*Rec. zool. Surv. India:* Vol. 123(4)/377-389, 2023
DOI: 10.26515/rzsi/v123/i4/2023/172388

ISSN (Online) : 2581-8686
ISSN (Print) : 0375-1511

# How altitudinal gradient affecting distributional pattern of pollinating Hover flies along the agro-climatic zones of Himachal Pradesh, India

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## Abstract

*The present study over a period of 4 years has mapped down the status of pollinating hoverflies across the entire elevational stretch across the state. So for long-term monitoring, this distribution data which was not available previously, recorded during the recent study is believed to be beneficial. The study has shown that the distributional trend of the pollinating hoverflies along this wide elevational range follows the rules of monotonal declination of species richness along with increasing altitude.*

**Keywords:** Agro Climatic Zone, Distribution, Digital Elevation Model, Hoverfly, Pollinator

## Introduction

Despite rising as an alternative superhero in pollination services of agro-economic ecosystems, the distributional scenario of hoverflies is always a matter of underrated consideration. Unfortunately, the research on hoverflies has always prioritized the taxonomic and ecological aspects more. But undoubtedly, without prior knowledge about the habitat specificity of this group of pollinators, it is always difficult to apply conservation measures and policies. Species distributional affinity along varied ecosystems and landscapes acts as a key factor in conservation management approaches. Unfortunately, the research on hoverfly's distributional empathy is always a more prioritized topic of research along with the Palearctic and Nearctic realms than the other zoogeographical realms. Research on hoverfly habitat specificity has taken place more methodically in this region in comparison to the Afrotropical, Indomalayan, and Oriental regions. (Thompson & Hauser, 2015) From these realms, research prioritizing hoverflies as a part of the pollination network was even somewhat neglected and underrated throughout the last few decades. Fortunately, it has seen a resurgence with a broader interest in hoverfly research since early phase of 2008 (Mengual *et al.,* 2008, 2012, 2013; Reemer & Hippa, 2008; Mengual & Ghorpade, 2010; Steenis, 2010, 2015a; Thompson, 2015; Shah *et al.,* 2014; Thompson & Skevington, 2014; Mengual *et al.*, 2015; Hippa *et al.*, 2015; Jordaens *et al.*, 2015a, 2015b; Doczkal *et al.*, 2016; Sengupta *et al.*, 2016a, 2016b, 2017, 2018a, 2019b; Wachkoo *et al.*, 2019). Moderately research history has shown that in the Oriental region exploration of hoverflies always prioritizes taxonomic aspects. Among the Oriental region, megadiverse countries like India have also followed this trend. Undoubtedly, the distributional category of research of this group of second-line pollinators is also underrated here. However, exploration regarding the evolution of hoverflies as an alternative major pollinator along the agricultural landscape has speeded the wheel in recent times (Sengupta *et al.*, 2018a, 2019a). To authenticate the facts it is always necessary to establish the potentiality of this pollinating group. Across all habitat scales, dipteran flies are available as pollinators but their efficiency as pollination leaders is mainly accredited in the higher elevational and latitudinal areas (Sengupta et *al.,* 2018b) where profusion of bee and other Hymenoptera is limited due to environmental hardship (Williams & Osborne, 2009; Sengupta *et al.,* 2019c). In such a higher elevational landscape, especially in mountain states, this needed to be considered and prioritised urgently for proper research to find out the current status of syrphid flies from there. Himachal Pradesh is one of the largest mountain states in

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the country (occupying 1.69% of India's total geographical area). It has always fascinated pollination biologists to explore its vast range of habitats ranging from agricultural landscapes, and high altitudinal forest patches to dry cold deserts (Sengupta *et al.,* 2018b). Apart from this, its geographical positioning has added an extra feather to this throne. Besides as the altitudinal range of this state includes more than 6,000 meters in its account, it falls under the radar of deprivation from efficient pollinators like the honey bee, bumblebee, butterflies, etc., (Godfray *et al*., 2010). Which makes it more obvious to track down the frequency and distributional status of the alternative second liners of the pollination network with priority? It is thus necessary to prioritize the pollination proficiency of hoverflies from this state. Besides the typical climatic condition of Himachal Pradesh makes it an uncanny representative of the Palearctic and Nearctic Realm in the form of a shape of state which is geographically coordinated in the Oriental realm.

To the best of our knowledge, no study on family hoverflies has been conducted so far regarding the distribution of the species alongside agro-economic zonation based upon an authenticated Geographical Information System. Further, there is also no consolidated report on the distributional scenario of hoverflies along elevational gradients and latitudinal trends, which is no doubt an essential tool for predictive Species Distribution Modelling (SDM) for the best-suited pollinators of the ecosystem. Further, no co-relation study has been done before about syrphid species distribution from other states as well as along all the zoogeographical realms which in turn was essential for the endemic status of this pollinating group of the fly. Therefore, this study has addressed the urgency of the facts and has pinpointed the geographic areas where there were either many pollinating species of hoverflies or of those habitats along elevational zones where hoverfly species are rare in distribution and need to be introduced as per pollination of agricultural and food crops are concerned. This study also highlighted the distributional scenario of those particular hoverfly species along the Western Himalayan landscape of Himachal Pradesh, which is of spatial concern. This further will help to mediate proper conservation management approaches.

So overall the present study is therefore aimed at producing agro-climatic zone-wise distributional maps of syrphid species to exhibit elevational variability in their distributional pattern (Figure 1). A Digital Elevation Model (DEM) map has been generated for every hoverfly species to track down its distributional pattern along with the entire state using an appropriate geographical information system. Not only that, the present study has generated data of the most suitable and frequent species from all of the subfamilies of Syrphidae to make an account of those species which have shown the most suitability in distribution and survivability across different habitat ranges of this higher altitudinal landscapes. This in turn helps to strategies and apprentice conservation-friendly policies for addressing the issues of pollinator decline and alarming rises in global hunger indexes across this state in future days.

## Materials and Methods

Distribution maps of syrphid fauna have been generated using ARC GIS 10.1 Software (Redlands, USA). The digital Elevation Model was extracted from Cartosat -1 and further processed in ARC GIS. The thematic map of Himachal Pradesh has been generated using DIVA GIS software version 6.0.2 (Figure 1). The tables showing distributional frequency as well as affinity along different geographical realms and the table representing the endemic species of hoverflies have been generated using Microsoft Word 2016. All the necessary files required for distributional map generation have been created using Microsoft Excel version 2016.

## Result

The current study is the first-ever consolidated study on the distributional pattern of hoverflies along this elevational range of 350-6000 mts. of agro-climatic zones landscape. The detailed study accounts for 22 species of hoverflies under 15 genera over 2 subfamilies from the Shivalik hill zone of Himachal Pradesh. This further includes the record of 3 species of syrphid flies namely *Allograpta (Allograpta) javana* (Wiedemann,1824), *Dideopsis aegrota* (Fabricius,1805) and *Eristalinus (Eristalinus) tabanoides* (Jaennicke,1867) for the first time from the state of Himachal Pradesh. Whereas 39 species of hoverflies under 22 genera over 2 subfamilies from the Mid hill zone of Himachal Pradesh of which 2 species namely *Scavea pyrastri* and *Eristalinus (Eristalinus) polychromata* (Fabricius, 1787) are recorded for the first time from this Mid Hill zone as well as from the state

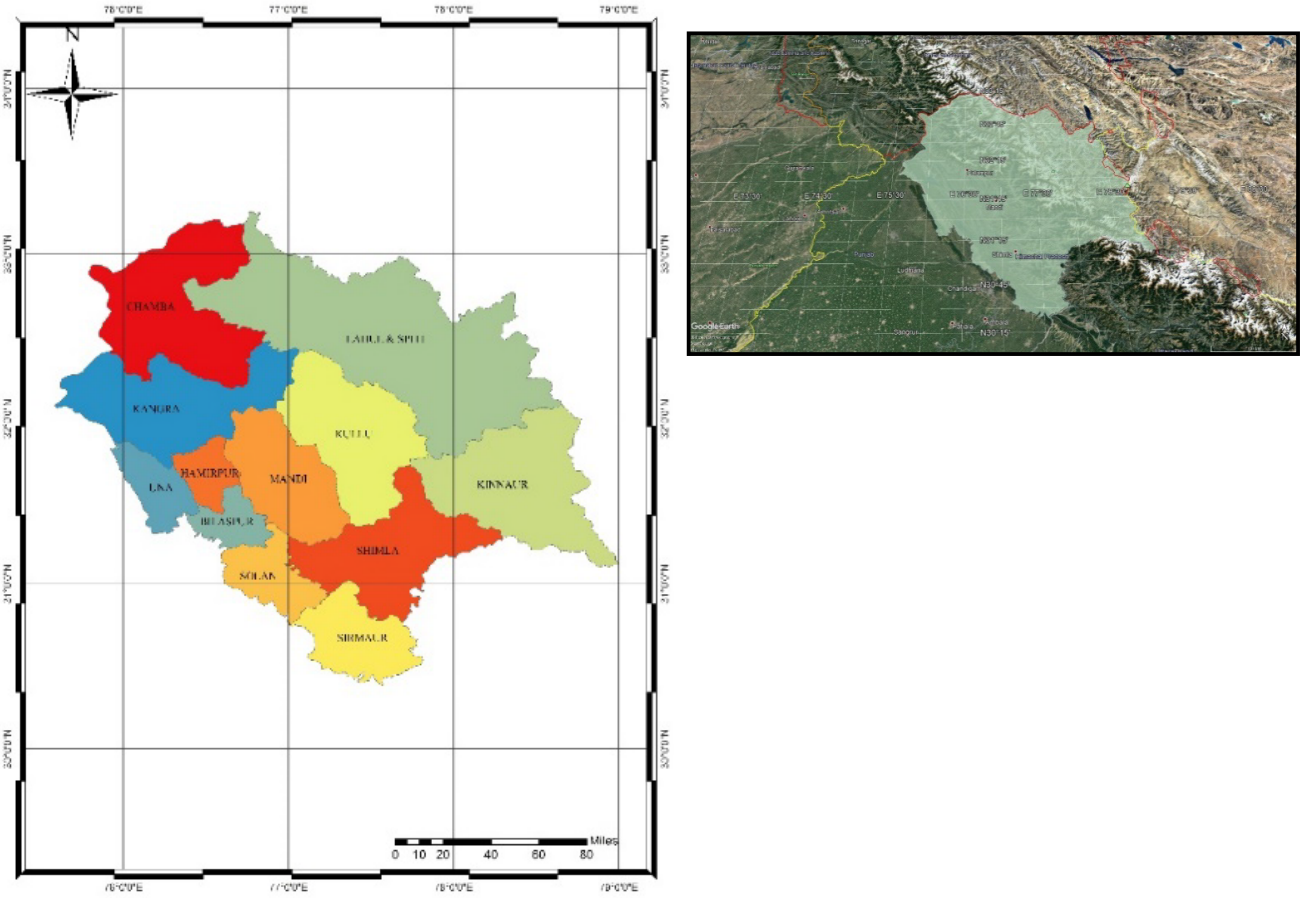


**Figure 1.** GIS and Satellite Map representation of the study area: State of Himachal Pradesh.

of Himachal Pradesh recorded for the first time from the state of Himachal Pradesh. Alternatively, this study altogether recorded 19 species of hoverflies under 13 genera over 2 subfamilies from this High hill zone of which 3 species namely *Syrphus (Syrphus) vitripennis* Megen,1822, *Eristalis (Eristalis) tenax* (Linnaeus,1758) and *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787) are recorded for the first time from this High hill zone as well as from the state of Himachal Pradesh recorded for the first time from the state of Himachal Pradesh Finally, altogether 18 species of hoverflies under 14 genera and 2 subfamilies have been reported from our study area of the cold and dry zone. Among which 4 species namely *Chrysotoxum violaceum* Brunetti, 1923, *Sphiximorpha triangulifera* (Brunetti, 1913), *Mallota (Mallota) orientalis* (Wiedemann, 1824), *Mallota (Mallota) varicolor* (Walker, 1856) has been reported from the first time from this cold and dry zone as well as from the state of Himachal Pradesh.

## *The distributional pattern of hoverflies across the Shivalik Hill zone of Himachal Pradesh*

The distribution pattern of these 22 species along the Shivalik Hill zone (351-650 mt) has been mapped down with the help of the Digital Elevation model map. According to Figure 2A-2B and Figure 3 the most commonly distributed species along this elevational gradient of 350-650 mt was *Episyrphus balteatus* followed by *Eristalinus tabanoides* whereas species like *Eristalis tenax*, *Melanostoma orientale*, *Asarkina ericetorum*, *Paragus serratus* have shown moderate distributional pattern along the entire Shivalik Hill Zone. The terrain map has shown that the distributional clumping of species has occurred mainly at an elevational range of 520-634mts. On the other hand, species like *Baccha maculata* (Walker, 1852), and *Eristalinus (Eristalinus) megacephalus* (Rossi, 1794) have shown a very rare distributional

pattern. Surprisingly another species from the genus *Eristalis, Eristalis (Eoseristalis) cerealis* Fabricius,1805 have shown a rare distributional pattern in comparison with other agro-climatic zones where this species has shown an extremely higher percentile of continuous distribution pattern. As Shivalik Hill zone is located at the comparatively lower elevational region, the tendency of the distribution of hoverflies which prefer plain land habitats are higher here in comparison with other high altitude specific hoverflies.

## Distributional pattern of hoverflies across Mid Hill zone of Himachal Pradesh

The distribution pattern of this 39 species along the Mid Hill zone (651-1800 mt) has been mapped down with the help of the DEM map. According to Figure 4A-4B and Figure 5 the most commonly distributed species along this elevational gradient was *Eristalis (Eristalis) tenax* (Linnaeus, 1758), *Eristalis (Eoseristalis) cerealis* (Fabricius, 1805) followed by *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) whereas species like *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787 *Syrphus (Syrphus) fulvifacies* (Brunetti, 1913) have shown moderate distributional pattern along the entire Mid Hill zone. Altitude gradient-wise terrain map has shown that the distributional clumping of species has occurred mainly at an elevational range of 651-1800 mt On the other hand, species like *Cheilosia nigroaenea* (Brunetti, 1915), *Lycastris flavohirta* (Brunetti, 1907) have shown very rare distributional pattern.

## Distributional pattern of hoverflies across the High Hill zone of Himachal Pradesh

The distribution pattern of these 19 species along the High Hill zone (1801-2200 mts.) has been mapped down with the help of a Digital Elevation model map. According to Figure 6A-6B and Figure 7 the most commonly distributed species along this elevational gradient of 1801-2200 mts. was *Eristalis (Eristalis) tenax* (Linnaeus,1758) followed by *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) whereas species like *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787), *Eristalis(Eoseristalis) cerealis* Fabricius, 1805, *Eristalinus (Eristalodes) paria* (Bigot, 1880) have shown moderate distributional pattern along the entire High Hill Zone. Altitude gradient-wise terrain map has shown that the distributional clumping of species has occurred mainly at an elevational range of 1809-1985 mts. On the other hand, species like *Eristalinus (Eristalinus) megacephalus* (Rossi,1794), and *Ischiodon scutellaris* (Fabricius, 1805) have shown very rare distributional patterns. Surprisingly the species from the genus *Eristalis, Eristalis (Eristalis)tenax* (Linnaeus, 1758) have shown a high continuous distributional pattern in comparison with lower elevational agro-climatic zones where this species has shown a comparatively low to moderate distribution pattern. As the High Hill zone is located at a comparatively higher elevational region, the tendency of the distribution of hoverflies which prefer higher altitude is more here in comparison with plain land preferring flies. The percentile of species from the Eristalinae subfamily has also exhibited a striking distribution here than that of small-sized species of the syrphinae subfamily. Summarily it can be said that out of the 19 species reported during the current study, only 10.52% of species have shown continuous distribution patterns across the elevational gradient of this zone. Whereas 15.78% of species have shown moderate and 73.68% have shown rare distributional patterns across the elevational gradient.

## Distributional pattern of hoverflies across Cold and Dry zones of Himachal Pradesh

The distribution pattern of these 18 species along the Cold and Dry Zone zone (2201 mts. and above) has been mapped down with the help of the Digital Elevation model map. According to Figure 8A-8B and Figure 9 the most commonly distributed species along this elevational gradient of 2201 mts. and above was *Eristalis (Eristalis) tenax* (Linnaeus, 1758) followed by *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) whereas species like *Eristalis (Eoseristalis) himalayensis (*Brunetti, 1908), *Eristalis(Eoseristalis) cerealis* (Fabricius,1805), *Scaeva pyrastri* (Linnaeus, 1758) have shown moderate distributional pattern along the entire Cold and Dry Zone. Altitude gradient-wise terrain map has shown that the distributional clumping of species has occurred mainly at an elevational range of 1809-1985 mts. On the other hand, species like *Phytomia* (*Dolichomerus*) *crassa* (Fabricius, 1787), and *Mallota (Mallota) orientalis (*Wiedemann, 1824) have shown very rare distributional patterns. Hoverflies are found to be abundant throughout

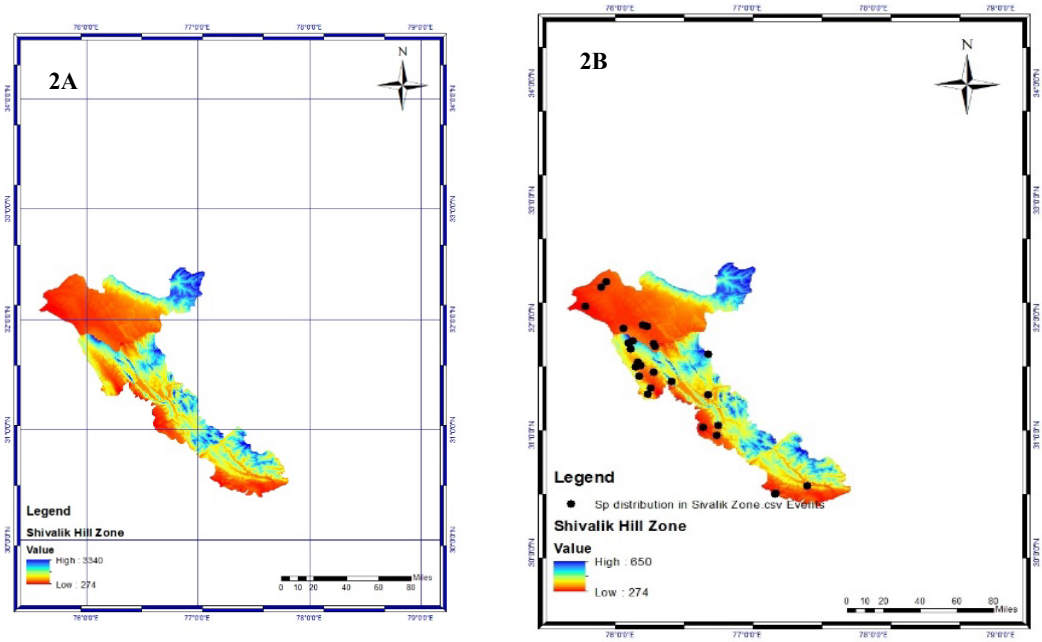


**Figure 2.** **A.** DEM Map of Shivalik Hill zone, **B.** DEM map representing the distribution of syrphid species along Shivalik Hill zone.

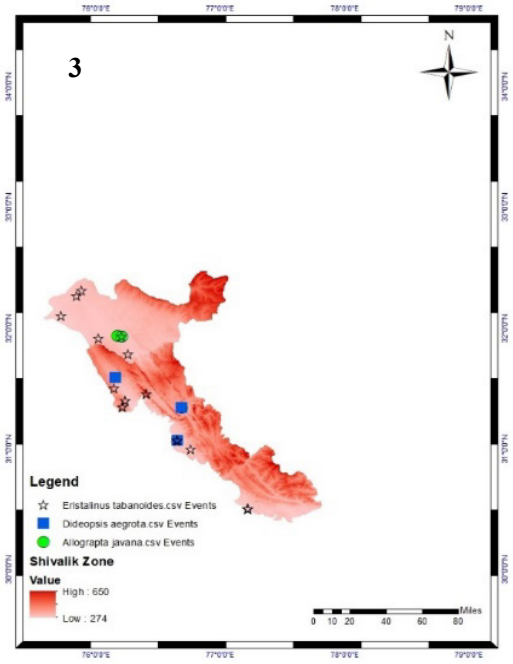


**Figure 3.** DEM map representing the distribution of newly recorded syrphid species along the Shivalik Hill zone.

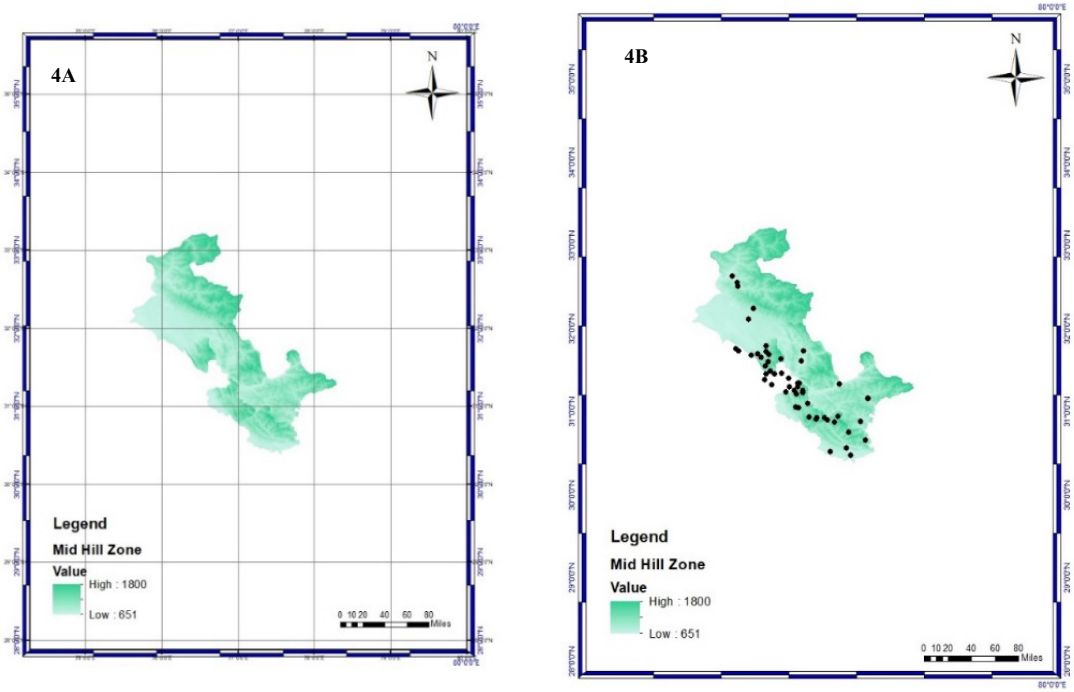


**Figure 4.** **A.** DEM Map of Mid Hill Zone, **B.** DEM map representing the distribution of syrphid species along Mid Hill zone.

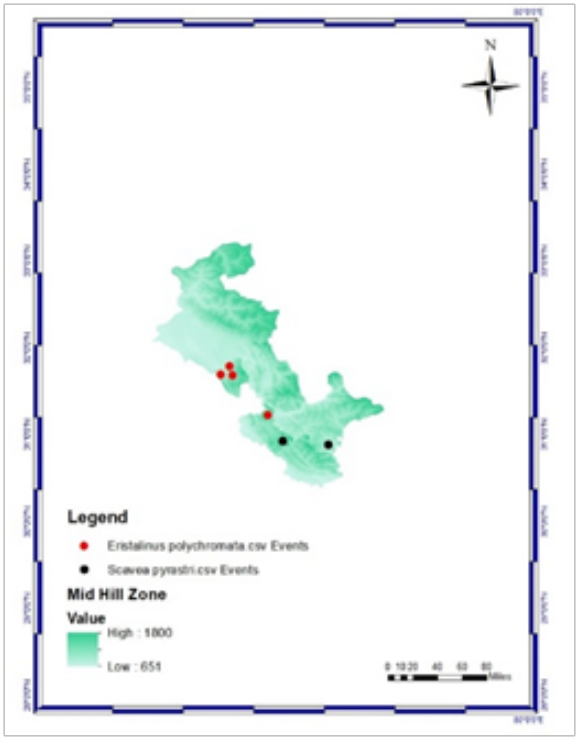


**Figure 5.** DEM map representing the distribution of newly recorded syrphid species along the Mid Hill zone.

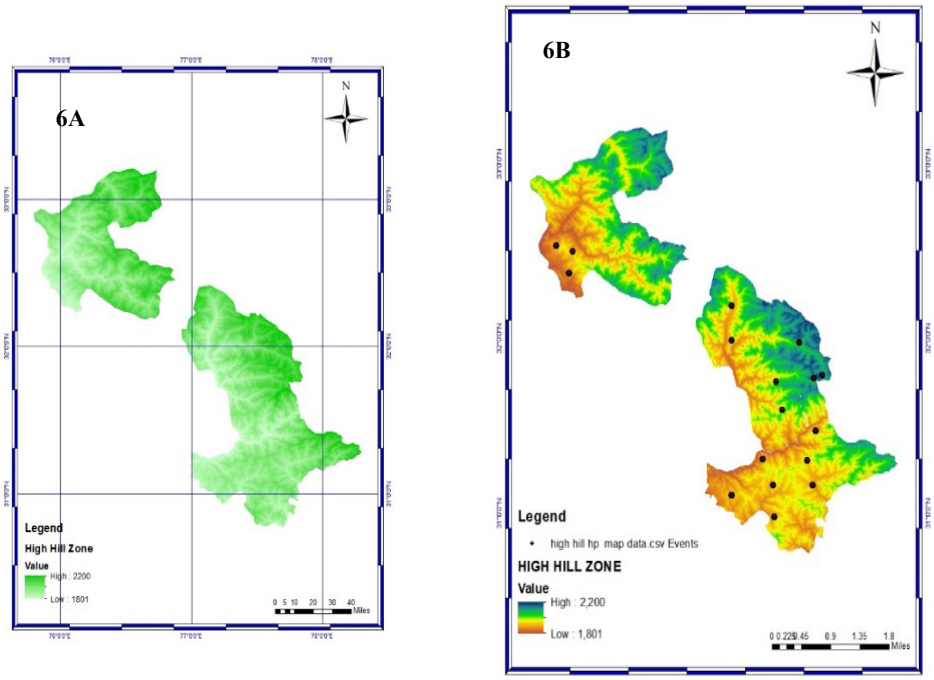


**Figure 6.** **A.** DEM Map of High Hill Zone, **B.** DEM map representing the distribution of syrphid species along High Hill zone range of 1801-2200 mtrs. of High Hill zone.

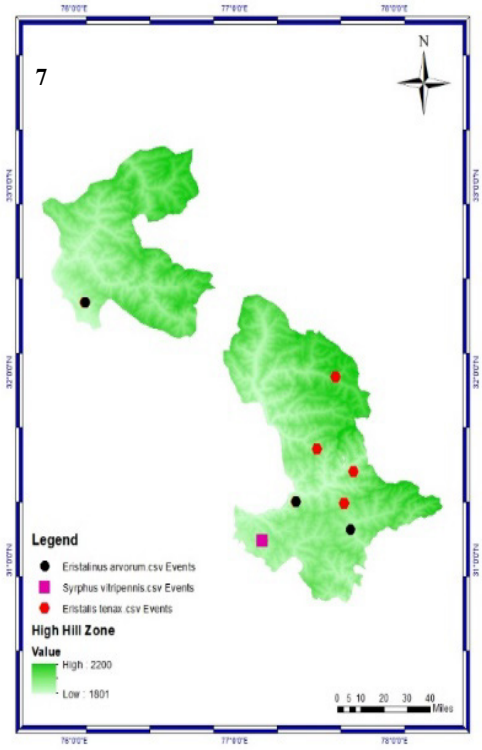


**Figure 7.** DEM map representing the distribution of newly recorded syrphid species along the High Hill zone.

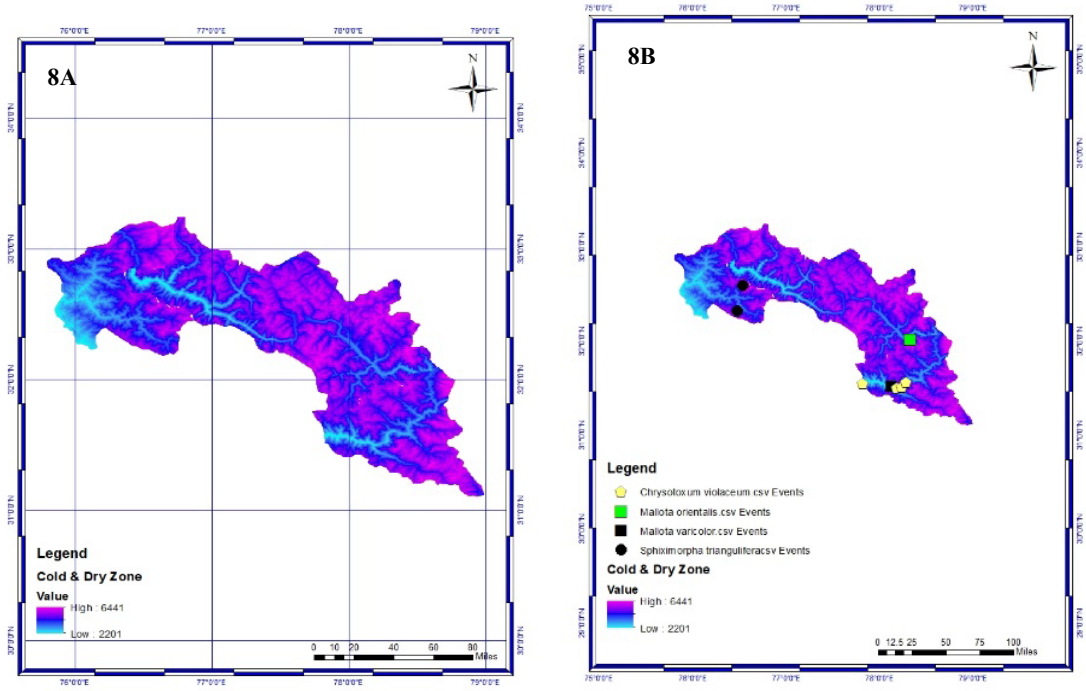


**Figure 8.** **A.** DEM Map of Cold and Dry zone, **B.** DEM map representing the distribution of syrphid species along Cold and Dry zone.

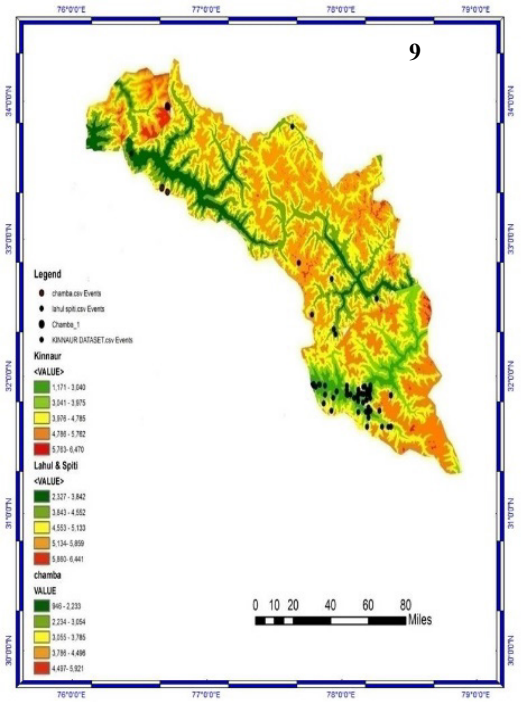


**Figure 9.** DEM map representing the distribution of newly recorded syrphid species along Cold and Dry zones.

all the seasons, although during the winter season, this zone of Himachal Pradesh remains isolated from the other parts of the world due to very heavy snowfall, thus the abundance of hoverflies during the winter season could not be determined from this zone. This is one of the gap areas which should be attempted in future days. Among the reported 18 species, 6 species were found to be widely distributed throughout the year while 3 species were found to be endemic from the state as well as from India. As this zone of Himachal Pradesh is very close to the boundary of China and Tibet, many of the species reported from this area have shown a more oriented distribution towards the Palearctic region. But overall the species richness, as well as species abundance, is low in this area which is mostly due to unfavourable climatic conditions excessive low levels of precipitation as well as adverse geographical characteristics including the dry and cold landscape of this zone.

Table 1 represents the detailed distributional scenario of hoverflies across the entire elevational range, this altogether represents the distribution of all 56 species across all of the 4 agro-climatic zones. The following

**Table 1.** Detailed distributional scenario of hoverflies across the entire elevational stretch

| Agro-climatic Zone | Elevation range | No. of species reported From the zone | Percentage of Species showing continuous distribution along the zone | Percentage of Species showing moderate distribution along the zone | Percentage of Species showing rare distribution along the zone |
|---|---|---|---|---|---|
| Shivalik Hill zone | 350-650 mt | 22 species | 9.09% | 36.36% | 54.54% |
| Mid Hill Zone | 651-1800 mt | 39 species | 17.96% | 76.92% | 5.12% |
| High Hill Zone | 1801-2200 | 19 species | 10.52% | 15.78% | 73.68% |
| Cold and Dry Zone | 2201-6500 | 18 species | 33.33% | 50.01% | 16.66% |

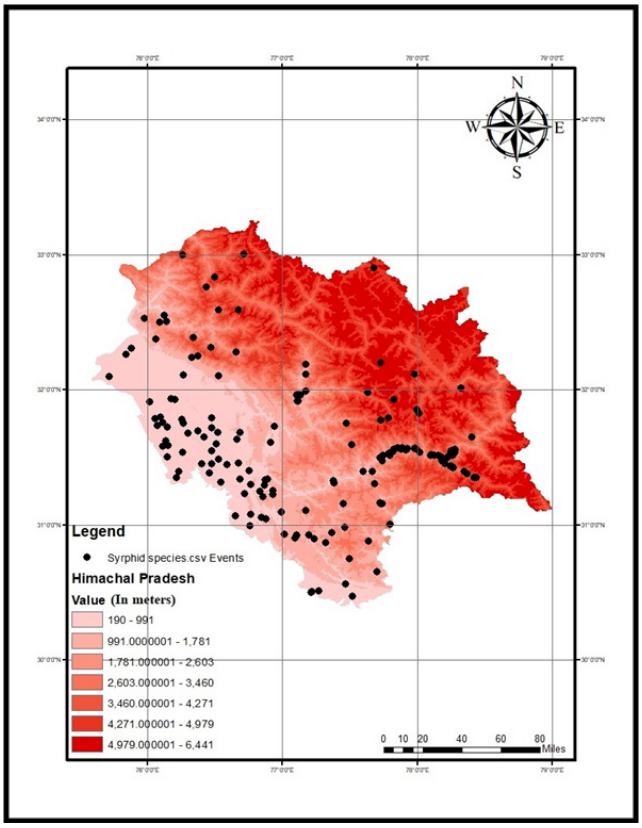


**Figure 10.** DEM map representing the distribution of all hoverfly species along the entire state's elevational stretch.

Digital Elevation Model (DEM) Figure 10 depicts the distributional pattern of all 56 species across the entire state, whereas, under 5 km* 5 km gradation, few habitats have shown the extremely dense distribution of species, whereas few areas showed moderate and few upper elevational regions have shown very rare availability of syrphid. This particular habitat with the rare distribution of pollinating syrphids can be further subjected to climatic modelling for habitat suitability prediction and the proper prediction of the reintroduction of pollinating hoverflies in those localities if habitat suitability happens to be appropriate from those landscapes.

## Discussion

The present study over a period of 4 years (2015-2018) has confirmed the rapid decline rate of pollinators across the state. Especially in a higher elevation zone (2500 mtrs. and above), there is a drastic scene of disappearance of first-line pollinators including the honey bee, bumblebee, etc. In such a critical situation, the introduction of an alternative pollinator line in this agroecosystem has become of utmost importance. The role of syrphids as alternative pollinators mainly in the upper elevational landscape has been established across other zoogeographical regions a few years back. But in India, there is still a taboo to overcome the research blockage of underrating the hoverfly pollination. In Himachal Pradesh too, the scenario is not different. The priority of introducing this second-line pollinator is also high here. Unfortunately, due to a lack of prioritization, no consolidated data is available about the elevational co-relation, climatic sustainability and distributional pattern, of these pollinating flies across the state. The present study is the first-ever consolidated account of the distributional preferences of this pollinating hoverfly across the wide range of altitudinal gradients of the state. The current study revealed 56 species of hoverfly pollinators under 30 genera along the four-classified agro-economic zones of the state (Sengupta *et al*., 2019d). Altogether the present study contributes towards the addition of 21 newly reported pollinators (excluding the two newly described ones) from this mountain state along with their GIS-based distributional updates across the agro-climatic zones. In recent times the relationship between species richness and accumulation with elevation at a global level has been an important theme in ecology (Joshi & Bhatt, 2015). The findings of the present study illustrate the diverse species distribution across the state with a pattern of species distributional affinity increasing up to 1800 meters and after that, there is a sharp decline in the rate of pollinating species distribution until the upper elevational region except for a few specialized pollinating hoverflies which have shown moderately continuous distribution across the entire range irrespective of classified zone of elevation. These factors are further supported by earlier studies on species distribution elevation correlation from other high altitudinal landscapes on other faunal groups (Rahbek, 2005; Acharya and *Vijayan,* 2011). The high abundance of the 6 species (commonly shared in all elevational zones) is also strikingly different. For instance that species like *Melanostoma orientale*, and *Eristalinus (Eristalinus) arvorum* have shown distributional preferences in lower elevational zones whereas few pollinators have shown distribution in upper zones *Eristalis* (*Eoseristalis*) *cereals*, *Eristalis* (*Eoseristalis*) *himalayensis, Eristalis* (*Eristalis*) *tenax* have shown distributional accumulation in the upper elevational zone, alternatively, species like *Episyrphus* (*Episyrphus*) *balteatus* are distributed throughout the entire altitudinal gradient.

For rest of the moderately distributed species like *Asarkina* (*Asarkina*) *ericetorum*, *Ischiodon scutellaris, Scaeva pyrastri*, *Sphaerophoria* (*Sphaerophoria*) *indiana, Syrphus* (*Syrphus*) *torvus, Chrysotoxum violaceum, Baccha maculata*, *Paragus* (*Paragus*) *serratus*, *Cheilosia nigroaenea, Volucella ruficauda*, *Eristalinus (Eristalinus) megacephalus*, *Eristalinus (Eristalinus) tabanoides*, *Eristalinus* (*Eristalinus*) *quinquestriatus*, *Mesembrius* (*Mesembrius*) *bengalensis, Syritta indica*, *Syritta pipiens,* etc., are moderately distributed with an affinity along the mid-elevation zone of an elevational range of 651 to 1800 mtrs. Such a higher percentile of distributional aggregation along the mid-hill zone indicates that this zone has rich food availability and niche sustainability. This reason may be solely due to the rich vegetation structure of this agro-climatic zone in comparison with 3 other zones. This region is highly responsible for a higher percentile of cash crop production from this zone. Besides, despite occupying only 32% of the geographical area of the state, it represents a striking percentage of 37% of the cultivated landscape. Such a higher percentile of vegetation is attributed towards the high aggregation of species from this agro-climatic zone. Besides factors like human disturbances, sampling, area effects, and temperature fluctuations have influences on the species

distribution along with the elevational range (McCain, 2009). The present study further indicates that the distribution of hoverfly species is positively correlated with the vegetation structure. This in turn indicates the diversity of flowering plants, natural and wild plantations, and cultivated agricultural lands also affected the distributional pattern. The presence of tiny hoverflies which are more preferably habited in lower elevational ranges like *Melanostoma orientale* (Wiedemann, 1824), *Syritta indica* (Wiedemann, 1824), etc has indicated the extension of their distributional ranges from comparatively lower to higher elevational gradients. Furthermore, some of the newly reported species from this state including *Dideopsis aegrota* (Fabricius, 1805), *Eristalinus (Eristalinus) polychromata* (Brunetti, 1923), *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787) also support the fact of range extension of this species from lower plain land to a moderate elevational level. On the other hand, the Shivalik hill zone being in the lowest elevation range still represents less species richness which may be attributed to the fact of the lesser ratio of cultivated area to the geographical area. On the other hand, the species distribution scenario is completely different above the mid-elevation range. Decreasement of species richness scenario above 1800 meters elevational range may be due to increasingly harsh natural conditions in the subalpine and alpine belts. The further drastic transition of climatic conditions from humid sub-tropical to temperate and sub-temperate climate in the High Hill and Cold and Dry zones is also acting as another key factor of distributional obstacles for species. (Colwell & Less, 2000; Grytnes & Vetass, 2002). Furthermore, this hypothesis has been supported by the lower percentile of cultivated lands from both of the agro-climatic zones (2% cultivated area from both of the zones). Another reason for the low species distribution percentile in cold and Dry zones is the effect of alpine vegetation in that area. The presence of alpine vegetation in this zone is further attributed to different limiting factors including scanty rainfall, high wind velocity, high intensity of ultraviolet radiation, blizzards, snowstorms, etc. (Nautiyal *et al*, 2004). Research has shown that as per recent reports from the Global Observation Research Initiative in Alpine Environments (Grabherr, 2000). Such ecosystems with predominant alpine vegetation are likely to show the effects of climate changes earlier and more clearly than other ecosystems (Grabherr, 2000). On that note, the low distributional ranges of pollinating hoverflies across the cold and dry zone especially after a certain elevational range of 3200 meters have thus further raised the issue of the impact of climatic change upon this crop pollination. So for long-term monitoring, this distribution data which was not available previously, recorded during the recent study is believed to be beneficial.

In summary, it can be said that the distributional trend of the pollinating hoverflies along this wide elevational range follows the rules of monotonal declination of species richness along with increasing altitude. Exceptionally the species with Palearctic affinity tend to be accumulated in higher altitudinal zones. Moreover, as this zone of Himachal Pradesh is very close to the boundary of China and Tibet, many of the species reported from this area have shown a more orientated distribution towards the Palaearctic region. But overall the species richness, as well as species abundance, is low in this area which is mostly due to unfavourable climatic conditions excessively low levels of precipitation as well and adverse geographical characteristics including cold deserts of this region.

The United Nations in October 2010, released a report stating that insect pollination was valued at $134 billion. Although the history of research has shown that the role of pollination is priceless, unfortunately, it is still underrated. The Earth's pollinator is in an ongoing state of collapse including the pollinators. An increased rate of threats to insect pollinators will appear soon as a serious global issue if not properly addressed. The shortage of this pollination will enhance the demand for agricultural land, a trend that will be more detrimental in countries of the developing world like India. Which will potentially lead to decreased food security in the future. As loss of diversity of pollinating flies will lead to a shortage of pollination services particularly in cooler and wetter habitats where flies replace bees. The state of Himachal Pradesh thus having a wide range of elevational extremities in her geographical basket is already under the threat of future food insecurity. To address this, tracking of distribution of hoverflies is of utter urgency to give them the status of second-line pollinators.

## Acknowledgement

The authors are also grateful to Mr. P. Parui, Retd. Scientist of ZSI for providing valuable suggestions. Thanks are also due to sectional staff for their constant encouragement.

## References


Acharya, B.K. and Vijayan, L. 2011. Butterflies of Sikkim with reference to elevational gradient in species, abundance, composition, similarity and range size distribution. Biodiversity of Sikkim: Exploring and Conserving A Global Hotspot. Information and Public Relations Department, Government of Sikkim, xxviii+ 542pp, 207-220.

Colwell, R.K. and Lees, D.C. 2000. The mid-domain effect: Geometric constraints on the geography of species richness. *Trends in ecology and evolution*, **15**(2): 70-76. https://doi.org/10.1016/S0169-5347(99)01767-X

Doczkal, D., Radenković, S., Lyneborg, L. and Pape, T. 2016. Taxonomic revision of the afrotropical genus Megatrigon Johnson, 1898 (Diptera: Syrphidae). *European Journal of Taxonomy*, **238**: 1-36. https://doi.org/10.5852/ejt.2016.238

Godfray, H. C. J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F. and Toulmin, C. 2010. Food security: The challenge of feeding 9 billion people. *Science*, **327**(5967): 812-818. https://doi.org/10.1126/science.1185383

Grabherr, G., Gottfried, M. and Pauli, H. 2000. GLORIA: A global observation research initiative in alpine environments. *Mountain Research and Development*, **20**(2):190-191. https://doi.org/10.1659/0276-4741(2000)020[0190:GAGORI]2.0.CO;2

Grytnes, J. A. and Vetaas, O.R. 2002. Species richness and altitude: A comparison between null models and interpolated plant species richness along the Himalayan altitudinal gradient, Nepal. *The American Naturalist*, **159**(3): 294-304. https://doi.org/10.1086/338542

Hippa, H., Van, J. S. and Mutin, V.A. 2015. The genus *Sphegina* Meigen (Diptera, Syrphidae) in a biodiversity hotspot: The thirty-six sympatric species in Kambaiti, Myanmar. *Zootaxa*, **3954**:1-67. https://doi.org/10.11646/zootaxa.3954.1.1

Jordaens, K., Goergen, G., Virgilio, M., Backeljau, T., Vokaer, A. and De Meyer, M. 2015a. DNA barcoding to improve the taxonomy of the Afrotropical hoverflies (Insecta: Diptera: Syrphidae). *PloS One*, **10**(10): Article e0140264. https://doi.org/10.1371/journal.pone.0140264

Jordaens, K., Goergen, G., Kirk-Spriggs, A.H., Vokaer, A., Backeljau, T. and De Mayer, M. 2015b. A second New World hoverfly, *Toxomerus floralis* (Fabricius) (Diptera: Syrphidae), recorded from the Old World, with description of larval pollen-feeding ecology. *Zootaxa*, **4044**(4): 567-576. https://doi.org/10.11646/zootaxa.4044.4.6

Joshi, K. and Bhatt, D. 2015. Avian species distribution along elevation at doon valley (foot hills of western Himalayas), Uttarakhand, and its association with vegetation structure. *Journal of Asia-Pacific Biodiversity*, **8**(2): 158-167. https://doi.org/10.1016/j.japb.2015.04.002

McCain, C.M. 2009. Vertebrate range sizes indicate that mountains may be 'higher' in the tropics. *Ecology Letters*, **12**(6):550-560.

Mengual, X., Ståhls, G. and Rojo, S. 2008. First phylogeny of predatory flower flies (Diptera, Syrphidae, Syrphinae) using mitochondrial COI and nuclear 28S rRNA genes: Conflict and congruence with the current tribal classification. *Cladistics*, **24**(4):543-562. https://doi.org/10.1111/j.1096-0031.2008.00200.x

Mengual, X. and Ghorpade K. 2010. The flower fly genus *Eosphaerophoria* Frey (Diptera, Syrphidae). *ZooKeys,* **33**: 39-80. https://doi.org/10.3897/zookeys.33.298

Mengual X. [with inputs by K. Ghorpade and F.C. Thompson] 2012. The flower fly genus *Citrogramma* Vockeroth (Diptera, Syrphidae), illustrated revision with descriptions of new species. *Zoological Journal of the Linnean Society*, **164**: 99-172. https://doi.org/10.1111/j.1096-3642.2011.00750.x

Mengual, X. 2013. Notes on *Citrogramma* Vockeroth and *Eosphaerophoria* Frey (Diptera: Syrphidae). *Zootaxa*, **3745**(3): 388-396. https://doi.org/10.11646/zootaxa.3745.3.6

Mengual, X., Ståhls, G. and Rojo, S. 2015. Phylogenetic relationships and taxonomic ranking of pipizine flower flies (Diptera: Syrphidae) with implications for the evolution of aphidophagy. *Cladistics*, **31**(5):491-508. https://doi.org/10.1111/cla.12105

Nautiyal, M.C., Nautiyal, B. P., and Prakash, V. 2004. Effect of grazing and climatic changes on alpine vegetation of Tungnath, Garhwal Himalaya, India. *Environmentalist*, **24**(2): 125-134. https://doi.org/10.1007/s10669-004-4803-z

Rahbek, C. 2005. The role of spatial scale and the perception of large-scale species-richness patterns. *Ecology Letters*, **8**(2): 224-239. https://doi.org/10.1111/j.1461-0248.2004.00701.x

Reemer, M. and Hippa, H. 2008. Review of the species of Pseudovolucella Shiraki, 1930 (Diptera: Syrphidae). *Tijdschrift voor Entomologie*, **151**(1): 77. https://doi.org/10.1163/22119434-900000253

Sengupta, J., Naskar, A., Maity, A., Hazra, S., Mukhopadhyay, E., Banerjee, D. and Ghosh, S. 2016a. An updated distributional account of Indian hoverflies (Insecta: Diptera: Syrphidae. *Journal of Entomology and Zoology Studies*, **4**: 381-396.

Sengupta, J, Naskar, A, Maity, A., Hazra, S. and Banerjee, D. 2016b. New distributional records and annotated keys of hoverflies (Insecta: Diptera: Syrphidae) from Himachal Pradesh India. *Journal of Advanced Zoology*, **37**(1): 31-54.

Sengupta, J., Naskar, A., Maity, A., Hazra, S., Sarkar, N.K. and Banerjee, D. 2017. Hover Flies (Diptera: Syrphidae) from Darjeeling HimalayaA Part of – Indo-Burmese Hotspot. *Indian Journal of Entomology,* **79**(3): 336-353. https://doi.org/10.5958/0974-8172.2017.00065.7

Sengupta, J., Naskar, A., Maity, A. and Banerjee, D. 2018a. Effects of selected environmental variable upon the distribution of Hover Fly (Insecta: Diptera: Syrphidae) along an altitudinal gradient. *International Journal of Advancement in Life Sciences Research,* **1**(3): 1-6. https://doi.org/10.31632/ijalsr.2018v01i03.001

Sengupta, J., Naskar, A., Maity, A., Homechaudhuri, S. and Banerjee, D. 2018b. A taxonomic account of Hover Flies (Insecta: Diptera: Syrphidae) with 4 new records from cold dry zones of Himachal Pradesh, India. *International Journal of Advancement in Life Sciences Research,* **1**(4): 13-30. https://doi.org/10.31632/ijalsr.2018v01i04.003

Sengupta, J., Naskar, A. and Banerjee, D. 2019a. Pollinating Diptera: The forgotten Superhero. *ENVIS Newsletter*, **1**(3):1-6.

Sengupta, J., Naskar, A., Maity, A., Homechaudhuri, S. and Banerjee, D. 2019b. A short taxonomic account of dipteran flies from the Renuka Wetland and adjacent Sanctuary, Himachal Pradesh, India. *Munis Entomology and Zoology Journal,* **14**(1): 224-231.

Sengupta. J., Naskar. A., Homechaudhuri, S. and Banerjee. D. 2019c. Diversity of Hover Flies (Insecta: Diptera: Syrphidae) with 3 new records from Shivalik Hill zone of Himachal Pradesh, India. *International Journal of Advancement in Life Sciences Research,* **2**(3): 39-55. https://doi.org/10.31632/ijalsr.2019v02i03.005

Sengupta, J., Naskar, A., Homechaudhuri, S. and Banerjee, D. 2019d. Diversity of Hover Flies (Insecta: Diptera: Syrphidae) with 3 New Records from High Hill zone of Himachal Pradesh, India. *International Journal of Advancement in Life Sciences Research,* **2**(4): 21-37. https://doi.org/10.31632/ijalsr.2019v02i04.004

Shah, G.M., Jan, U. and Wachkoo, A.A. 2014. A checklist of Hoverflies (Diptera: Syrphidae) in the Western Himalaya, India. *Acta Zoologica Academiae Scientiarum Hungaricae*, **60**(4): 283-305.

Steenis, V.J. 2010. A new species of the genus *Syritta* Le Peletier and Serville, 1828 (Diptera, Syrphidae), with new distributional records of other Syritta species. *Norwegian Journal of Entomology*, **57**: 111-119

Steenis, V.J. 2015a. New data on the hoverflies (Diptera: Syrphidae) of Serbia and Montenegro. *Acta Entomologica Serbica*, **20**: 67-98.

Steenis, V.J. 2015b. The first Oriental species of the genus *Brachyopa* Meigen (Diptera: Syrphidae), with a discussion on the Syrphidae fauna of the Indo-Malayan transition zone. *Studia dipterologica,* **21**(2): 293-300.

Thompson, F.C. and Skevington, J.H. 2014. Afrotropical flower flies (Diptera: Syrphidae). A new genus and species from Kenya, with a review of the melanostomine group of genera. *Zootaxa*, **3847**(1): 97-114. https://doi.org/10.11646/zootaxa.3847.1.5

Thompson, F.C. and Hauser, M. 2015. In honor of Brian Stuckenberg: Two new *Spheginobaccha* species of flower flies (Diptera: Syrphidae) from the Afrotropics. *African Invertebrates*, **56**(3): 769-777. https://doi.org/10.5733/afin.056.0318

Wachkoo, A.A., Van Steenis, J., Rather, Z.A., Sengupta, J. and Banerjee, D. 2019. First record of the genus Spilomyia (Diptera, Syrphidae) from the Oriental region. *Turkish Journal of Zoology*, **43**(2): 239-242. https://doi.org/10.3906/zoo-1811-27

Williams, P.H. and Osborne, J.L. 2009. Bumblebee vulnerability and conservation world-wide. *Apidologie*, **40**(3): 367-387. https://doi.org/10.1051/apido/2009025