trapline foraging by bumble bees: III. Temporal patterns of visitation and foraging success at single plants. *Behav. Ecol*., 9: 612–621

Williams, P.H., 1991. The bumble bees of the Kashmir Himalaya (Hymenoptera: Apidae: Bombini). *Bull. Nat. History Mus., London, UK. Entomol.*, 60: 1–204

Williams, P.H., 1998. An annotated checklist of bumblebees with an analysis of patterns of description. *Bull. Nat. History Mus. London UK. Entomol.*, 67: 79–152

Williams, P.H., S.A. Cameron, H.M. Hines, B. Cederberg and P. Rasmont, 2008. A simplified subgeneric classification of the bumblebees (genus *Bombus*). *Apidology*, 39: 46–74

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