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Diversity of Bumblebees (Bombini, Apidae: Hymenoptera) in Chitwan Annapurna Landscape (CHAL) of Central Himalaya, Nepal

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Abstract

Bumblebees (Hymenoptera: Apidae: genus Bombus Latreille, 1802) are the effective group of pollinators for various crops and wild plants in the north high-hills of Nepal. Over the past few decades, it has been expected that the population of these insects has declined since there are still unexplored areas and rich floral and faunal diversity. However, there are very few scientific publications as well as little researches have been carried out focusing on bumble bees in high-hills of Nepal. Therefore, this research was focused to explore the bumblebees in Chitwan Annapurna Landscape (CHAL) in Manang, Mustang and Gorkha districts with altitudinal gradients from 500 -2700 m asl from June to September 2019. The data were collected following accessible walking trails by opportunistic survey method and specimens were captured using sweeping net. Total 7 subgenera with 8 species of genus Bombus were identified. Bombus festivus (subgenus: Festivobombus) was the most dominant species. The diversity of bumblebee species was more in Gorkha site compared to the Manang and Mustang sites. Bombus haemorrhoidalis, B. eximus, and B. rotundiceps were the dominant species in Gorkha site, whereas B. festivus, B. lepidus, and B. tunicatus were dominant in Manang districts. Bombus festivus, B. tunicatus, and B. turneri were the most encountered species in Mustang. This study indicates that each district has the unique diversity of bumblebees particularly a site-specific variation of the Bombus species, which are likely to the variations in floral resources, microclimate and habitat types.

Keywords habitat types, pollinator, subgenus, species dominant

1. Introduction

Bumblebees (Hymenoptera, Apidae, Latreille, 1802) are important social insects that pollinate both wild and agricultural plants. It has been suggested that they originated in the central Asian mountains where temperature variations occur (Williams, 1985). Since they can show endothermic behaviour, bumblebees are better adapted than most other bees to their activity in cool climates (Williams, 2007). The bumblebee's foraging actions are related to nectar gathering (Goulson, 2010), whilst the choice of food plants are based on the pollen's characteristics (Roger *et al*., 2016). Typically, an old bumblebees have high experiences of collecting pollen (Raine and Chittka, 2007). Long- tongue species are more specialized in their choice of food plants and are the pollinators of deep nectar flowers based on the length of their tongues (Kawakita *et al*

2004; Goulson, *et al*. 2006). They avoid feeding the bloom that has already been visited by other bees since their feet smell and leave a scent after they have fed (Bumblebee Conservation Trust, 2014). According to Chacoff *et al*. (2010) and Bommarco *et al*. (2012), bumblebees provide buzz pollination for seed production or in seed breeding process, making them significant pollinators of agricultural production and natural ecosystems (Sabir *et al*, 2011).

According to the recent taxonomy, all bumblebees are classified under the genus *Bombus*, which contains 250 species worldwide and 34 species from Nepal (Cameron *et al*., 2007; Williams, *et al*., 2010). The size of species is greater in cooler climates than in warmer ones (Goulson *et al*. 2005; Peat *et al*. 2005). In the Himalaya, they can be found in between 1000 and 56000 meters above sea level (Williams, 1985). Higher species richness has been noted in the mountains of central Asia and the mountains to the east of Tibet (Williams, 1994). Although a typical species is found in the lowland tropics of South East Asia, Central America, and South America, they are primarily restricted to the Northern Hemisphere (Williams, 2007; Goulson, 2010). In the Himalayas, they are typically located between 1,000 and 5,600 meters above sea level.

The environmental variables affect the floral and faunal diversity (Williams *et al*. 2010; Rawat, 2017). West Himalaya has temperate broad leaf forests, parched alpine meadows, and pastures at high elevations because of the region's comparatively low annual rainfall (Rawat, 2017). As a result of the formation of moist alpine meadows at higher elevations and subtropical broadleaf forests at the eastern part, which experiences high annual precipitation of up to 5,000 mm (Dhar and Nandargi, 2006), the East Himalaya is found to have particularly rich biodiversity and is regarded as a global hotspot of biodiversity (Myers *et al*. 2000). Even though the Central and the West Himalya (Williams, 1991; Saini *et al*., 2015) have both conducted extensive research on bumble bee composition (Williams *et al*. 2010).

The Central Himalaya, specifically from Nepal and the Indian state of Sikkim, has the highest abundance of bumblebees (Williams, *et al*. 2010, Saini, *et al*. 2015). In Nepal, both the eastern and western species reach the limits of their ranges, and the overlap of these two faunal zones may be a factor in the region's high bumble bee diversity (Williams, *et al*. 2010). Even though the range and variety of the bumblebee fauna have been well studied in regions like North America, the Eastern, and Western United States, it is still essential to catalog the species of bumblebees from other continents like South-East Asia and Africa.

There is still a deficit of knowledge on the bumblebee's relationship with its host plant, feeding habits, and ecology. Therefore, in order to conserve, protect, and preserve Nepal's natural ecosystem, a complete species inventory is still required. Hence, this study has proposed to collect the species diversity, floral and faunal relationships, bumblebee ecology etc. The scientists may conduct a thorough investigation into the species inventory of the bumblebee. The interaction between bumblebees and their host plants, as well as the presence of an appropriate climatic pattern, must also be clarified

2. Materials and methods

2.1 Study areas

The study was conducted in Chitwan Annapurna Landscape (CHAL) specially focusing Gorkha, Manang and Mustang districts represents high Himalayan ecosystem within the range of 500- 2700-meter altitude. It possesses diverse micro-climatic variation that creates suitable habitats for many species of pollinating insects including bumblebees. This landscape has high biodiversity value and contains seven major sub-river basins: Trishuli, Marsyangdi, Seti, Kaligandaki, Budigandaki, Rapti and Narayani. Kaligandaki river basin is the most important river basin in Nepal. It is originated from the southern edge of Tibetan Plateau. It covers around 11,7770 sq. km area and has longitudinal range of 82°53' - 84°26'E and latitudinal range of 27°43' - 29°19'N and covers the altitudinal range from 188m- 8,143m asl. Diverse climatic condition is found in this river basin so the temperature, precipitation and vegetation vary in these areas. **(Fig 1**)

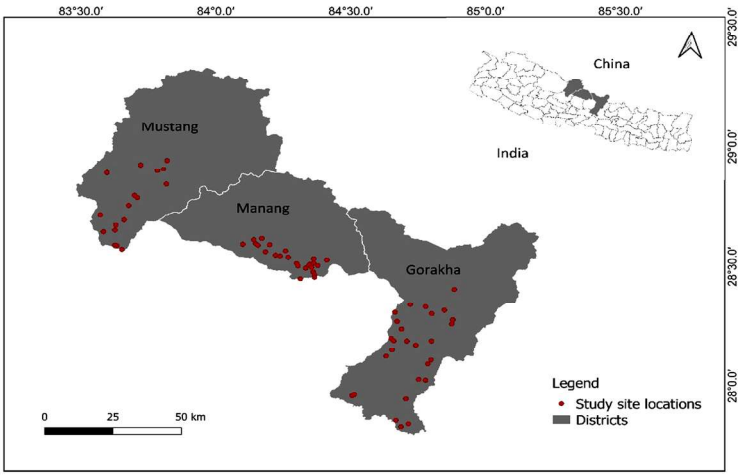

Fig. 1. Map of Chitwan Annapurna Landscape (CHAL). Sampling sites: Gorkha site, Manang site and Mustang site

2.2. Methods

An accessible walking trails was followed in Manang, Mustang and Gorkha districts with in the range of 500- 2700-meter altitude. The species were collected by opportunistic method (Goulson 2010). Whenever bumblebee observed along the route, searched them by making a circle of fifty meter radius from the standing point of observer and survey was carried until 40 minutes. The field sampling was conducted in suitable timing for Bumblebees i.e. April to August. Only unidentified specimens were collected by using standard insect collection protocol using a sweeping net. In the field frequency of bumblebees, host plant, temperature and humidity were recorded. Species were identified by using identification key developed by Williams *et al.* (2010), An *et al*. (2014) and Saini *et al*. (2015). The collected specimen was preserved in Central Department of Zoology, Tribhuvan University as a voucher specimen. Data obtained from the field were managed and analysed using Microsoft Excel 2010.

3. Results

3.1. List of identified species

Among 387 individual 8 species of 7 subgenera were recorded. Species were identified using identification key developed by Williams *et al.* (2010), An *et al*. (2014) and Saini *et al.* (2015). The recorded sub genera, their species and diagnostic characteristics of these species are described, likewise, location, altitude, habitat and host plants are mention below.

1. Sub genus -Alpigenobombus

Bombus breviceps, Smith, 1852, (**Photo 2a**)

Diagnostic features

Females: The first two abdominal tergites are black, creamy white, and the third to fifth abdominal tergites are brick red in color. The queen's length is 18 to 21 millimeters, while the worker's is 10 to 16 millimeters. The head is covered in thick pubescence, with the exception of the molar space, the clypeus, the labrum, the area laterals to and in front of the ocelli, and the narrow stripes on the inner and post orbits. heavily infuscated wings. Between prominent lateral tubracles, the labrum has a deep median furrow and a basal transverse depression. The distal half of the metabasitarsus' posterior margin is concave, and the proximal margin's thick pubescence (the auricle) extends to the projection's outer surface as a few sparse hairs.

Distribution

Gumda, alt- 1709, female 2, hab- agricultural field, hp- *Imatiens scabrida*, Gumda, alt- 1702, female 1, hab- agricultural field, hp- *Cucurbita sp* , Barpak, alt- 2780, female 3, hab-grassland, hp- *Parochetus communis*, Gumda, alt- 2082, female 2, hab- grassland, hp- *Strobilanthes attenuta*, Gumda, alt-2040, female 3 , hab- grassland, hp- *Strobilanthes attenuta*, alt- 2017, female 1 , hab- grassland, hp- *Imatiens scabrida*, Gumda, alt- 2570 female 3, hab- grassland, hp- *Anaphalis busua* , Gumda, alt- 1656, female 4, hab- agricultural field, hp- *Aster karvinkianus*

2. Sub genus - Melanobombus

Bombus (Melanobombus) *eximus*, Smith, 1852 (**photo 2b**)

Diagnostic features

Female - Pubescence of thorax is black, hair of the mid and hind tibiae and the basitarsi orange, metatasomal tergum 2 black. It is very large species, queen length is 28-29 mm and worker's length is 14-19 mm. Wings light orange brown with the mid basitarsus having the distal posterior corner forming nearly a right angle and not sharply pointed. Hind basitarsus with the posterior margin nearly straight. Oculo-molar distance approximately equal to the proxomal breadth of the mendible. Labrum with the lamella irregular but nearly straight and about half of the labrum. Ocello-ocular area along the inner eye margin with scattered large puncture but with few small punctures.

Distribution

Lapu, alt 1760, female 2, hab- agricultural field, hp- *Cucurbita sp*, Lapu, alt 2353, female 2, hab – forest, hp - *Jasminum humile*, Lapu, alt 2371, female 6, hab – forest,

hp - Jasminum humile, Laprak alt 2400, female 2, hab – forest, hp - *Jasminum humile*, , Laprak alt 2413, female 3, hab – forest, hp - *Jasminum humile,* Lapu alt 2423, female 2, hab-forest, hp - *Trifolium repens* , Laprak alt 2351, female 3,hab- forest, hp -*Cercium verutum*, , Laprak alt 2279, female 1, hab-agricultural field, hp- *Lindera pulcherrila*, Lapu ,alt 2256, female 1, hab – agriculture, hp - *Solanum tuberosum*, , Laprak alt 2092, female 2, hab – forest, hp - *Prinsepia uitilis*, , Laprak alt 2202, female 3, hab - forest, hp - *Viburnum erubescens*, Lapu, alt 2284, female 1, hab – forest, hp - *Jasminum humile*, , Laprak alt 2263, female 1, hab – forest, hp - *Opuntia dillei*, Barpak, alt 2237, female 5, hab- agriculture, hp - *Cucurbita sp*., Laprak, alt 2066 female 1, hab – grassland, hp – *Anemone elongate*,Lapu, alt 2043, female 1, hab – grassland, hp – *Anemone elongate*, alt 2039 female 1, hab – grassland, hp – *Anemone elongate*, alt 2044, female 2, hab – forest, hp - *Colquhounia coccinea*, Barpak, alt 2258, female 1, hab – grassland, hp - *Vibumum erubescens*, Lapu, alt 2351 female 1, hab-forest, hp - *Rosa brunonii*, , Laprak alt 2422, female 1, hab - agricultural field, hp - *Solanum tuberosum*, Barpak, alt 2544, female 3, hab – agricultural field, hp - *Cucurbita sp*. , Laprak alt 2351, female 2, hab – forest, hp - *Colquhounia coccinea*, , Laprak alt 2592, female 2, hab – agricultural field, hp - *Gaultheria fragrantissima*, , Laprak alt 2423, female 3, hab - forest, hp -*Lavatera cachemiriana*, , Laprak alt 2424, female 2, hab - forest, hp - *Lavatera cachemiriana*, Barpak,alt 2003, female 2, hab - forest, hp - *Lavatera cachemiriana*, Barpak,alt 2013, female 3, hab – forest, hp - *Opuntia dillei*.

3. Sub genus - Festivobombus

Bombus (festivobombus) *festivus* Smith, 1861 (**Photo 2c**)

Queen length is 22–25 mm, worker length is 12–17 mm. The pubescence is black in the thorax and white in the two abdominal tergite, except for the labrum, clypeus, and molar spaces, the head is covered in thick pubescence. Thick pubescence is evenly present on the visible thorax and abdomen. Strongly infuscated wings. a labrum with a deep median furrow and a basal transverse depression. The lateral and basal margins of the clypeus are extremely protuberant, and they curve back to join the gena and supraclapeal region. The mesobasi tarsus' distoposterior is entirely spherical. The meta tibia's outer corbicular surface is shiny, smooth, and devoid of any long, stout hairs that protrude from the surface.

Distribution

Ghasa,, alt – 1472, Female 3, hab – agricultural field, hp - *Allium sativum*, Ghasa, alt – 1506, Female – 6, hab – agricultural field, hp - *Phaseolus vulgaris*, Ghasa, alt – 1506, female 1 (dead), hab – home garden, hp - *Canna indica*, Lower Kerunja alt – 1690, female 1, hab - home garden, hp – *Lavatera cachemiriana*, Lower Kerunja, alt – 1732, female 1, hab – agricultural field, hp - *Solanum tuberosum*, Lower Kerunja, Lete, alt- 1948, femmale 10, hab- forest, hp - *Jasminum humile* , Lete, alt- 1948, female 1, hab- home garden, hp - *Dahalia pinnata* , Lete, alt – 2492, female 10, hab – forest, hp- *Cotoneaster frigidus*, Lete, alt – 2559, Female 20, hab - forest, hp - *Rosa brunonii*, Lower Kerunja alt-2595, female 10, hab – forest, hp - *Rosa brunonii*, Lower Kerunja,

alt- 2632, Female 10, hab- Forest, hp - *Rosa brunonii*, Ghasa, alt-2633,female 2, hab-forest, hp- *Trifolium repens*, Ghasa, alt-2638, female 2, hab – grass land, hp - *Anemone elongate*, Ghasa, alt- 2660, Queen 10, hab – forest, hp - *Cotoneaster frigidus*, Thumi, alt- 2691, Female 2, hab- grassland, hp- *Trifolium repens*, Thumi, alt- 2693, female 4, hab- forest, hp- *Jasminum humile*, Thumi, alt- 2724, female 2, hab- forest, hp - *Rosa brunonii*, Thumi, alt-2724, Female 1, hab – forest, hp- *Jasminum humile*, Thumi, alt- 2724, Female 1, hab- forest hp- *Jasminum humile*, Thumi, alt- 2724, Female 2, hab-forest, hp- *Jasminum humile*, Thumi,,alt- 2724, female 3, hab forest, hp - *Jasminum humile*, Thumi, alt- 2774, Female 2, hab- forest, hp- *Jasminum humile*,Ghasa, Kabra, alt-2774, female 1, hab-forest, hp - *Jasminum humile*, Kabre, alt- 2774, Female 1, hab agriculuural field, hp- *Solanum tuberosum*

4. Sub genus - Orientalibombus

Bombus haemorrhoidalis Smith, 1852, (**Photo 2d)**

They are a huge species with totally black queen pubescence on the head and thoracic dorsum, white abdominal tergites 1 and 2, black abdominal tergum 3, and brick red tergites 4-5; worker with head, thorax, and abdominal tergum 3 totally black, yellow; abdominal tergites 1 and 2; abdominal tergites 4 and 5 are brick red; wings are firmly infuscated; pubescence is short and extremely even. Except for the malar space, the clypeus, a region lateral to and in front of the ocelli, and narrow stripes on the inner and post orbits, the head is completely covered in pubescence. Labrum having lateral tubercles that are prominent, a lateral lamella that is broad and takes up more than half of the labrum's basal width, and a basal transverse depression that extends apically as a deep median furrow between them.

Distribution

Yeya, alt-1407, female 6, hab- agricultural field, hp -*Lantena sp.*, Yeya, alt- 1518, female 1, hab - grassland, hp- *Elsholtzia fruticose*, Yeya, alt- 1539, female 5, hab- agricultural field, hp - *Lantena sp.*, Yeya, Yeya, alt- 1571, female 1, hab- agricultural field, hp- *Aster karvinkianus*, Yeya, alt- 1709, female 2, hab- agricultural field, hp- *Anisomeles indica* , Dharapani, alt-1816 , female 5, hab-agricultural field, hp- *Fagopyrum dibotrys*, Dharapani, alt-1870, female 2,hab-agricultural field, hp- *Fagopyrum dibotrys*, Yeya, Lower kerunja, alt- 1906, female 1, hab-garden, hp -*Lavatera cachemiriana*, Lower kerunja, alt- 1973, female 1, hab-garden, hp- *Lavatera cachemiriana*, Lower kerunja alt-1594, queen 2, hab-agricultural field , hp- *Cucurbita* sp., Lower kerunja, alt-1760, queen 2 , hab-agricultural field, hp- *Cucurbita* sp., Thumi, alt-1700, queen 1, hab- agricultural field, hp- *Duranta reopens*, Barpak, alt-2349, queen 1 , hab- forest, hp- *Viburnum erubescens*, Barpak, alt-2326, queen 1, hab –forest, hp- *Jasminum humile*, Barpak, alt-2090, queen 2, hab-agricultural field, hp- *Solanum tuberosum*, Barpak, alt-2097, queen 1, hab- agricultural field, hp- *Solanum tuberosum* , Barpak, alt-2126, queen 1, hab -forest, hp- *Solanum tuberosum*, Barpak, alt-597, female 2, hab-agricultural field , hp- *Cucurbita sp.*,Barpak**,** alt-1906, female 2 , hab-garden, hp-

Dahlia pinnata, Barpak, alt-2067, female 6, hab- forest, hp- *Opuntia dillei*, Barpak, alt-2083 , female 2 , hab- forest, hp- *Imatiens scabrida*, Barpak, alt-2093, female 1, hab - forest, hp- *Imatiens scabrida*, Barpak, alt- 2366, female 1 , hab- grassland, hp- *Impatiens stenantha*, Laprak, alt- 2505, female 2, hab- agricultural field , hp- *Anaphalis contorta*, Laprak, alt-2592, female 2, hab- grassland, hp- *Imatiens scabrida*, Laprak, alt- 2590, female 2, hab- grassland, hp- *Aconogonum molle*, Laprak, alt-2614, female 1, hab- grassland, hp- *Hypericum elodeoides*, Barpak, alt-2284, queen 1, hab- grassland, hp- *Vibumum erubescens*, Laprak, alt-2443, female 2, hab- forest, hp- *Rosa brunonii*, Laprak, alt-2739, queen 2, hab- forest, hp- *Jasmium humile*, Laprak, alt-2360, queen 1, hab- agricultural field, hp- *Cucurbita sp*., Barpak, alt-2020, queen 1, hab- garden, hp- *Cercium verutum*, Barpak, alt-2060, queen 1, hab- forest, hp- *Impatiens stenantha*, Barpak, alt 2081, queen 1, hab- agricultural field, hp- *Impatiens stenantha*, Dharapani, alt – 1904, Female 1, hab- home garden, hp- *Lavatera cachemiriana*, Bokekhola, alt- 1386, Female 2, hab- agricultural field, hp- *Phaseolus vulgaris*,

5. Sub genus - Pyrobombus

a. *Bombus lepidus* Skorikov, 1972, (**Photo 2e**)

Female – Head, pronotum, metanotum, abdominal tergites 1 and 2 is yellow, mesonotum, malar space, and tergum 3 is black, and abdominal tergites 4-5 is brick red. Truncate, bean-shaped lateral tubercles on the anterior labrum's edge are divided in the middle by a shallow median depression that is the same length as the tubercle. The rest of the labrum is macro perforated, with the exception of the raised section of the lateral tubercle. Unpunctured area adjacent to the lateral ocellus in the ocello-ocular region that is the same size as the lateral ocellus. One-fourth of the space between the lateral ocellus and the eye margin is covered by a band of punctures along the eye margin.

Distribution

Thanchock, alt- 2633, female 3, hab – grassland, hp - *Trifolium repens*, Larjung, alt- 2655, female 1, hab- grassland, hp- *Anemone elongate*, Larjung, alt – 2669, female 10, hab- forest, hp- *Jasminum humile*, Thanchock, alt – 2691, female 6, hab- grassland, hp - *Trifolium repens*, Thanchock, alt-2722, female 3, hab – forest, hp - *Trifolium repens*.

b. *Bombus rotundiceps* (Friese, 1916), **Photo 2f)**

Female- The first three abdominal tergites pubescence are black and dingy yellow. Brick red describes the final 3. Except for the malar space, clypeus, the region lateral to and in front of the ocelli, and the short stripes on the inner and post orbits, the head is covered in heavy pubescence. Thick pubescence is evenly seen on the thorax and abdomen. Labrum with pronounced lateral tubercles that are slightly bluntly elevated and a deep median furrow between them that displaces the ridge between them to form a lamella that overhangs the apical border. The lateral and basal margins of the clypeus are substantially protuberant, and they curve back to connect the gena and the supraclypeal area, respectively.

Distribution

Danaque, alt- 2780, female 1, hab- forest, hp - *Jasmium humile*, Danaque, alt – 2098, queen 1, hab – grassland, hp - *Bidens pilosa*, Gumda, alt – 2090, queen 1, hab – agricultural field, hp – *Solanum tuberosum*, Gumda, alt – 1822, female 1, hab – forest, hp – *Osbectis parvifolia*, Gumda, alt – 1852, female 1, hab – agricultural field, hp – *Osbectia parvifolia*, Thumi, alt – 1731, female 4, hab - forest, hp – *Trifolium repens*, Thumi, alt – 1656, female 5, hab – agicultural field, hp – *Biden pilosa*, Thumi alt – 1660, female 3, hab - agricultural field, hp – *Stribilianthes tomentosa*,Thumi, alt – 1470, Female – 2, hab – agricultural field, hp – *Impatiens glandulifera*, Gumda, alt – 1320, Female – 5, hab – forest, hp - *Opuntia dillei,* Gumda, alt – 2632, female 1, hab – forest, hp - *Jasminum humile*

6. Sub genus - Bombus

Bombus tunicatus (Smith, 1852), (**Photo 2g**)

Female- Mesonotum and abdominal tergum 3 are black, pronotum, metanotum, and abdominal tergum 1 are white, abdominal tergites 4 and 5 are brick red, and there is a well-developed black stripe between the wings in the queen. Worker with a black head, mesonotum, and third abdominal tergite; white pronotum and metanotum; and brick-red abdomen tergite 4 and 5. The visible portions of the thorax and abdomen are uniformly covered in pubescence. With prominent lateral tubercles and a basal transverse depression that extends apically as a deep median furrow between them, the labrum has a lamella that overhangs the apical border. Labrum's anterior edge is complete; the abdominal tergum is crimson; the lateral tubercles are bean-shaped and do not connect in the middle. The lateral and basal margins of the clypeus are substantially protuberant, and they curve back to connect the gena and the supraclypeal area, respectively. presence of numerous, big punctures all over the central, flattened portion of the clypeus.

Distribution

Boksekhola alt – 2132, female 1, hab- forest, hp- *Rosa brunonii*, Danque, alt – 2270, female 10, hab- forest, hp - *Rosa brunonii*, Khokhethati, alt – 2515, female 10, hab – 10, hp - *Anemone elongate*, Danque, alt – 2515, female 8, hab – grassland, hp - *Anemone elongate*, Lete, alt – 2536, female 2, hab – grassland, hp - *Anemone elongate*, Lete, alt – 2536, female 2, hab- home garden, hp - *Antirrhinum Majus*.

7. Sub genus - Psithyrus

Bombus turneri (Richards, 1929), (**Photo 2h**)

Female- Strongly protruding as a broad, rounded triangle from the labrum is the labral lamella. The pubescence of the thoracic dorsum is black with sparsely interspersed yellow hairs anteriorly and posteriorly.

Distribution

Gumda, alt – 2270, female 2, hab – forest, hp - *Jasmium humile*, Boksekhola, alt – 2592, female 3, hab- grassland, hp - *Anaphalis busua*, Thumi, alt – 2096, female 1, hab

– forest, hp - *Imatiens scabrida*,Thumi, alt – 2127, female 1, hab – forest, hp - *Imatiens scabrida*, Lowerkerunja, alt – 2211, female 1, hab-forest, hp- *Prinsepia uitilis*, Barpak, alt – 2191, female 2, hab – forest, hp - *Chirita bifolia*, Upperkerunja, alt 2550, Female 10, hab - forest, hp - *Rosa brunonii*, Boksekhola, alt – 2550, Female 7, hab – forest, hp - *Jasminum humile*.
(alt= altitude, hab= Habitat, hp= Host plant)

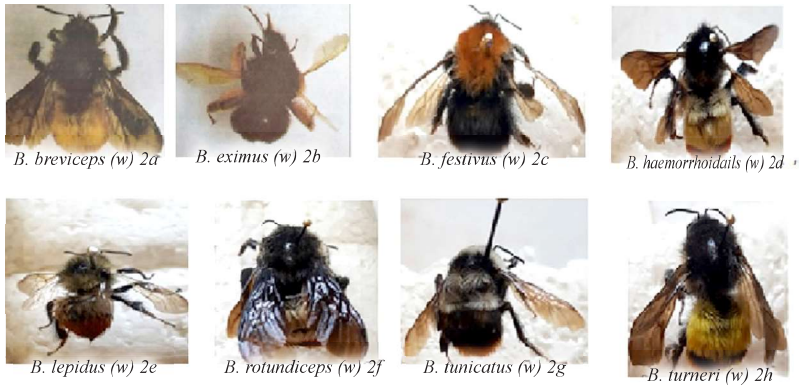

Fig. 2: photos of different identified species of bumblebees in CHAL region of Nepal

Discussion

Species variation in three sites are related to the local microhabitats, floral composition and land use change. Due to the different microhabitat such as grassland, agricultural land, forest and home garden of three sample sites, the distribution pattern of bumblebees' species are different. Due to their limited foraging ranges, bumblebees require close proximity between landscape elements that provide nesting sites, foraging habitats, and undisturbed structures for hibernation (Diekötter *et al* 2006)). The diversity and abundance of flowering plant species, as well as vegetation shape and height, were habitat variables that influenced the overall abundance, species richness, and foraging activity of bumblebees. According to their unique needs for foraging and nesting, many Bombus species may respond to certain ecological factors (Carvell *et al*. 2002). The size, color, and shape of the flowers, the amount and kind of pollen, the season, and the location are some of the variables that affect the floral composition of host plants (Tai *et al* 2020). The bumblebees prefer flower grown on the open slope of mountain instead of closed deep and dense forest. For these insects, the shape of the flower is crucial when selecting a bloom. Flowers have funnel-shaped that facilitate direct movement and make it easier to collect pollen and nectar. Bumblebees have also been observed to favor symmetrical flower over asymmetrical ones (Moler, 1995; Vaudo, 2016). Instead of color and categories, host plant selection was heavily influenced by host plant families and flower types (Bhusal *et al*. 2019). Land use change in Europe's subalpine regions is a main driver in biodiversity changes, and it also has a serious influence on the presence of European bumblebees (Fourcade, 2019, Marsal, 2018).

During several field survey in the Gorkha, Manang and Mustang of three river basins of

Kaligandaki, Marsyngdi and Budigandaki of Chitwan Annapurna Landscape, over 387 bumble bee specimens were collected, belonging to 8 species. As a biodiversity hotspot and an important area for conservation priority, the central Himalayan range is a site to the first systematic study of bumble bee diversity (Myers *et al*., 2000).Out of eight subgenera of *Bombus*, *B. festivus* was most abundant as the species of this subgenus inhabit in high alpine grassland, open grassland, semi-desert and tropical hill forest and have short, medium or may have long tongue-length visiting shallow to deep flowers while subgenus Pressibombus was least abundant as the species of this subgenus inhabit in higher alpine grassland and semi-desert (Williams *et al*. 2008). *Bombus festivus* was found more abundant representing 25.91% of total species recorded. *B. haemorrhoidalis* was low in abundance in Manang and Mustang but high in Gorkha as it was recorded from low elevation and warmest altitude as a species of western Oriental region (Williams, 1991; Streinzer *et al* 2018). Similarly, *B. asiaticus* was recorded as it a Himalayan species (Williams, 1991). The least abundance species were *B. asiaticus, B. cornotus* and *B. pressus*. All the recorded species were recognized as Himalaya species. So, no species have yet been assessed for red list status. Of the total, only *B. tunicatus* is categorized as endemic species from Himalayan (Williams and Jepsen, 2017). Species richness (11) of study area is higher than the species richness (eight) of Iowa as reported by Hines and Hendrix (2005) and from Japan (six) recorded by Teruyoshi *et al* (2006) and from Scotland (six) recorded by Brodie (1996). The reason for higher diversity of bumblebee in central Himalaya (especially Nepal) is because of overlap of both eastern and western bumblebee species (Williams *et al*., 2010).

5. Conclusion

The Chiwan Annapurna Landscape CHAL's Gorkha, Manang, and Mustang Districts provide a variety of climatic settings for bumblebees. A total of 387 bumble bee specimens were collected, and 8 species from 7 subgenera were identified. The *Bombus festivus* (subgenus: Festivobombus) was the most common species in the research area. When compared to the Gorkha, Manang and Mustang sites, the Gorkha site had the highest species richness. The main species at the Gorkha site were *B. haemorrhoidalis, B. eximus*, and *B. rotundiceps*, whilst *B. festivus, B. lepidus*, and *B. tunicatus* were main species recorded in Manang, and *B. festivus, B. tunicatus*, and *B. turneri* were major species in Mustang during our field study.

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