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Distribution Pattern of *Synotis* (C.B. Clake) C. Jeffrey & Y.L. Chen (Senecioneae : Asteraceae) in Nepal Himalaya

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Abstract

The distribution pattern of ten species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen in phytogeographical regions and bio-climatic zones in Nepal along with the species richness was studied. Central Nepal houses the highest number of species, followed by the east Nepal. West Nepal has the least number of species. Within the bio-climatic zones, the highest numbers of species are present in the temperate zone, followed by subalpine zone and then subtropical zone. Alpine zone houses only three species of *Synotis.* The species richness is peaked in the central Nepal and at the elevation of 2100 – 2200 m and 2400 – 2600 m.

Key words: *Synotis*, Bio-climatic zone; Distribution; Elevation; Phytogeographical region; Species richness

INTRODUCTION

Nepal lying in the central part of the Himalaya and covering less than 0.1 % of the earth's land area has disproportionately rich species diversity (Chaudhary *et al*. 2016). The condition of high species diversity is attributed mainly because of varied altitudinal gradients and topographical variations combined with the edaphic factors within the small area. Presently Nepal Himalaya is reported to have 6,973 species of angiosperms accounting for 3.2 % of global diversity of angiosperms (GoN/MoFSC 2014). The genus *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen is an important genus of tribe Senecioneae Cassini of Asteraceae Berchtold & J. Presl (Compositae Giseke *nom. cons.*), which is one of the largest families of the flowering plants of the world and comprises about 22,750 species (Shrestha 2016). The members of the family are usually abundant in geologically recent habitats like the areas of Mediterranean (summer dry climate), deserts and their margins, open prairies and recently evolved mountains. However, quite a few are in danger of extinction due to the destruction of habitats and global warming (Raven 2009). The type specimen of the genus is the type of *Synotis wallichii* (DC.) C. Jeffrey & Y.L. Chen (Basionym: *Senecio wallichii* DC.). The genus with clearly defined geographical area had been delimited from *Senecio* L. by Jeffrey and Chen in 1984. Out of the 24 species of *Senecio* L. reported from Nepal Himalaya by Hara *et al.* (1982) and Press *et al.* (2000), ten species are in the subgenus *Synotis* C.B. Clarke and include a new species reported by Joshi *et al.* (2013), Nepal Himalaya presently houses 11 species of *Synotis*. These species are predominantly distributed in the moist and shady habitat (Joshi *et al.,* 2013). However, in this paper the distribution pattern of only 10 species are given.

The genus is characterized by the erect or weakly scandent herbs or subshrubs with woody rhizomes, absence of radical leaves at the time of anthesis, calyculate involucres, flat receptacle, phyllaries not exceeding 15 and the caudate anther base. The genus with about 54 species is confined to the Sino-Himalayan range except *S. atractylidifolius,* which occurs in N. China (Chen *et al*. 2011).

The information about the distribution of species at different phytogeographical regions and elevation gradients are important for their conservation and management of diversity. Hunter and Younzon (1993) were of the views that lack of detailed knowledge about distribution patterns of species and ecosystems lead to problems in conserving species and relationship between species richness and elevation is important for conservation and management of species (Grytnes 2003).

The main aim of this paper is to provide information on the distribution pattern of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen in different phytogeographical regions and bioclimatic zones of Nepal and find the species richness of the genus along the horizontal and vertical gradients.

Botanical explorations in Nepal

Because of extreme elevation gradients with unique geographical location on the globe, Nepal Himalaya provides good opportunities to the botanists. Botanical heritage of Nepal Himalaya had been explored from the beginning of 19th century. Buchanan Hamilton (1802-1803) explored the country for the first time, followed by N. Wallich (1820 – 1821), J.D. Hooker (1848), I.H. Burkill (1907), Lal Dhwoj & K.N. Sharma (1927 – 1931), B.L. Gupta (1929), B. Ram (1929), M.L. Banerji (1948) and so on (Rajbhandari 2002). Specially, Nepal's rich unique flora became more explored after the revolution in 1950 – 1951, a number of botanical expeditions were carried out then after and a vast number of specimens were collected. Most of those collections which also included many species of *Synotis* were housed at the well reputed herbaria of the world like BM, K, CAL, G-DC, E, KYO, TI, P, KATH, etc. Type specimens of most species were collected at that time and housed in those herbaria. KATH herbarium, the oldest and largest herbarium of Nepal also houses many species of *Synotis*. Moreover, TUCH at Central Department of Botany, Tribhuvan University also houses a large number of specimens deposited by the students and other researchers.

MATERIAL AND METHODS

Data Collection

The distribution pattern of ten species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen viz., *Synotis acuminata* (Wall. ex DC.) C. Jeffrey & Y.L.Chen., *Synotis alata* (Wall. ex DC.) C. Jeffrey & Y.L. Chen., *Synotis brunneo-villosus* (Kitam.) C. Jeffrey & Y.L. Chen., *Synotis cappa* (Buch.-Ham. ex D. Don) C. Jeffrey & Y.L. Chen and *Synotis cappa* var. *pubescens* (Kitam.) H.B. Naithani, *Synotis managensis* S. Joshi, K. Shrestha & D. Bajracharya., *Synotis rufinervis* (DC) C. Jeffrey & Y.L. Chen, *Synotis tetrantha* (DC.) C. Jeffrey & Y.L. Chen, *Synotis triligulata* (Buch.-Ham. ex D. Don) C. Jeffrey & Y.L. Chen, *Synotis vagans* (Wall. ex DC.) C. Jeffrey & Y.L. Chen and *Synotis wallichii* (DC.) C. Jeffrey & Y.L. Chen, are highlighted in this work. The study was based on intensive literature survey, voucher specimens deposited at different herbaria such as KATH, TUCH, BM, KEW, E, G-DC, NYBG, CAL etc. and field observations and live collections from different localities of Nepal during 2009 to 2013. The voucher specimens and the live specimens were identified and authenticated by verifying the specimens with protologue

texts, taxonomic literatures and type specimens (D. Don 1825; De Candolle 1838; Hooker 1882; Jeffrey & Chen 1984; Joshi *et al.* 2013). The protologues and images of type specimens were acquired from different sources including the different websites such as http://apps.kew.org/herbcat/navigator.do, www.plants.jstor.org, www.nybg.org and personal communications.

The phytogeographical regions of Nepal as recognized by Stearn (1960) are West Nepal (with upto 83° E latitude), Central Nepal (between 83° E to 86°30' E) and East Nepal (from 86°30' E onwards) and that has been followed in this work. Six bioclimatic zones with 11 subzones given by Dobremez (1975) were recognized for the analysis of species on the vertical zones:

1. Tropical zone (up to 1,000 m): Lower up to 500 m and upper 500 – 1,000 m
2. Subtropical zone (1,000 – 2000 m): Lower 1,000 – 1,500 m and upper 1,500 – 2,000 m
3. Temperate zone (2,000 – 3,000 m): Lower 2,000 – 2,500 m and upper 2,500 – 3,000 m
4. Subalpine zone (3,000 – 4,000 m): Lower 3,000 – 3,500 m and upper 3,500 – 4,000 m
5. Alpine zone (4,000 – 5,000): Lower 4,000 – 4,500 m and upper 4,500 – 5,000 m
6. Nival zone (Above 5,000 m).

Data analysis

The distribution maps of different species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen on the phytogeographical regions of Nepal Himalaya were generated by the software Arc GIS using their geolocations and their distribution on the vertical gradient was evaluated by Excel software. The geolocations of some of the localities mentioned in the voucher specimens are also acquired from the website http://rbg-web2.rbge.org.uk/nepal/locator/index.html. For the distribution at different bioclimatic zones and elevation gradients, presence of species was estimated by interpolation (Vetaas & Grytnes 2002). The species is assumed to be present in the elevation range from its minimum records to maximum records made from herbarium data as well as from the field observation. The species richness at particular elevation was determined by scattered plot method. The overall elevation range from 1000 m to 5,000 m was divided into 40 bands, each with the 100 m interval. The species is considered to be present in each elevation band within its minimum level of occurrence to maximum level of occurrence. For example, *Synotis tetrantha* with its elevation gradient from 2400 m – 3100 m, is considered to be present in each elevation band of 2400, 2500, 2600, 2700, 2800, 2900, 3000 and 3100 m (Bhattarai *et al*. 2004).

RESULT AND DISCUSSION

The list of *Synotis* species studied along with their distribution in phytogeographical regions and elevation gradients of Nepal is given in Annexure - I. Out of the species of *Synotis* studied, except *S. cappa* and *S. triligulata*, all other species are endemic to the Himalayan region. One species, S. brunneo-villosus and one infraspecies S.cappa var. pubescens are endemic to Nepal Himalaya (http://www.leca.univ-savoie.fr/db/florhy/infos.html). More over S. managensis is also endemic to Nepal Himalaya.

Distribution in Phytogeographical regions

Three species viz. *S. alata*, *S. cappa* and *S. triligulata* have well diversified habitat from west Nepal to east Nepal (Figure 1). Two species, *S. rufinervis* and *S. vagans* have their eastern range up to the central Nepal (Figure 2), while *S. acuminata*, *S. tetrantha* and *S.*

wallichii have their western range up to central Nepal (Figure 3). One species *S. managensis* is confined only to central Nepal (Figure 4) and one species *S. brunneo-villosus* is confined only to east Nepal (Figure 5).

West Nepal thus houses five species viz. *S. alata*, *S. cappa, S. rufinervis, S. triligulata* and *S. vagans*; central Nepal houses all species except *S. brunneo-villosus* and east Nepal houses seven species viz. *S. acuminata, S. alata, S. brunneo-villosus, S. cappa, S. tetrantha, S. triligulata,* and *S. wallichii.*.

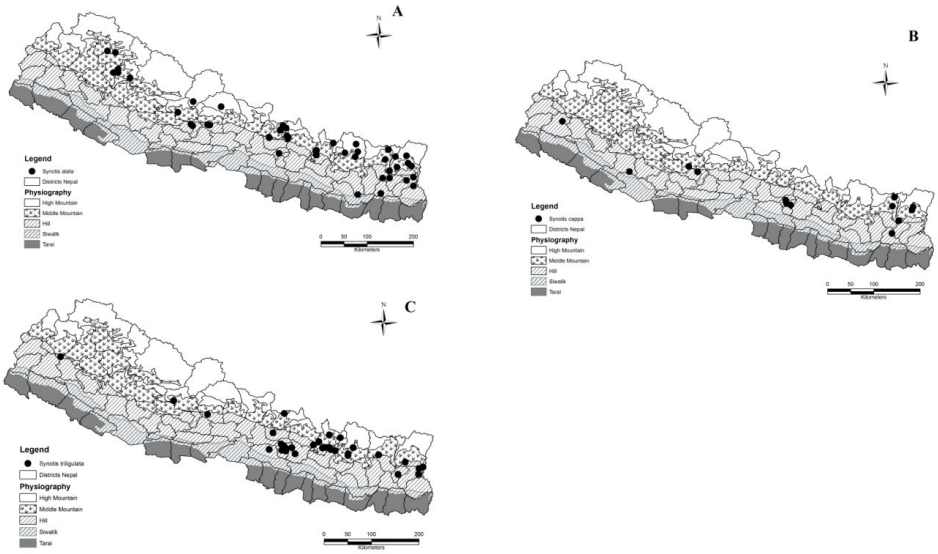

Figure 1. Species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen distributed in West, Central and East Nepal: A = *S. alata*; B = *S. cappa*; C = *S. triligulata*

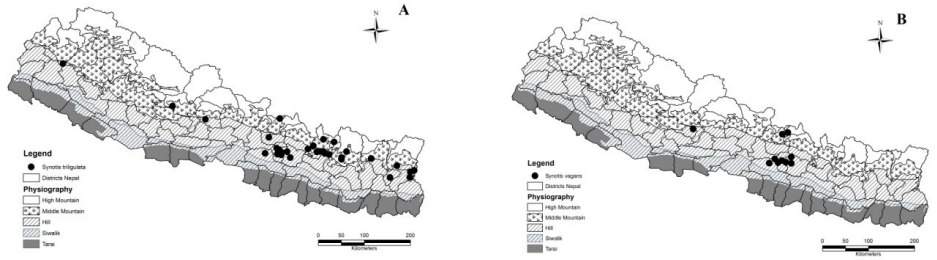

Figure 2. Species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chendistributed in West and Central Nepal: A = *S. rufinervis*; B = *S. vagans*

Distribution in Bio-climatic zones

The distribution of species of *Synotis* have elevation gradient from 1200 – 4400 m. i.e. from lower subtropical to lower alpine region (Figure 6). Species like *S. acuminata* and *S. alata* are distributed from upper subtropical to lower alpine region. Species *S. brunneo-villosus* is confined only to temperate region; *S. cappa* and *S. rufinervis, S. triligulata* and *S. wallichii* are distributed from lower subtropical to lower subalpine region; *S. vagans* is distributed from upper subtropical to lower temperate zone; *S. managensis* is confined to lower subalpine to lower alpine region; *S. tetrantha* from lower temperate to lower subalpine (Figure 7). The

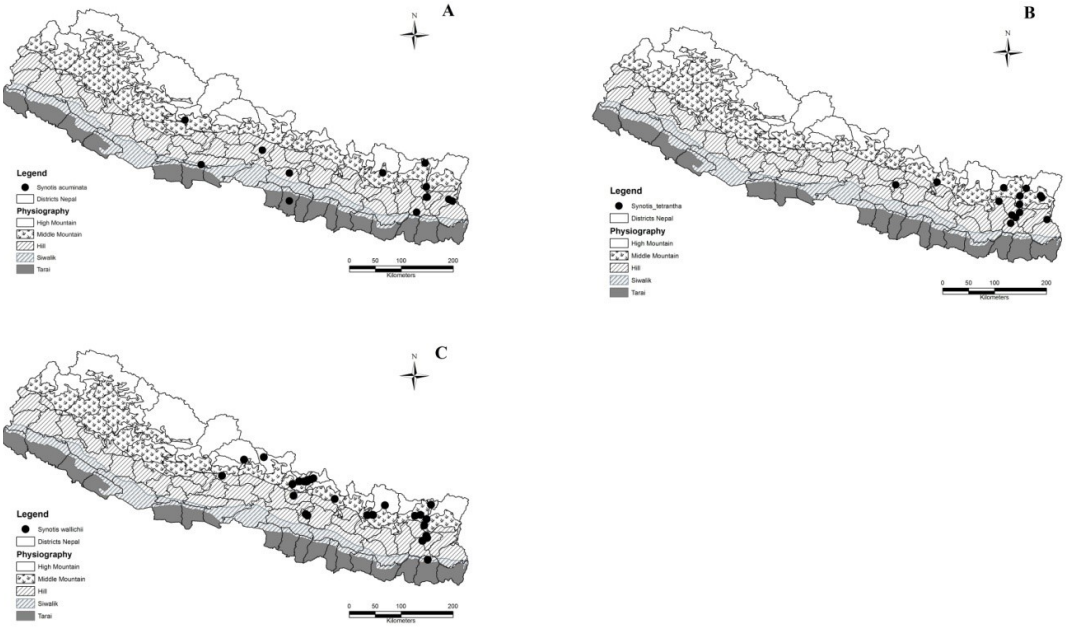

Figure 3. Species of Synotis (C.B. Clarke) C. Jeffrey & Y.L. Chendistributrd in Central and East Nepal: **A.** *S. acuminata*; **B.** *S. tetrantha*; **C.** *S. wallichii*

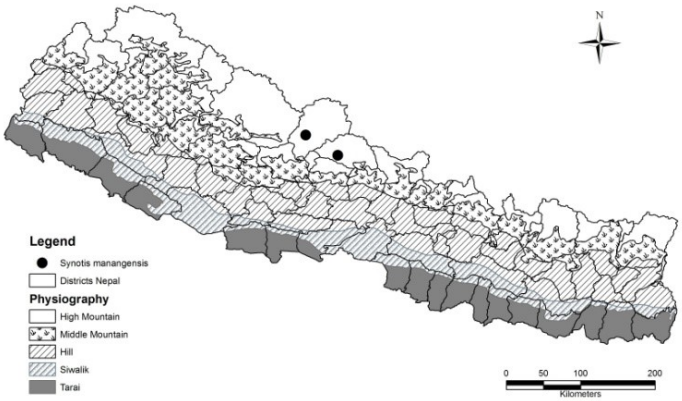

Figure 4. Species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chendistributed in Central Nepal only: *S. managensis*

species, *S. vagans* is found to have the narrow range of distribution from upper subtropical to lower temperate region only with the narrow elevation gradient (Table 1). However, no species is recorded from the tropical zone and upper alpine zone (Figure 6).

The highest number of 9 species of *Synotis* are reported from the temperate zone; followed by subalpine with 8 species and subtropical zone with 7 species. The alpine zone houses the least number of 3 species only (Figure 8).

Species richness

The horizontal distribution of species of *Synotis* is peaked at the central Nepal with nine species, followed by east Nepal with seven species (Figure 9). The west is found to have the least number of species with five species (Figure 9).

Table 1. Distribution pattern of *Synotis* spp. in Nepal Himalaya

Sl. No	Botanical Name	Region	Elevation (m)
1.	*S. acuminata* (Wall. ex DC.) C.Jeffrey & Y.L.Chen	CE	1800 – 4300
2.	*S. alata* (Wall. ex DC.) C. Jeffrey & Y.L. Chen	WCE	1500 – 4400
3.	*S. brunneo-villosus* (Kitam.) C. Jeffrey & Y.L.Chen	E	2100 – 2600
4.	*S. cappa* (Buch.-Ham. ex D. Don) C. Jeffrey & Y.L Chen	WCE	1300 – 3000
	S. cappa var. *pubescens* (Kitam.) H.B. Naithani	CE	1200 – 3200
5.	*S. managensis* S.Joshi, K.Shrestha & D. Bajracharya	C	3200 – 4100
6.	*S. rufinervis* (DC.) C. Jeffrey & Y.L. Chen	WC	1200 – 3200
7.	*S. tetrantha* (DC.) C. Jeffrey & Y.L. Chen	CE	2400 – 3100
8.	*S. triligulata* (Buch.-Ham. ex D.Don) C. Jeffrey &	WCE	1500 – 3300
9.	*S. vagans* (Wall. ex DC.) C. Jeffrey & Y.L. Chen	WC	1890 – 2200
10.	*S. wallichii* (DC.) C. Jeffrey & Y.L. Chen	CE	1500 – 3300

The species of *Synotis* in vertical gradient showed a significant curvilinear relationship with the elevation gradients. The maximum richness peaked with eight species at the elevation belt of 2100 – 2200 m and 2400 – 2600 m (Figure 10), followed by seven species at the elevation from 1800 – 2000 m; at 2300 m and from 2700 – 3200 m. The result thus revealed the species richness is high from upper subtropical region to lower subalpine regions with the maximum richness at temperate zone of Nepal Himalaya.

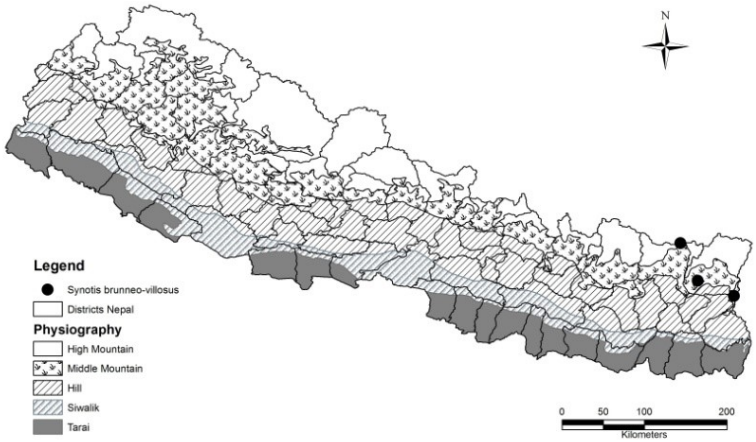

Figure 5. Species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chendistributed in East Nepal only: *S. brunneo-villosus*

DISCUSSION

The majority species of *Synotis* are mostly found to inhibit the moist and shady places and hence the availability of water is one of the major factors in the distribution of its species. In Nepal, monsoon rain originates from Bay of Bengal and the amount of rains gradually

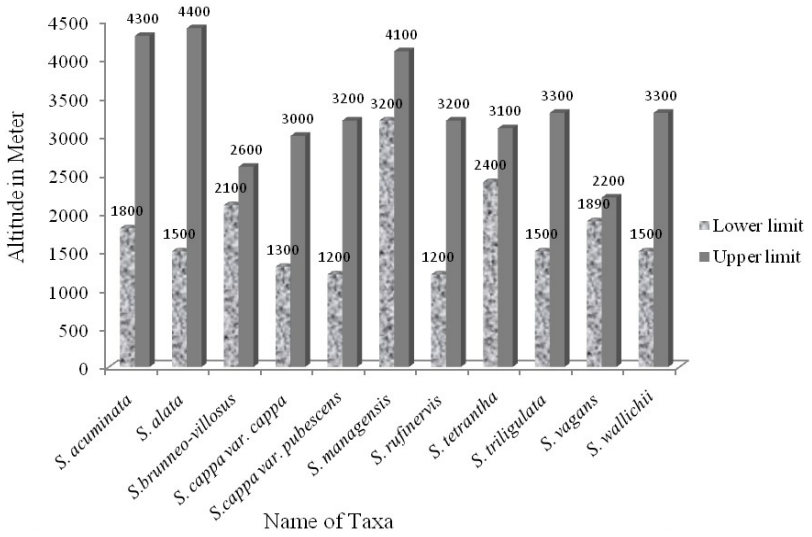

Figure 6. Altitudinal range of distribution of different species of *Sinotis* (C.B. Clarke) C. Jeffrey & Y.L. Chenin Nepal Himalaya

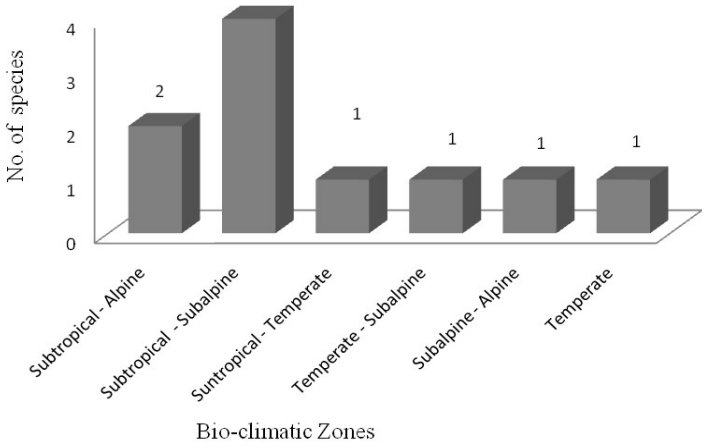

Figure 7. Distribution of species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chenin different Bio-climatic zones in Nepal

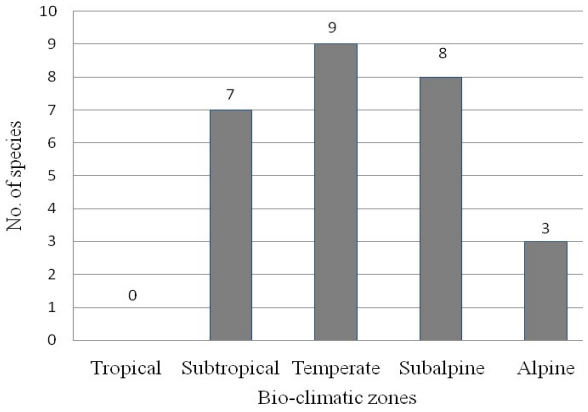

Figure 8. Number of species of *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chenin bio-climatic zones of Nepal

decreases from east to west (Acharya *et al.* 2009). Regarding the regional distribution, the highest numbers of species are found at central Nepal followed by east Nepal. West Nepal houses the least number of species. The less number of species in west Nepal is correlated with climatic conditions as the west is drier than central and east Nepal. The species like *S. rufinervis* and *S. vagans* end their eastern range in central Nepal. Similarly the species like *S. acuminata, S. cappa* var. *pubescens, S. tetrantha* and *S. wallichii,* end their western range at central Nepal. Thus central Nepal becomes rich in *Synotis* species because species from west and east end their range here at central region and thus becomes the merging point of species from west and east Nepal.

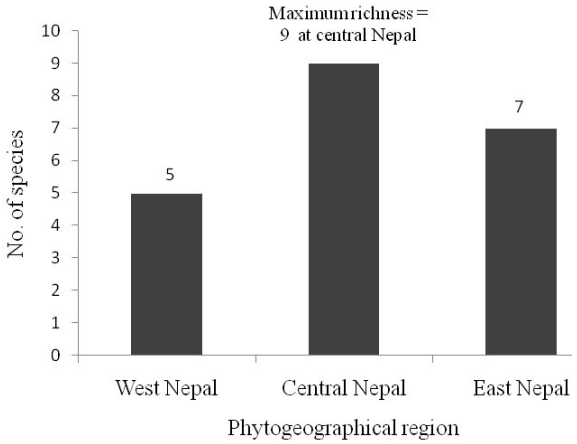

Figure 9. Number of *Synotis* spp. in different phytogeographical regions of Nepal

Within the bioclimatic zones, the *Synotis* species are distributed from subtropical to alpine zone with almost universal distribution at temperate zone. Out of ten species studied, nine species are well distributed in temperate zone. Only one species, *S. managensis,* is not found in temperate zone. The temperate zone is represented by cool and humid climate and thus become suitable for the occurrence and growth of *Synotis* species. Species richness is the highest at 2100 – 2200 m and 2400 – 2600 m tiers. It is also noted that the species richness of *Synotis* correlates with vascular plants richness, which had the maximum richness between the elevations of 1500 m to 2500 m (Acharya *et al.* 2009).

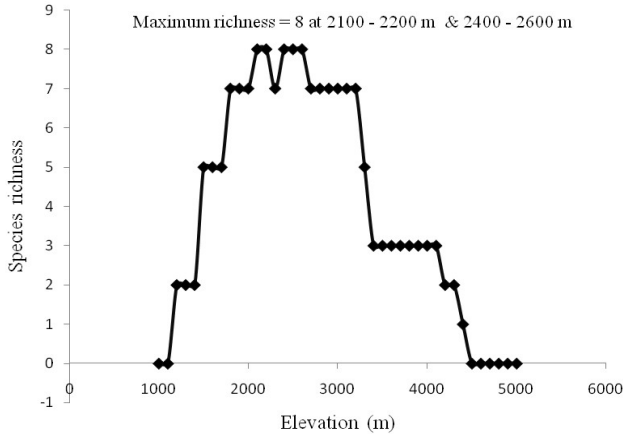

Figure 10. Richness of *Synotis* spp. in vertical gradients in Nepal

CONCLUSION

The present study revealed the distribution pattern of species *Synotis* (C.B. Clarke) C. Jeffrey & Y.L. Chen in Nepal Himalaya within the phytogeographical regions and bio-climatic zones along with the species richness in both horizontal and vertical gradients. Central Nepal harbours the highest number of species of *Synotis*. All the species, except *S. brunneo-villosus* are reported from central Nepal. One species *S. managensis* is endemic to central Nepal and one species *S. brunneo-villosus* is endemic to east Nepal. Moreover, one infraspecies *S. cappa* var. *cappa* is also endemic to central and east Nepal. The species are distributed from subtropical zone to alpine zone with the elevation gradients from 1200 m to 4400 m. All the species except *S. managensis* are reported from the temperate zone. The alpine zone houses only three species namely, *S. acuminata, S. alata* and *S. managensis*. The species richness peaked at the elevation of 2100 – 2200 m and 2400 – 2600 m with eight species in each band. The distribution pattern revealed by present study is envisaged to be helpful in conservation and management of its species especially the endemic ones. For the conservation and sustainable uses of biodiversity, the conservation activities should be prioritized within the range with maximum species richness.

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