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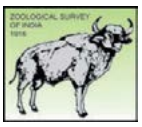

An insight into the taxonomy and diversity of pollinating Hoverflies (Insecta: Diptera: Syrphidae) from dry deciduous landscape of West Bengal

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Abstract

Alternative uses of land use pattern have caused declination in pollinator globally. The current pollinator catastrophe anomaly affects food scarcity, magnifies problems with hidden hunger, erodes ecological resilience and threatens ecosystems. Despite visiting at least 72% of global food crops, dipteran pollinators always have received much less research attention than hymenopterans. Hoverflies (Insecta:Diptera: Syrphidae) being one of the largest pollinator group from the Dipteran lineage is worthy of more research priorities. The study on this group of flies represents a huge research gap, particularly from the plain land ecosystems of West Bengal. According to the report, the ISHI score (India State Hunger Index) is 20.97 which is atan alarming level. The current study includes a detailed systematics & diversity analysis of this pollinator from the dry deciduous landscape (Sonamukhi Forest) from the state. For the current study purpose, pollinators have been collected by net sweeping & by using different traps over 3 years. The detailed study includes 20 species under 16 genera over two subfamilies where Syrphinae (53%) are more prevalent than Eristalinae (47%). The most prevalent species is found to be *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) whereas *Sphaerophoria indiana* Bigot, 1884 is rarely present in all the seasons. On the other hand, the results of the diversity analysis study show species diversity to be at its highest during the Pre-Monsoon season (H = 4.261) and its lowest during the Monsoon season (H=1.12). Further detailed studies at periodic interval are necessary for more accurate database development and for ecosystem monitoring.

Keywords: Pollinator, Hoverfly, Food security, Diversity, Ecosystem

Introduction

The current valuation of insect pollination globally is approximately $577 billion (Decourtye *et al.*2019), unfortunately it is still underrated (Chain *et al.*2019). Over the past few years, a dramatic decline in the ratio of insects to insect pollinators has occurred across the globe (Rhodes, 2019). Syrphids are one of the most widespread groups of flies with considerable potentiality as the first liner pollinator of the ecosystem (Gilbert, 1985). Particularly in specific landscape, where the hymenopteran pollination proficiency is facing a high risk of exhaustion due to their dependency on endothermically generated energy (Milicic *et al*, 2017). Such ecosystem thus have an immediate urgency of the introduction of a strong alternate line of pollinators. Who can act strongly to conserve the network. Here lies the utmost importance of conservation of the second line pollinators like hoverflies. Although hover flies have been recognized for their role in increasing and stabilizing crop pollination services in very recent times (Garibaldi *et al* 2011). But are still struggling for their identity as principal pollinators (Jauker *et al.*2019), pollination services rendered by all of them thus should be properly assessed and addressed (Winder, 1978).

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The syrphid adults feed on nectar and pollens whereas the larvae are aphidophagous (Rothery, 1981).Thus making these groups a twofold beneficial fly group (Woodcock *et al.* 2014). Accurate species identification is the first and fundamental step required to generate other biological information on this emerging pollinators.

In the current work, an attempt is made encompassing taxonomy and ecological diversity study across Sonamukhi protected forest area of Bankura district. It represents unique geographical features for its location as an Ecotone which houses a unique pattern in its annual climatic scenario, as well as in vegetation & topographical fashion. the data on Syrphidae from this region was not updated and sufficient (Fabricius 1787, Brunetti: 1907), because although stray survey had been done over this long time by different dipterists altogether consolidated information regarding Syrphid fauna was not available from this region. Despite of vast distribution of hoverflies still past the British era much major contribution was lacking in the field of syrphid fauna from dry deciduous forest ecosystems like the Sonamukhi forest. This study is therefore the first exhaustive study of syrphid fauna from the Sonamukhi protected forest area and thereby it carries immense importance as it leads to the discovery of biodiversity and also depicts the extensive species richness of syrphid fauna from this area. Our current study includes **20** species of syrphid under **16** genera from this protected area. This study depicts the updated taxonomic account of hoverflies from this protected forest area. Furthermore, Seasonal changes in dipteran abundance in the dry deciduous forest of Sonamukhi Protected Area, Bankura, West Bengal has been studied over three years w.e.f from November 2017 to March 2020. Population abundance, species composition and community structure were investigated over these 3 yearlong study periods. Out of the total reported species from our collected data, 47% of the species belong to Eristalinae subfamily and 53% to the Syrphinae subfamily. The current study was intended to determine: the year-long variations in abundance and composition of hoverfly species; the similarity of resources use among different hoverfly species; the relationship between abundance and species composition and abiotic (temperature and rainfall) and biotic factors. For such a comprehensive assessment, the diversity of this pollinating Diptera has been studied here extensively for three years. Such an attempt and their outcome thus further validate their emergence as an alternative leading pollinator of present and future time, an insurance against the rising hunger index from this dry deciduous landscape of West Bengal.

As for the study we have chosen Sonamukhi protected forest area of Bankura district. It represents unique geographical features for its location as an Ecotone which houses a unique pattern in its annual climatic scenario, as well as in vegetation & topographical fashion. the data on Syrphidae from this region was not updated and sufficient (Fabricius 1787, Brunetti: 1907), because although stray survey had been done over this long time by different dipterists altogether consolidated information regarding Syrphid fauna was not available from this region. Despite of vast distribution of hoverflies still past the British era much major contribution was lacking in the field of syrphid fauna from dry deciduous forest ecosystems like the Sonamukhi forest. This study is therefore the first exhaustive study of syrphid fauna from the Sonamukhi protected forest area and thereby it carries immense importance as it leads to the discovery of biodiversity and also depicts the extensive species richness of syrphid fauna from this area. Our current study includes **20** species of syrphid under **16** genera from this protected area.

This study thus includes a thorough out study of Syrphidae fauna from the Sonamukhi Protected Forest area, as updated knowledge on this important group of pollinators from this region is essential for further and future studies. This study depicts the updated taxonomic account of hoverflies from this protected forest area. Furthermore, Seasonal changes in dipteran abundance in the dry deciduous forest of Sonamukhi Protected Area, Bankura, West Bengal has been studied over three years w.e.f from November 2017 to March 2020. Population abundance, species composition and community structure were investigated over these 3 yearlong study periods. Out of the total reported species from our collected data, 47% of the species belong to Eristalinae subfamily and 53% to the Syrphinae subfamily. The current study was intended to determine: the year-long variations in abundance and composition of hoverfly species; the similarity of resources use among different hoverfly species; the relationship between abundance and species composition and abiotic (temperature and rainfall) and biotic factors.

Materials and Methods

i. **Study area:** Our study area for survey was the Sonamukhi Protected Forest area, which is located in the Sonamukhi Block of Bankura district, West Bengal. This proposed area was surveyed extensively in the

period of three years (2017-2020) covering all three seasons of pre-monsoon, Monsoon and post-monsoon. Sonamukhi protected forest, Bankura holds one of the best quality Sal forests in West Bengal. The soil profile of this forest area is typically characterised by red-lateritic soil. The forest is mainly dominated by medium-density Sal trees. The survey was done thoroughly in Sonamukhi protected forest and its adjacent villages to get a complete scenario of pollinating hoverflies' diversity in this protected forest area. The places that have been surveyed mostly are namely: Sonamukhi forest area, Churamanipur, Muslo, Balarampur, Patharmura, Krishtobati, Kalyanpur, Pachal, Lokesol, Naphardanga, Palsora, Bandarhati, Hamirhati, Kasdihi beat area, Naphardanga, Lokesol, Inkata, Bhulara, Manik Bazar. The landscape and vegetation pattern of some of these areas where collection has been done extensively has been discussed shortly. Altogether we have selected 10 study sites for collection. The collection has been done through net sweepning and using different traps including Pan traps , Malaise trap etc. The collected samples are narcotized by using ethyl acetate and stored for further study in insect envelopes in the field. This envelope is specialised dehydration envelope which helps to dehydrate the collected samples. The specimens were later carried back to the laboratory, where they are kept in desiccator for rehydration purposes and then mounted on insect pins and stored in insect cabinets.

Identification of the adults followed the keys of Thomson (2013), Vockeroth (1992) and Brunetti (1923) keeping in mind the recent nomenclatural changes (Pape and Thompson, 2016; Pape and Evenhuis, N.L.2010). All the identified specimens were deposited in the designated repository of National Zoological Collection, Diptera section, Zoological Survey of India, Kolkata. The graphical representations here were made by using Microsoft Excel 2013. The GPS data has been taken by using Garmin GPS 72H reader. The photograph of habitus and insect body and parts were taken by using Leica Microscope M205A, where 0.32x Acro lens was used for habitus photography and PLANAPO 1.0X lens was used for the photography of body parts.

ii. **Ecological diversity calculation:** We have used Microsoft Excel 2016 for statistical analysis and graph preparation.

- **Species diversity:** It is defined as the number of species and abundance of each species that live in a particular location.
- **Species richness**: The number of species in a certain location is called the species richness of that particular area.
- **Abundance:** It is defined as the number of individuals of each species.
- **Evenness:** Evenness is a measure of the relative abundance of the different species making up the richness of an area.
- **Simpson's Index of Diversity:** Simpson's Diversity Index is a measure of diversity which takes into account both richness and evenness. Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species. The value of D ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. **D=1- [∑n (n-1)/N(N-1)]**

  Where n = the total number of organisms of a particular species, N = the total number of organisms of all species.
- **Shannon Diversity Index (H):** High values of H would be representative of more diverse communities. If the species are evenly distributed then the H value would be high. So the H value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the community. H = ∑ - (Pi * ln Pi), Where, H = the Shannon diversity index, Pi = fraction of the entire population made up of species i, S = numbers of species encountered, ∑ = sum from species 1 to species S
- **Menhinick's richness index** (I_{Mn})**:** Another index of measuring species richness. The ratio of the number of taxa to the square root of the sample size. I_{Mn} =S/

  where S= Number of species, N= total number of individuals.
- **Margalef's richness index:** An index measuring species richness *(S-1)*/ln*(n)*, where *S* is the number of taxa, and *n* is the total number of individuals.
- **Berger-Parker index of dominance (d):** It is an index of dominance, simply the number of individuals in the dominant taxon relative to n. d=N_{max}/N, where N_{max}= no of individual from the most abundant spe-

cies, N= total number of individuals.

- **Relative abundance (p_i):** It is the per cent composition of an organism of a particular kind relative to the total number of organisms in the area.

  Pi is denoted as the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: n_i/N where n_i is the number of individuals of particular species; N= total number of individuals.

Result

A. Taxonomic Account

Systematic list of taxa (New record from the state is marked with double asterisk marks)

Order DIPTERA

Suborder BRACHYCERA Macquart, 1834

Clade ASCHIZA Becher, 1882

Superfamily SYRPHOIDEA Latreille, 1802

Family SYRPHIDAE Latreille, 1802

Subfamily SYRPHINAE Latreille, 1802

Tribe Bacchini Bigot, 1883

I. Genus ***Baccha*** Fabricius, 1805

1. ***Baccha maculate*** Walker, 1852

II. Genus ***Melanostoma*** Schiner, 1860

2. ***Melanostoma orientale*** (Wiedemann, 1824)

Tribe Paragini Glumac, 1961

III. Genus ***Paragus*** Latreille, 1804

SubGenus *Paragus* Latreille, 1804

3. ***Paragus (Paragus) serratus*** (Fabricius, 1805)

Tribe Syrphini Latreille, 1802

IV. Genus ***Asarkina*** Macquart, 1842

SubGenus ***Asarkina*** Macquart, 1842

4. ***Asarkina* (*Asarkina*) *ericetorum*** (Fabricius, 1781)

V. Genus ***Dasysyrphus***Enderlein, 1938

5. ***Dasysyrphus orsua***(Walker, 1852)

VI. Genus ***Dideopsis*** Matsumura 1917

6. ***Dideopsis aegrota*** (Fabricius, 1805)

VII. Genus ***Episyrphus*** Matsumura & Adachi, 1917

SubGenus *Episyrphus* Matsumura & Adachi, 1917

7. ***Episyrphus* (*Episyrphus*) *balteatus*** (De Geer, 1776)

VIII. Genus ***Eupeodes*** Osten Sacken, 1877

SubGenus ***Macrosyrphus*** Matsumura, 1917

8. ***Eupeodes* (*Macrosyrphus*) *confrater*** (Wiedemann, 1830)

IX. Genus ***Ischiodon*** Sack, 1913

9. ***Ischiodon scutellaris***(Fabricius, 1805)

X. Genus ***Sphaerophoria*** Lepeletier & Serville, 1828

SubGenus ***Sphaerophoria*** Wiedemann, 1830

10. ***Sphaerophoria (Sphaerophoria scripta) Indiana*** Bigot, 1884

Subfamily ERISTALINAE (Newman, 1834)

Tribe EristaliniNewman, 1834

XI. Genus ***Eristalinus*** Rondani, 1845

Subgenus ***Eristalinus*** Rondani, 1845

11. ***Eristalinus* (*Eristalinus*) *arvorum*** (Fabricius, 1787)

12. ***Eristalinus (Eristalinus) tabanoides*** (Jaennicke, 1867)**

Subgenus ***Eristalode s***Mik, 1897

XII.Genus ***Eristalis*** Latreille, 1804

Subgenus ***Eoseristalis***Kanervo, 1938

13. ***Eristalis* (*Eoseristalis*) *cerealis***Fabricius, 1805

XIII. Genus ***Phytomia*** Guerin-Meneville, 1833

Subgenus ***Phytomia*** Guerin-Meneville, 1833

14. ***Phytomia (Phytomia) errans*** (Fabricius, 1787)

Subgenus ***Dolichmerus*** Macquart, 1850

15. ***Phytomia* (*Dolichomerus*) *crassa*** (Fabricius, 1787)

XIV. Genus ***Mesembrius*** Rondani, 1857

Subgenus ***Mesembrius*** Rondani, 1857

16. ***Mesembrius (Mesembrius) bengalensis*** (Wiedemann, 1819)

17. ***Mesembrius* (*Mesembrius*) *quadrivittatus*** (Wiedemann, 1819)

Tribe Merodontini Edwards, 1915

XV. Genus ***Eumerus*** Meigen, 1822

18. ***Eumerus aeneithorax*** Brunetti, 1915

19. ***Eumerus aurifrons*** (Wiedemann, 1824)

Tribe Milesiini (Rondani, 1845)

XVI. Genus ***Syritta*** Lepeletier & Serville, 1828

20. ***Syritta indica*** (Wiedemann, 1824)

Subfamily SYRPHINI

Tribe: Bachini

1. ***Baccha maculata*** Walker, 1852

1852.*Baccha maculata* Walker, *Insecta Saundersiana..***1**: 223.

Type-locality: East Indies.

Material examined: 3♀♀ 5♂♂Chachanpur agricultural field,Bankura district, 23° 17 '54.9"N, 86°53'55.3"E, 110 Mt.21.xi.2017, coll. D.Banerjee& party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Himachal Pradesh, Uttar Pradesh.

Elsewhere: Borneo, Formosa, Java, Japan; Korea, Malaya, Philippines, Sumatra.

I. **Genus *Melanostoma*** Schiner, 1860

1860, *Melanostoma* Schiner, *Wien.Ent.Monats*, **4**:213

Type species: *Musca mellina* Linnaeus

2. ***Melanostoma orientale*** Wiedemann, 1824

1824. *Syrphus orientale* Wiedemann. *Analecta. Ent*: 36.

Type-locality: "Ind. Or."

Material examined:5♀♀ Churamanipur forest village, Bankura district, 23°19'59.3"N, 86°55'55.1"E, 144 Mt, 26.ii.2017, 4♀♀ Churamanipur forest village, Bankura district, 23°19'59.3"N, 86°55'55.1"E, 144 Mt, 26.vi.2018, coll. D.Banerjee& party.12♂♂ Chachanpur river belt, 23°17'48.4"N, 86°54'10.9"E, 109 Mt, 21.xi.2017, coll. D.Banerjee& party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Arunachal Pradesh, Himachal Pradesh, J & K, Karnataka, Meghalaya, Sikkim, T.N, Tripura, Uttar Pradesh.

Elsewhere: Bhutan, Nepal, Pakistan, Sri Lanka, and other parts of oriental region and Palaearctic region.

Tribe Syrphini

II. Genus ***Asarkina*** Macquart 1834

1842. *Asarkina* Macquart, *Dipt. Exot.***2** (2): 77(137)

Type species: *Syrphus rostrata* Wiedemann.

Subgenus ***Asarkina*** Macquart, 1842

3. ***Asarkina (Asarkina) ericetorum*** (Fabricius, 1781)

1781. *Syrphus ericetorum* Fabricius, *Spec. Insect.* ,**2**: 425.

=*Asarkina formosae* Bezzi, 1908

=*Asarkina typical* Bezzi, 1908

=*Asarkina usambarensis* Bezzi, 1908

=*Didea diaphana* Doleschall, 1857

=*Didea macquarti* Doleschall, 1857

=*Syrphus incisuralis* Macquart, 1855

Type-locality: Africa..

Material examined: 3♂♂ 2♀♀ Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 116 Mt., 26.ii.2020, coll. D. Banerjee & party. 18♀♀Sonamukhi protected forest area, Bankura district,23°17'04.7"N, 87°22'20.2"E, 78 Mt., 22.xi.2017, coll. D.Banerjee & party.

***Distribution*:** India:West Bengal (Bankura: Sonamukhi Protected Forest Area), Arunachal Pradesh, Assam, Chandigarh, Gujarat, Himachal Pradesh, Jammu & Kashmir, Manipur, Meghalaya, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh.

Elsewhere: Widely distributed through Oriental region.; Afrotropical region.; Australian region.

III. Genus ***Dasysyrphus*** Enderlein 1938

1938. *Dasysyrphus* Enderlein*Sber. Ges. Naturf. Freunde Berl.***1937**:208

Type species: *Scaeva albostriata* Fallen

4. ***Dasysyrphus orsua*** (Walker, 1852)

1852. *Syrphus orsua* Walker, *Insecta. Saund.***1**:231

=*Syrphus brunettii* Herve-Bazin, 1924

Type-locality: East Indies.

Material examined: 2♂♂Kalayanpur, Bankura district, 23°14'12.1"N, 86°51'19.1"E, 123 Mt., 28.ii.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Himachal Pradesh, Jammu & Kashmir, Uttarakhand.

Elsewhere: Nepal, Sri Lanka, Sumatra..

IV. Genus ***Dideopsis* Matsumura 1917**

1917. *Dideopsis* Matsumura, *Ent.Mag., Kyoto***2**(4):142

Type species: *Eristalis aegrotus* Fabricius

5. ***Dideopsis aegrota*** (Fabricius, 1805)

1805. *Eristalis aegrota,* Fabricius, *Syst.antl.***14**:243

Type locality: India: Tamil Nadu: Tharangambadi

Material examined:4♀♀5 ♂♂Bandarhati, Bankura district, 23°13'16.9"N, 86°51'59.2"E, 167 Mt., 26.ii.2018, coll. D.Banerjee & party.8♂♂ 6♀♀Sonamukhi Village side, Bankura district, 23°13'48.8"N, 87°04'44.7"E, 101 Mt., coll. D.Banerjee & party.

***Distribution*:** India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Karnataka, Kerala, Meghalaya, Sikkim, Tamil Nadu, Tripura..

Elsewhere: Nepal, SE Asia, New Guinea, Australia.

V. Genus ***Episyrphus*** Matsumara & Adichi, 1917

1917 *Episyrphus*, Matsumura & Adachi. *Ent. Mag. Kyoto*, **3**:16

Type species: *Musca balteata* De Geer

Sub Genus ***Episyrphus*** Matsumura & Adachi, 1917

6. ***Episyrphus*(*Episyrphus*) *balteatus*** (DeGeer, 1776)

1776. *Musca balteata* De Geer, *Mem. Pour. serv. Hist. Ins*. **6**:116

= *Episyrphus fallaciosus* Matsumura, 1917

=*Episyrphus hirayamae* Matsumura, 1918

=*Musca alternate* Schrank, 1781

=*Musca cannabina* Scopoli, 1763

=*Musca elegans* Villers, 1789

=*Musca nectarine* Gmelin, 1790

=*Musca palustris* Scopoli, 1763

=*Musca scitule* Harris, 1780

=*Musca scitulus* Harris, 1780

=*Syrphus andalusiacus* Strobl, 1899

=*Syrphus cretensis* Becker, 1921

=*Syrphus nectareus* Fabricius, 1787

=*Syrphus pleuralis* Thomson, 1869

=*Syrphus proximus* Abreu, 1924

=*Syrphus signatus* Abreu, 1924

Type locality: Sweden.

Material examined:8 ♂♂ 2 ♀♀Dihipara, Bankura district, 23°19'32.5"N, 86°56'15.7"E, 167 Mt., 28.ii.2019 coll. D.Banerjee & party.6♂♂Dihipara, Bankura district, 23°19'32.5"N, 86°56'15.7"E, 167 Mt., 18.vii.2017, coll. D. Banerjee & party.18♀♀ 10♂♂Anchuri, Bankura district,23°13'48.6"N, 87°04'44.5"E, 100 Mt.,22.xi.2018, coll. D.Banerjee& party.

***Distribution*:** India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam. Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Kerala. Meghalaya, Orissa, Punjab. Sikkim, Tripura.

Elsewhere: Oriental region, Australia, Bonin Island, Palaearctic region.

VI. Genus ***Eupeodes*** OstenSacken, 1877

1877. *Eupeodes* OstenSacken; *Bull. U.S. Geol. Surv. Terr.***3**:328

Type species: *Eupeodes volucris* OstenSacken.

Sub Genus ***Macrosyrphus*** Matsumura,1917

1917. *Macrosyrphus* Matsumura *Ent. Mag., Kyoto.***3**:23

Type- species: *Syrphus* okinawae Matsumura

7. ***Eupeodes* (*Macrosyrphus*) *confrater*** (Wiedemann, 1830)

1830, *Syrphus confrater* Wiedemann, Auss. *Zweifl. Theil. Schulz, Hamm.* **12**: 684

Type-locality: China.

Material examined:3♂♂ Lokesol, Bankura district,23°21'27.3"N, 86°56'47.1"E, 143 Mt., 28.ii.2017, coll. D.Banerjee & party.1♂ Dihipara, Bankura district, 23°19'32.5"N, 86°56'15.7"E, 167 Mt., 19.vii.2018,

coll. D.Banerjee& party 13♀♀ Namoachari, Bankura district,23°16'02.4"N, 87°00'19.3"E,104 Mt., 22.xi.2017coll. D.Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Manipur, Meghalaya, Punjab, Sikkim, Tamil Nadu, Uttarakhand.

Elsewhere: Afghanistan, Australia, China, Nepal, New Guinea, Pakistan, Sri Lanka, Sumatra.

VII. Genus ***Ischiodon*** Sack, 1913

1913. ***Ischiodon*** Sack, *Ent. Mitt.***2**:5

Type species: *Ischiodon trochanterica* Sack

8. ***Ischiodon scutellaris*** (Fabricius, 1805)

1805. *Scaeva scutellaris* Fabricius, *Syst. Antliat.*:**252**.

=*Epistrophe magnicornis* Shiraki, 1963

=*Epistrophe platychiroides* Frey, 1946

=*Ischiodon boninensis* Matsumura, 1919

=*Ischiodon penicillatus* Hardy, 1952

=*Ischiodon trochanterica* Sack, 1913

=*Melithreptus novaeguineae* Kertesz, 1899

=*Melithreptus ogasawarensis* Matsumura, 1916

=*Sphaerophoria annulipes* Macquart, 1855

=*Sphaerophoria macquarti* Goot, 1964

=*Syrphus coromandelensis* Macquart, 1842

=*Syrphus erythropygus* Bigot, 1884

=*Syrphus nodalis* Thomson, 1869

=*Syrphus ruficauda* Bigot, 1884

=*Syrphus splendens* Doleschall, 1856

Type-locality: Tranquebar, India.

Material examined: 5♂♂ Naphardanga, Bankura district, 23°26'16.2"N, 86°61'32.1"E, 187 Mt., 26.ii.2020, coll. D. Banerjee & party.11 ♀♀ Namoachari, Bankura district, 23°16'02.4"N, 87°00'19.3"E,104 Mt., 22.xi.2017coll. D. Banerjee & party.

***Distribution*:** India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Andhra Pradesh, Assam, Chandigarh, Delhi, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Manipur, Meghalaya, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand.

Elsewhere: Java, Philippines, Taiwan and other parts of the S.E. Asia; Australia, Hawaii, Japan and Micronesia.

VIII. Genus ***Sphaerophoria*** Lepeletier & Serville, 1828

1828. *Sphaerophoria* Lepeletier & Serville, *Encycl.method*,: 513.

Type species: *Musca cripta* Linnaeus.

9. ***Sphaerophoria* (*Sphaerophoriascripta*) *Indiana*** Bigot, 1884

1884. *Sphaerophoria indiana* Bigot, *Annls. Soc. ent. Fr.* (6) **4**: 99

=*Melithreptus diminutus* Matsumura, 1916

=*Melithreptus kumamotensis* Matsumura, 1916

=*Sphaerophoria nigritarsis* Brunetti, 1915

Type-locality: "Indes"

Material examined: 3♂♂ Hamirhati, Bankura district,23°27'49.6"N, 86°62'35.3"E, 103 Mt., 24.ii.2017, coll. D. Banerjee & party.2♂♂ Dihipara, Bankura district, 23°19'32.5"N, 86°56'15.7"E, 167 Mt., 19.vii.2018, coll. D. Banerjee & party.6♀♀Agua, Bankura district, 23°23'42.2"N, 86°58'36.3"E, 195Mt., 22.xi.2019.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Arunachal Pradesh, Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Meghalaya, Sikkim, Uttar Pradesh.

Elsewhere: China, Sri Lanka, Korea.

Tribe Paragini

IX. Genus ***Paragus*** Latereille, 1804

1804. *Paragus* Latereille, *Hist.Nat.Crust.Ins*, **14**:259.

Type species: *Mulio bicolor* Fabricius.

10. ***Paragus (Paragus) serratus*** (Fabricius, 1805)

1805. *Mulio serratus* Fabricius, *Syst. Antliat.*:186

Type-locality: (Tranquebar) Tamilnadu, India

Material examined: 2 ♂♂ Muslo, Bankura district,23°36.1‹18»N, 349.1‹54°86»E, 124 Mt.,

26.ii.2017, coll. D.Banerjee & party. 16♀♀ 6♂♂ Cochdihi, Bankura district, 23°17'48.4"N, 86°54'10.9"E, 109 Mt., 22.xi.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area, Assam, Bihar, Delhi, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Punjab, Tamil Nadu, Tripura, Uttar Pradesh.

Elsewhere: Jakarta, Java, E. Malaysia, Nepal, Pakistan, Sri Lanka, Africa and Papuya.

Sub family ERISTALINAE

Tribe Eristalini

X. Genus ***Eristalinus*** Rondani 1845

1845. *Eristalinus* Rondani, *Nuovi Ann. Sci. Nat. Bologna.***2** (2): 453

Type species: *Musca sepulchralis* Linnaeus

SubGenus ***Eristalinus*** Rondani, 1845

11. ***Eristalinus*(*Eristalinus*)*arvorum*** (Fabricius, 1787)

1787. *Syrphus arvorum* Fabricius, *Mantissa insectorum*. **2**: 335

=*Eristalis anicetus* Walker, 1849

=*Eristalis antidotus* Walker, 1849

=*Eristali sfulvipes* Macquart, 1846

=*Eristalis okinawensis* Matsumura, 1916

=*Eristalomyia eunotata* Bigot, 1890

=*Eristalomyia fo* Bigot, 1880

=*Musca tranquebarica* Gmelin, 1790

=*Syrphus aruorum* Fabricius, 1787

=*Syrphus quadrilineatus* Fabricius, 1787

Type-locality: (Tranquebar) Tamilnadu, India

Material examined:12♂♂14♀♀Palsora, Bankura district,23°27'49.6"N, 86°62'35.3"E, 103 Mt., 01.iii.2019, coll. D.Banerjee & party.11♂♂Namoachari, Bankura district, 23°16'02.4"N, 87°00'19.3"E,104 Mt., 25.xi.2018, coll. D.Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area, Arunachal Pradesh, Jammu & Kashmir, Meghalaya, Odisha, Sikkim, Tripura.

Elsewhere: Australia, China, Hawaii, Japan, Micronessi, South East Asia.

12. ***Eristalinus (Eristalinus) tabanoides*** (Jaennicke, 1867)

(Plate 1a-f)

1867. *Eristalis tabanoides* Jaennicke, *Neu. exot. Dipt. Asen. Nat. Ges.***6**: 402

=*Eristalis punctifer* Walker, 1871

Type-locality: (Tranquebar) Tamilnadu, India

Material examined:16 ♂♂ Krishtobati, Bankura district, 23°22'47.9"N, 86°'59.8"E, 97 Mt., 01.iii.2018, coll. D. Banerjee & party.12♀♀ Pechuasimue, Bankura district, 23°23'41.2"N,

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Delhi.

Elsewhere: Eritrea, Djibouti, Tunisia, Egypt.

XI. **Genus** ***Eristalis*** Latreille 1804

1804, *Eristalis*, Latreille, *Hist. Nat. Crust. Ins*. **14**: 363.

Type species: *Musca tenax* Linnaeus

Sub Genus ***Eoseristalis*** Kanervo, 1938

Type species: *Musca tenax* Linnaeus

13. ***Eristalis (Eoseristalis) cerealis*** Fabricius, 1805

1805. *Eoseristalis cerealis* Fabricius, *Syst. Antliat*. **14**: 232.

Type-locality: China.

Material examined: 13♀♀ Muslo, Bankura district, 23°22'42.2"N, 86°57'52.1"E,114Mt., 2.xii.2017, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Himachal Pradesh, Jammu &Kashmir, Meghalaya, Sikkim, Tamil Nadu, West Bengal. ***Elsewhere:*** Widespread in Oriental region.

XII. Genus ***Phytomia*** Guerin-Meneville, 1833

1833. ***Phytomia*** Guerin-Meneville, *Insectes.*: 509

Type species: *Eristalis chrysopygus* Wiedemann

Sub Genus ***Phytomia*** Guerin-Meneville, 1833

14. ***Phytomia (Phytomia) errans*** (Fabricius, 1787)

1787. *Syrphus errans* Fabricius,*Mantissa insectorum*. **2**: 337

=*Eristalis agyrus* Walker, 1849

=*Eristalis amphicrates* Walker, 1849

=*Eristalis babytace* Walker, 1849

=*Eristalis macquartii* Doleschall, 1856

=*Eristalis plistoanax* Walker, 1849

=*Eristalis varipes* Macquart, 1842

=*Phytomia aryrus* Knutson, Thompson & Vockeroth, 1975

Type-locality: India. Tamil Nadu: Tharangambadi.

Material examined: 1♀Sonamukhi forest area, Bankura district,23°15'41.3"N, 86°51'29.3"E,144mt., 04.iii.2019, coll. D. Banerjee & party.2♀♀ Bandarhati, Bankura district,23°18'36.01"N, 86°54'34.1"E, 124 Mt., 2.xii.2017, coll. D. Banerjee & party.

Elsewhere: China, Throughout SE Asia, Japan.

Sub Genus ***Dolichomerus*** Macquart, 1850

15. ***Phytomia*(*Dolichomerus*) *crassa*** (Fabricius, 1787)

1787.*Syrphus crassa* Fabricius, *Mantissa Insect.***2:** 334.

=*Phytomyia sculptata* Wulp, 1868

=*Syrphus megacephalus* Fabricius, 1798

Type-locality: Tranquebar, Chennai (Tamil Nadu), India

Material examined:1♀ Churamanipur forest village, Bankura District, 23°17'59.9"N, 86°53'55.3"E, 110 Mt., 04.iii.2017, coll. D. Banerjee & party.1♀Sonamukhi forest area, Bankura district,23°15'41.3"N, 86°51'29.3"E, 144mt., 17.vii.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Andhra Pradesh, Assam, Himachal Pradesh, Tamil Nadu.

Elsewhere: Sri Lanka, Laos, Malaya, Nepal, Thailand.

XIII. Genus ***Mesembrius*** Rondani 1857

1857. *Mesembrius* Rondani, *Dipterol Italic prodromus.***2**: 50

Type species: *Helophilus peregrinus* Loew

16. ***Mesembrius (Mesembrius) bengalensis*** (Wiedemann, 1819)

=*Eumerosyrphus indianus* Bigot, 1882

1819. *Eristalis bengalensis* Wiedemann, *Zool. Mag. (Wied)* **1**: 16.

Type-locality: Bengal, India.

Material examined: 3♀♀ 3♂♂ Muslo, Bankura district, 23°18'16.6"N, 86°54'03.1"E, 116 Mt., 5.iii.2018, coll. D. Banerjee & party.14♀♀Hamirhati, Bankura district,23°22'47.9"N, 86° 59'08.0"E, 97 Mt., 4.xii.2020,coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area, Himachal Pradesh.

Elsewhere: SE Asia to New Guinea & northern Australia.

17. ***Mesembrius (Mesembrius) quadrivittatus*** (Wiedemann, 1819)

1819. *Eristalis quadrivittatus* Wiedemann, *Zool. Mag,* **1:**17

Type-locality: Tranquebar, India.

Material examined:3♀♀, Naphardanga, Bankura Distict, 23°26'16.2"N, 86°61'32.1"E, 187 Mt., 05.iii.2019, coll. D. Banerjee & party.11♂♂ Palsora, Bankura District, 23°27'49.6"N, 86° 52' 35.3"E, 103 Mt., 4.xii.2017, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Bihar, Chhattisgarh, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Punjab, Tamil Nadu, Tripura.

Elsewhere: Java, Moluccas, Nepal, Sri Lanka.

Tribe Merodontini

XIV. Genus ***Eumerus*** Meigen, 1822

1822. *Eumerus* Meigen, *zweifl. Insekten. Dritter Theil.***10**: 202

Type species: *Syrphus tricolor* Fabricius

18. ***Eumerus aenithorax*** Brunetti, 1915

1915.*Eumerus aenithorax* Brunetti; *Rec.Ind.Mus*; **11**:244.

Type-locality: Shimla, Himachal Pradesh, India

Material examined:1♀ Krishtobati, Bankura District, 23°22'47.9"N, 86°'59.8"E, 97 Mt., 05.iii.2017, coll. D. Banerjee & party.3♂♂ Palsora, Bankura District, 23°27'49.6"N, 86° 52' 35.3"E, 103 Mt., 5.xii.2018, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Himachal Pradesh.

Elsewhere: Nil.

19. ***Eumerus aurifrons*** (Wiedemann, 1824)

(Plate 2 a-e)

1824. *Eumerus aurifrons* Wiedemann, *Analecta. ent.***1**:32

Type locality: Ind Orient region.

Material examined:10♀♀3♂♂Sonamukhi Forest Area, Bankura District, 23°15'41.3"N, 86°51'29.3"E, 144 Mt., 05.iii.2019, coll. D. Banerjee & party.4♂♂ Palsora, Bankura District, 23°27'49.6"N, 86° 52' 35.3"E, 103 Mt., 5.xii.2017, coll. D. Banerjee & party.

Distribution: India West Bengal (Bankura: Sonamukhi Protected Forest Area).

Elsewhere: Philippines, Indonesia, Hawaii.

XV. **Genus Syritta** Lepeletier & Serville, 1828

1825. *Syritta* St.Fargeau&Serville, *Encyl.Meth.* 10:888,

Type species: *Musca pipiens* Linnaeus.

20. ***Syritta indica*** (Wiedemann, 1824)

1884. *Syritta rufifacies* Bigot, *Ann. Soc. Ent. Fr. Ser*. **6**, 3: 535-560.

=*Syritta femorata* Sack, 1913

=*Syritta rufifacies* Bigot, 1884

Type locality: East Indies.

Material examined: 6♂♂ Kalyanpur, BankuraDistict, 23°14'12.1"N, 86°51'19.1"E, 123 Mt., 05.iii.2018, coll. D. Banerjee & party.9♀♀ Dihipara, Bankura District, 23°13'16.9"N, 86° 51' 59.2"E, 167 Mt., 2.xii.2019, coll. D. Banerjee & party.

Distribution: India: West Bengal (Bankura: Sonamukhi Protected Forest Area), Assam, Bihar, Himachal Pradesh, Karnataka, Pondicherry.

Elsewhere: No

1A. Dorsal view of head of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1B. Dorsal view of thorax of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1C. Dorsal view of abdomen of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1D. Dorso lateral view of leg of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1E. Dorso lateral view of wing of *Episyrphus* (*Episyrphus*) *balteatus* (De Geer, 1776)

1F. Habitus of *Episyrphus* (*Episyrphus*)*balteatus* (De Geer, 1776)

2A. Dorsal view of head of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2B. Dorsal view of thorax of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2C. Dorsal view of abdomen of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2D. Dorso lateral view of leg of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2E. Dorsal view of wing of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

2F. Habitus of *Sphaerophoria* (*Sphaerophoria*) *indiana* Bigot, 1884

Figure 3: Status of subfamilies of family Syrphidae from Sonamukhi Protected Forest area.

Figure 4: Status of tribes of family Syrphidae from Sonamukhi Protected Forest area.

Figure 5: Status of genera of family Syrphidae from Sonamukhi Protected Forest area.

B. **Ecological Studies**

The overall species diversity from Sonamukhi protected forest area was qualitatively and quantitatively satisfactory. Altogether 20 species under 16 genera have been found here. Species diversity found to be maximum at pre-monsoon season that is in the month of march to June while least during the monsoon season that is in the month of July to October (figure 6-7). Overall collection scenario depicts a positive correlation between seasonal factors (temperature and rainfall) with diversity of pollinating hoverflies. Among this 20 species ***Eristalinus (Eristalinus) arvorum*** (Fabricius, 1787)found to be the most abundant species throughout the survey period, while among other hoverflies,***Paragus (Paragus) serratus*** (Fabricius, 1805), ***Asarkina (Asarkina) ericetorum*** (Fabricius, 1781)found to be quite abundant. ***Phytomia (Dolichomerus) crassa*** (Fabricius, 1787) found to be least abundant among this group of pollinating hoverflies (figure 6). Considering the species richness status, thePre-monsoon andpost-monsoon season depicts nearly

similar level of species richness while the monsoon season exhibits the least in term of richness percentile. Simple linear regression reveals that species abundance has a direct negative correlation with temperature, thereby species abundance is found to be maximum at comparatively lower temperatures. That is why collection scenario found to be most enriched during pre-monsoon season, we have also considered other environmental parameters like rainfall, humidity, latitude, availability of host plants, habitat type. It has been found that species availability is positively correlated with availability of host plants and habitat type. While negatively correlated with rainfall and humidity and latitude does not reveal any correlation at all. During the preceding 3 years, we have surveyed casing pre monsoon, monsoon and post monsoon season to observe seasonal correlation with dipteran diversity if any. Summarising the results of the study revealed that dipteran alpha diversity in this protected forest area is reliably getting affected by the seasonal arrangement there.The assortment is maximum in the pre monsoon season, while slightly in a lesser amount during post monsoon atmosphere and nearly minuscule in amount duringmonsoonal time. If we consider theyear-wise assortment scenario, then dipteran diversity was supreme during the year of 2019-20, while least in the year of 2018, and if we consider the non-dipteran diversity, then profusion was maximum in the year of 2018-19.

Along the Protected Forest Area, the species are distributed at low densities with high turnover of insect species across the latitudinal and longitudinal axis. Considering the species abundance, the data suggests that ***Eristalinus (Eristalinus) arvorum*** (Fabricius, 1787) is the most abundant species while ***Phytomia (Dolichomerus) crassa*** Fabricius, 1787 is the least abundant. Among the two subfamilies, Syrphinae has a higher percentile of species abundance (53%) than Eristalinae (47%) (figure 3). Whereas species richness is nearly similar (49%-49.5%) for both subfamilies. While among the tribes Syrphini shows the highest species abundance (69%) and Eristalini the highest species richness percentile (55%) (figure 4). Among the genera *Eristalinus* has shown the maximum abundance while the least (figure 5). The least percentile of species richness and abundance is represented by theMilesiini tribe (3% and 5% respectively). Unexpectedly species richness relative abundance and overall diversity found to be highest in pre monsoon season in comparison with post monsoon and monsoon season. Relative abundance has shown that during pre-monsoon season *Eristalinus (Eristalinus) arvorum* (Fabricius, 1787) is most abundant and *Eumerus aeneithorax* Brunetti, 1915 is the least abundant species, while both in monsoon and post monsoon *Episyrphus (Episyrphus) balteatus* (De Geer, 1776) is most abundant syrphid while *Eupeodes (Macrosyrphus) confrater* (Wiedemann, 1830) is least abundant during monsoon and *Syritta indica* (Wiedemann, 1824) is least abundant duringpost-monsoon season. Even considering the very low floristic diversity and the harsh conditions of the environment. Another reason of such high level of diversity is that this ecosystem act as an Ecotone, a connecting fringe between agro and forest ecosystem, thereby expected to exhibit a higher range of species diversity (Sajjad *et al.* 2010)

Figure 6: Overall species collection scenario from Sonamukhi Protected Forest area

Figure 7: Species collection scenario from Sonamukhi Protected Forest area on seasonal account.

Different Alpha (α) diversity indices:

Alpha Biodiversity [α] of the surveyed area refers to a group of organisms interacting and competing for the same resources or sharing the same environment. The calculation is based upon the indexes that have been calculated based upon our overall collected data covering all 3 seasons, it is given in a chart as follows (table 1-3). We have calculated here Shannon index, Simpson index, Menhinick's richness index, Margalef's richness index, Berger-Parker dominance.

Figure 8A-8E: Comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

Figure 9: Overall comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

Figure 10: Relative abundance scenario of species collected from study area during Pre monsoon season.

Figure 11: Relative abundance scenario of species collected from study area during monsoon season.

Figure 12: Relative abundance scenario of species collected from study area during post monsoon season.

Discussion

This work is consolidated taxonomical work on Family Syrphidae from this protected forest area. Several reseach work have been carried out across different graphic regions of West Bengal previously (Sengupta *et al* 2018), in this study

we consider the dry deciduous forest of Bankura district as a study site.. So, from that point of view, this work carries immense taxonomical importance. Altogether **20** species of hoverflies under **16** genera have been reported. The **20** species which are found are from **2** subfamilies namely Syrphinae and Eristalinae. Subfamily Syrphinae has shown higher abundance than subfamily Eristalinae throughout our survey period.Altogether 7 tribes are reported from the study area of which tribe syrphini has shown the maximum abundance while tribe merodontini the lowest . Among the 16 genera reported *Eristalinus* has shown the Highest abundance while *Dasysyrphus* the lowest

During preceding 3 years (2018-2020), we have surveyed the selected study areas casing pre-monsoon, monsoon and post monsoon season. Further extensive studies throughout all the month should help to construct a clearer cut picture the taxonomical scenario of hoverflies from this protected area with a schematic concept their annual availability. Perhaps such extensive studies and careful attention will be needed to attain far higher counts of this pollinating dipteran insects, although the current taxonomic study has shown a satisfactory result quantitative & qualitatively.

Seasonal variation of the physicochemical circumstances plays an imperative role in syrphid diversity and community structure (Colley *et al.* 2000). Knowledge of seasonal variation, abundance and diversity of syrphid in relation floral abundance and abiotic factors has generally been documented here (Sajjad *et al.* 2010) as it helps their conservation strategies (Mengual, 2010). At the landscape level, positive relationships between the richness and abundance of floral resources and dipteran diversity and activity have been found (Reemer, 2013). But on a micro-scale very little is known about the overall activity patterns of syrphid fly with the distribution of resources. Therefore, to investigate the relation present between seasonal variation and the diversity of syrphid flies in a protected area we have studied here the hoverfly diversity in year-wise collection pattern as well at the seasonal level too. The pattern of seasonal changes in numbers of Syrphidae was similar over the 3-year study period. The species composition was highest during the year 2019 and lowest during 2018. While discussing species abundance, large proportion of species were relatively common while few species were very abundant (Figure 10-12). The most 2 abundant species accounts for nearly 47.5% of total species individuals.

Alpha diversity indices were also calculated. The performance of all species diversity estimators showed remarkable differences between 3 seasons. There is a large super position range in species richness estimates which varied in 3 seasons. Thus, the alpha diversity analysis of this data has shown a consistent pattern of higher diversity at pre monsoon with descending trend at post monsoon and monsoon season

The value of H is higher at pre monsoon rather than monsoon and post monsoon season indicates higher diversity this factor is also supported by higher value of Simpson index of diversity at pre monsoon season. Both Mechinick's and Margalef's richness index are also higher in pre monsoon season. The higher value of Berger Parker index during monsoon season predicts that the community during monsoon season is dominated by few species that is the evenness is lower here compared to the other two seasons where lower value of Berger Parker index attributes to a more even community of hoverfly's population. Although species richness is slightly higher in post monsoon season rather than pre monsoon season while remarkably lower at monsoon season.

The general result of this study suggests that rainfall and temperature play the pivotal role in the hoverfly species composition and relative abundance in the given area, thus the species diversity found to be maximum at pre monsoon season when rainfall was minimum and temperature also in an optimum level comparatively. This prediction has been done based upon the statistical differentiation of the diversity measures, species abundance as well as in the light of species richness estimators

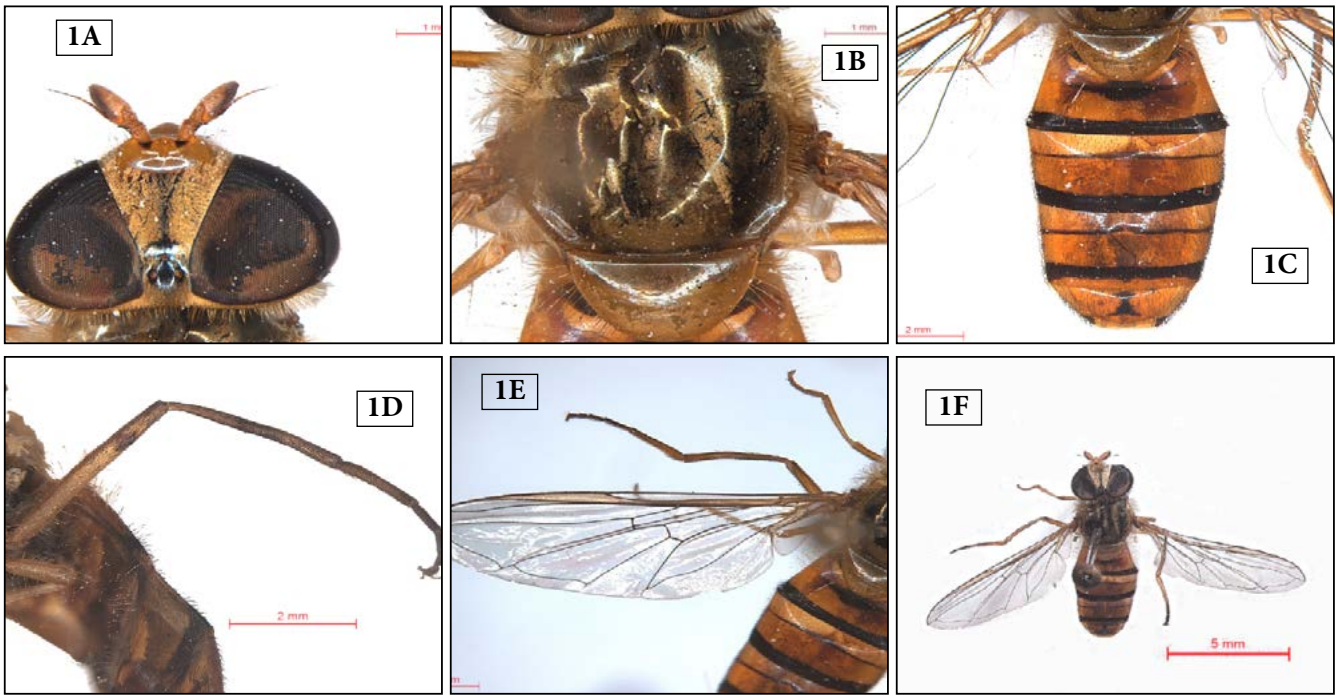
Furthermore, our study suggests that heterogeneity in the dry deciduous forest's hoverfly assemblages occur due to contrasting type of environmental factors, phytophagous nature of feeding, and level of urbanization of the surroundings of forest. Responses to different level of seasonal fluctuation were also found in hoverfly assemblages (Gottschalk *et al.* 2001). Finally considering the availability of feeding and breeding sites, we suggest that such dry deciduous forest ecosystem is acting as sink habitats for hover fly population.

Concluding it can be said Insect abundance in the understory vegetation varies significantly among the habitats. Among these three dominant seasons of our studied area, the pre monsoon season has shown a relatively high abundance of insects. The comparison of the seasonal fluctuations in the insect abundance of the dry deciduous forest revealed that the seasonality of the overall insect population of the

understory vegetation is controlled by common micro climatic factors rather than by any habitat specific factors. The factors and process that maintain the numbers of species in a given locality remain unknowing most cases (Whittaker, 1972). Local communities are open, and coupled to broader landscape via movement of flies there by creating a Source Sink system (Amarasekare *et al.* 2001). This effect can increase the species diversity in heterogeneous landscapes shortly. Although this concept of source-sink study needs further scientific attention to get a clearer picture.

Conclusion

The overall species diversity from Sonamukhi protected forest area depicts altogether 20 species under 16 genera are found. The flies of *Ersistalinus* genus are the most abundant whereas *Dasysyrphus* genus are less abundant in this region. *Episyrphus balteatus* (DeGeer, 1776) is found to be most common and the *Sphaerophoria Indiana* Bigot, 1884 are very rare. Diversity analysis study has revealed that species diversity found to be maximum at pre monsoon season (66.75%) While least during monsoon season (2.5%). Overall collection scenario depicts a positive correlation between seasonal factors (temperature and rainfall) with diversity of pollinating hoverflies.



1A. Dorsal view of head of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1B. Dorsal view of thorax of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

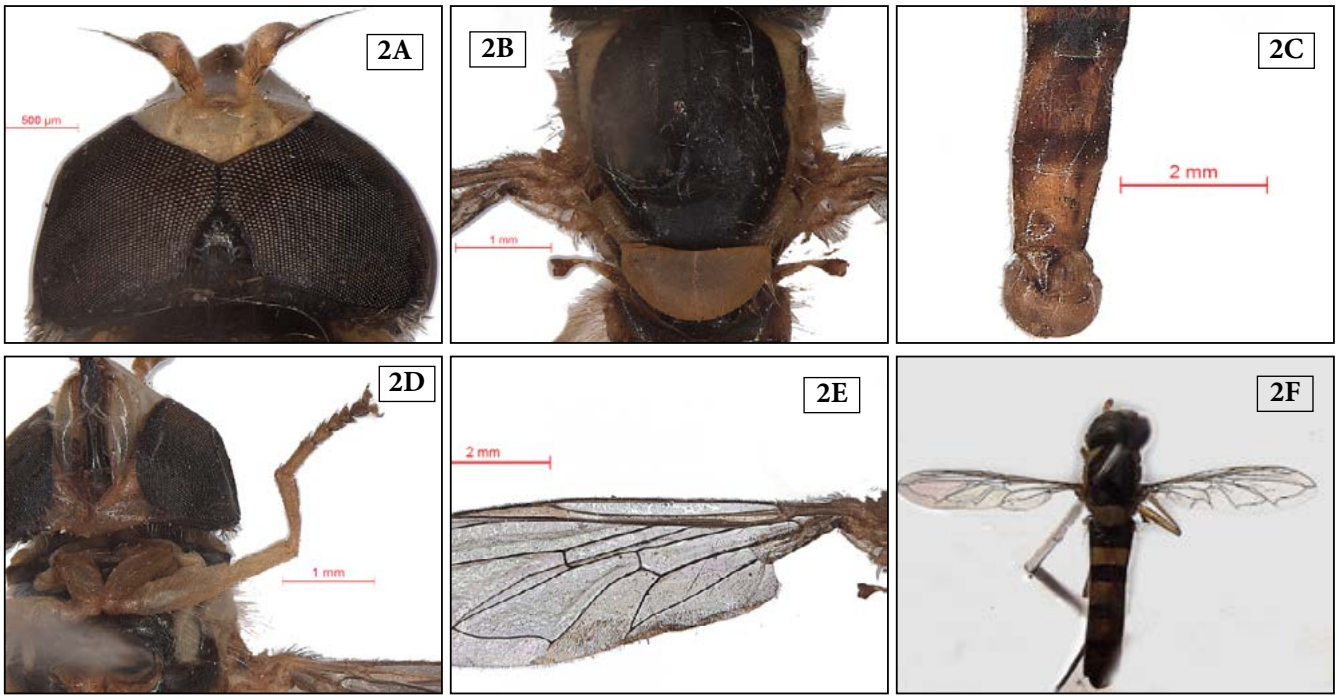
1C. Dorsal view of abdomen of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1D. Dorso lateral view of leg of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1E. Dorso lateral view of wing of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

1F. Habitus of *Episyrphus (Episyrphus) balteatus* (De Geer, 1776)

FIGURE-2



2A. Dorsal view of head of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2B. Dorsal view of thorax of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2C. Dorsal view of abdomen of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2D. Dorso lateral view of leg of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2E. Dorsal view of wing of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

2F. Habitus of *Sphaerophoria*(*Sphaerophoria*) *indiana* Bigot, 1884

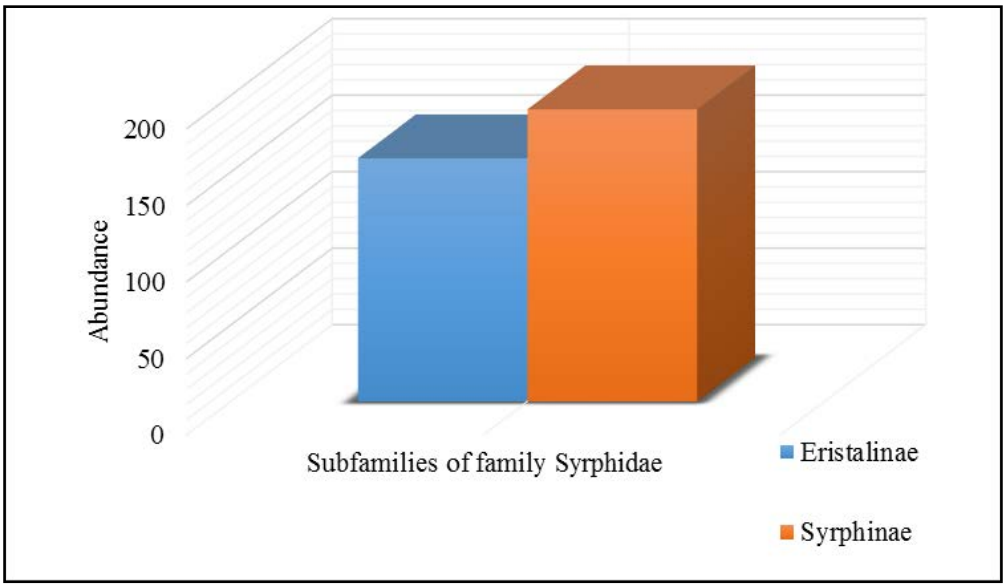


Figure 3: Status of subfamilies of family Syrphidae from Sonamukhi Protected Forest area.

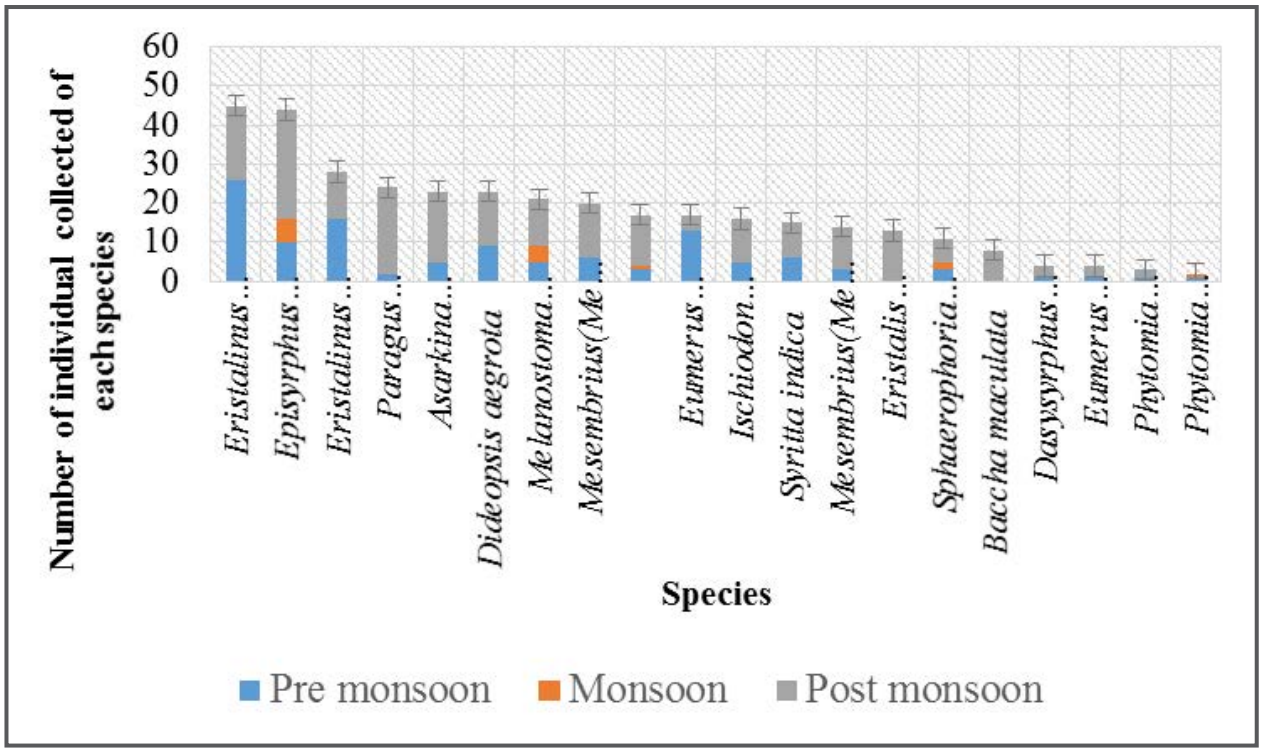


Figure 4: Status of tribes of family Syrphidae from Sonamukhi Protected Forest area.

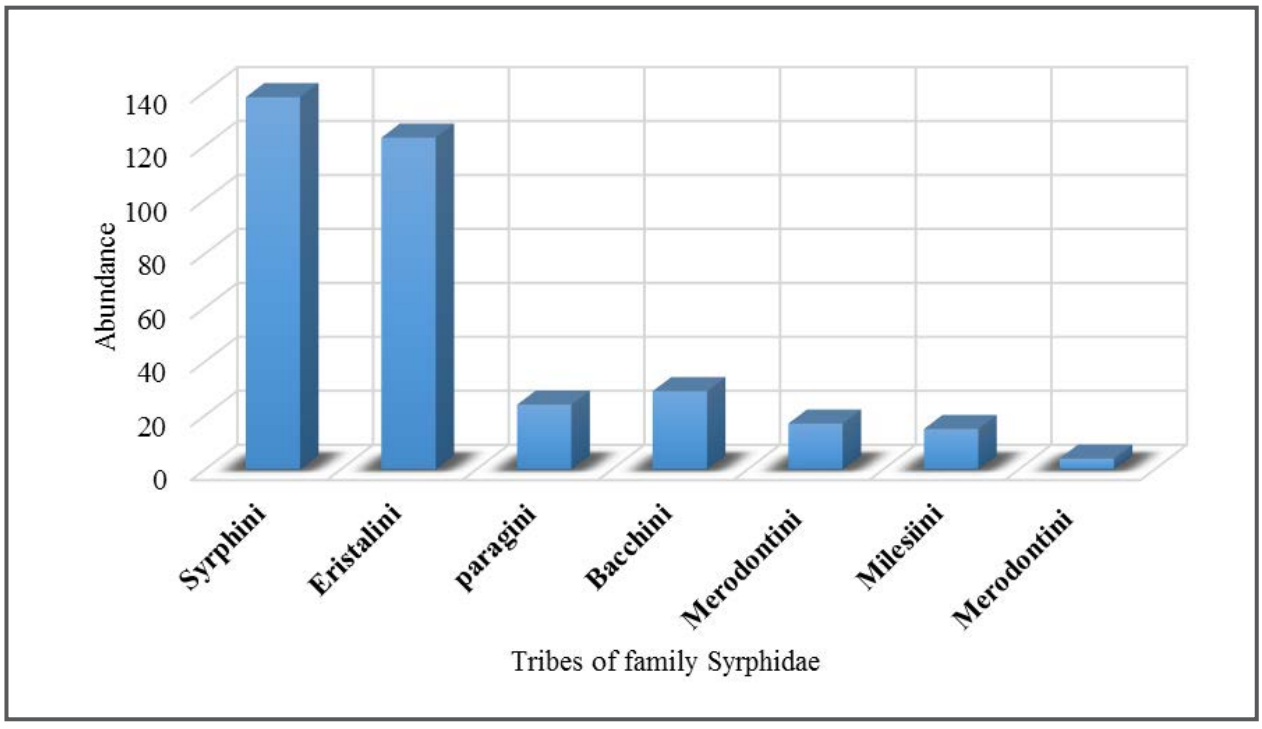


Figure 5: Status of genera of family Syrphidae from Sonamukhi Protected Forest area

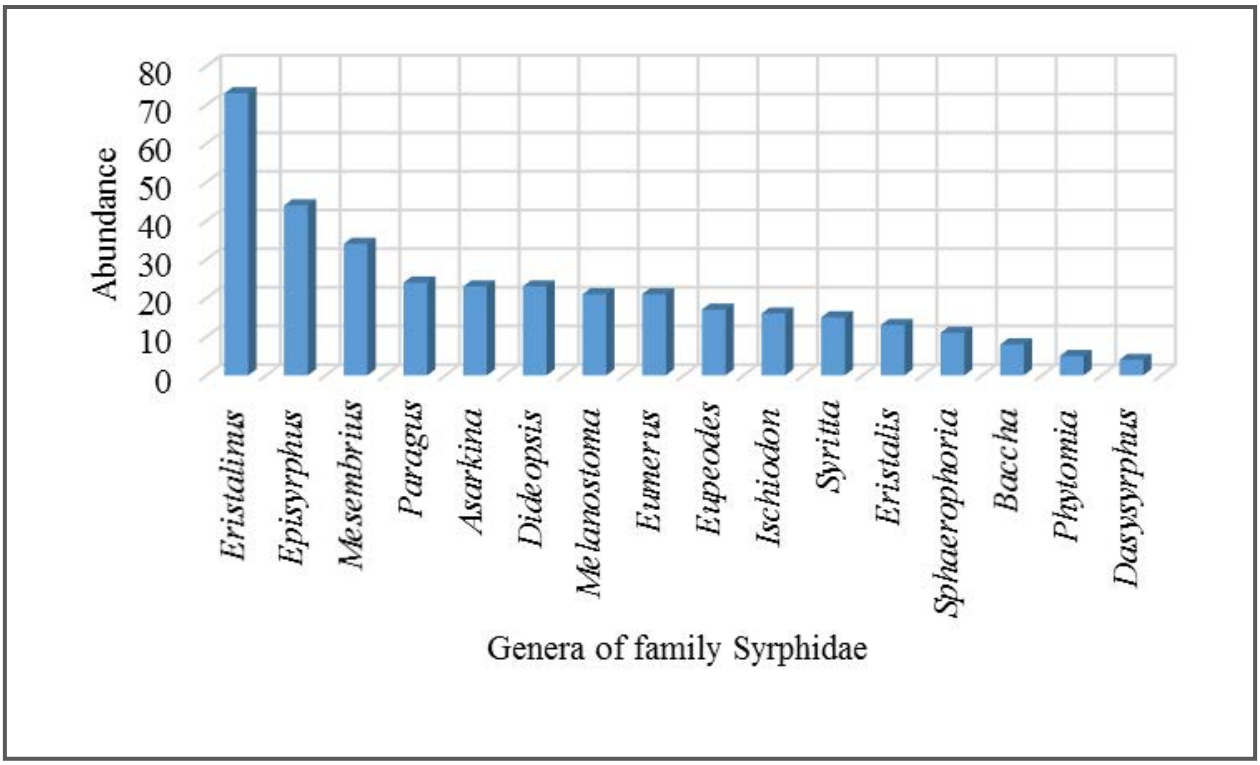


Figure 6: Overall species collection scenario from Sonamukhi Protected Forest area

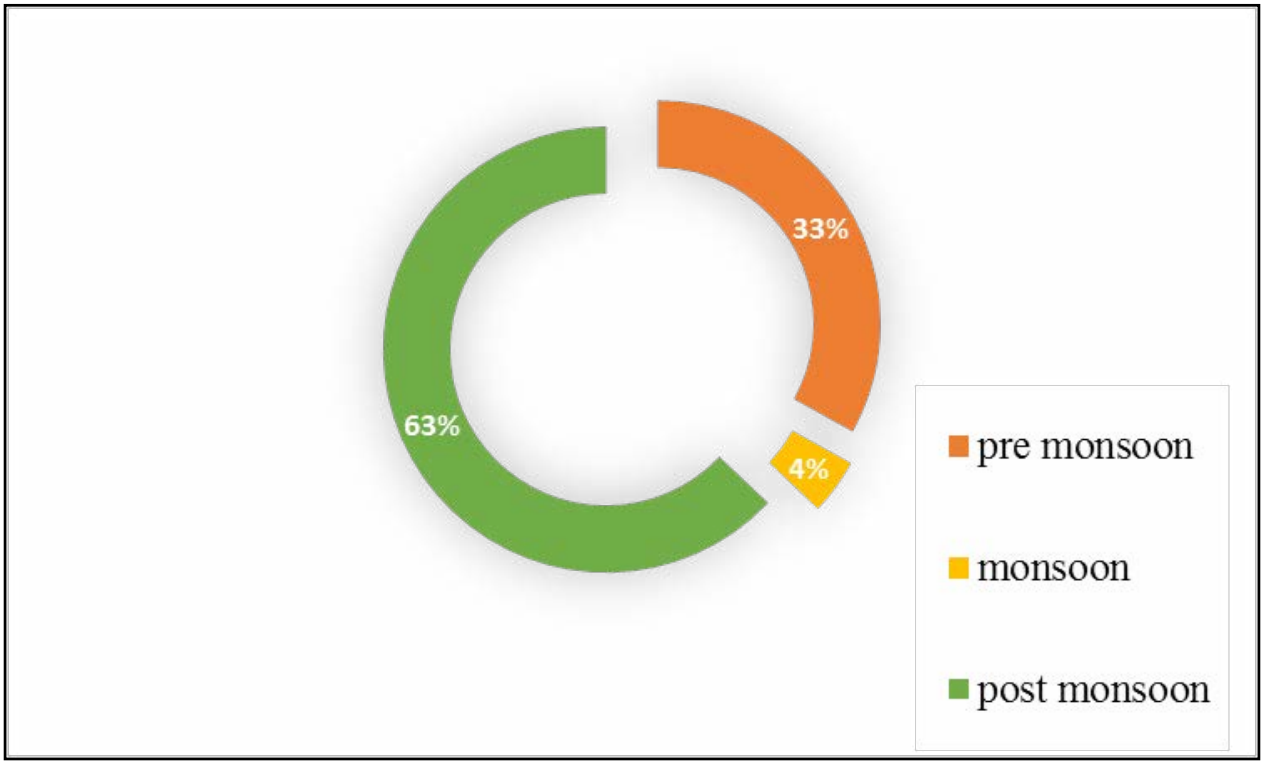


Figure 7: Species collection scenario from Sonamukhi Protected Forest area on seasonal account

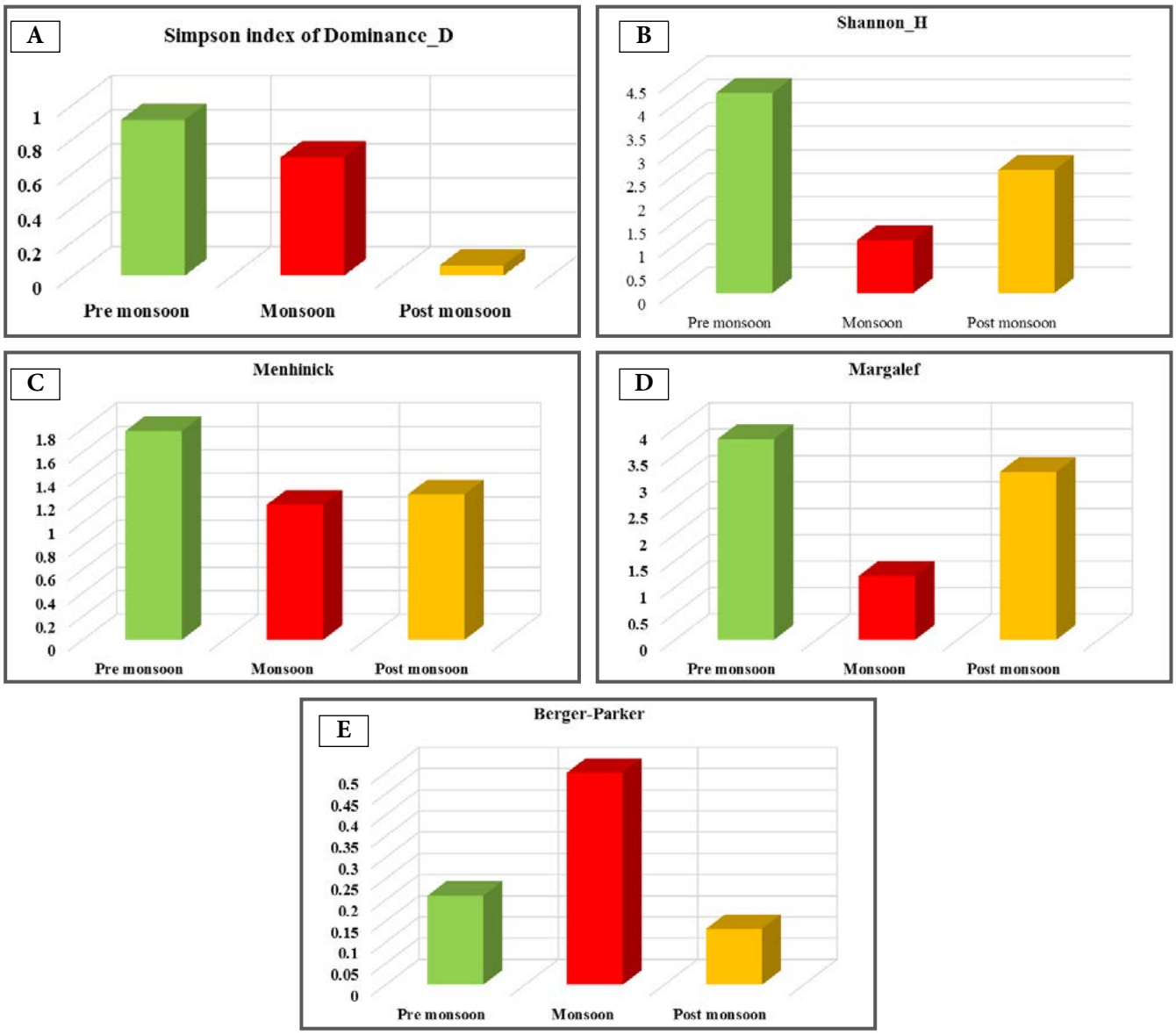


Figure 8A-8E: Comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

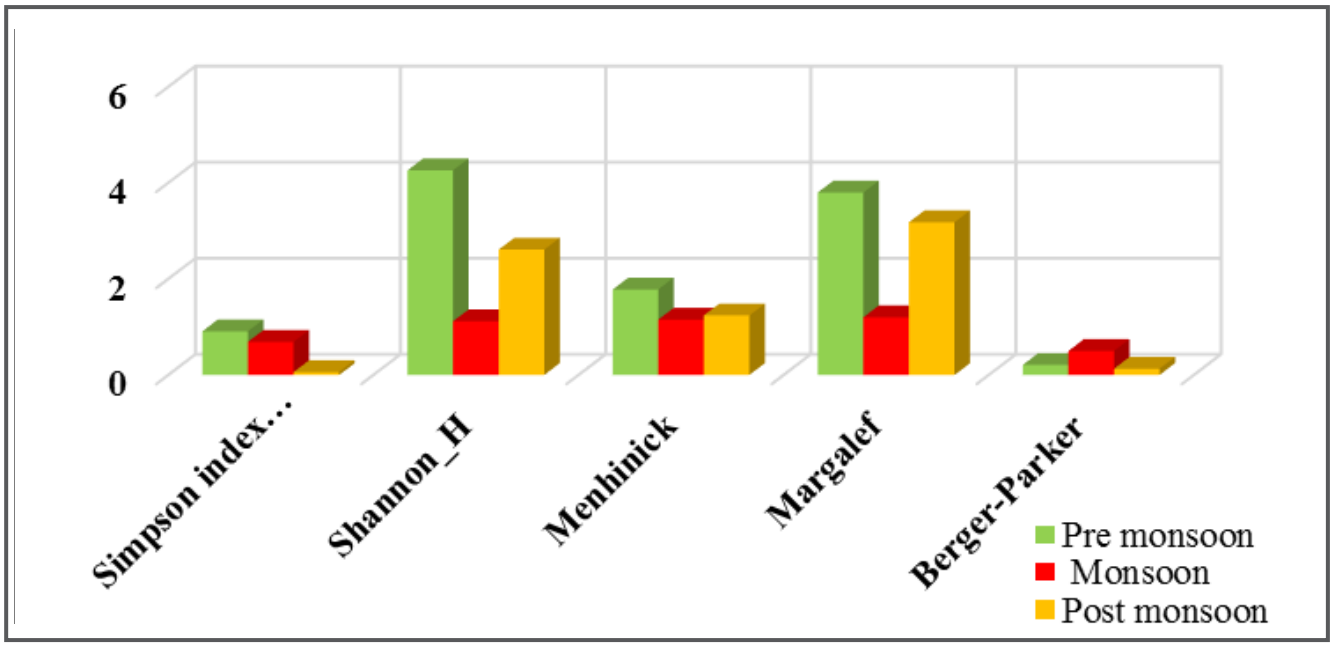


Figure 9: Overall comparative graphical representation of calculated diversity indexes from three studied seasons (Pre monsoon, monsoon and post monsoon).

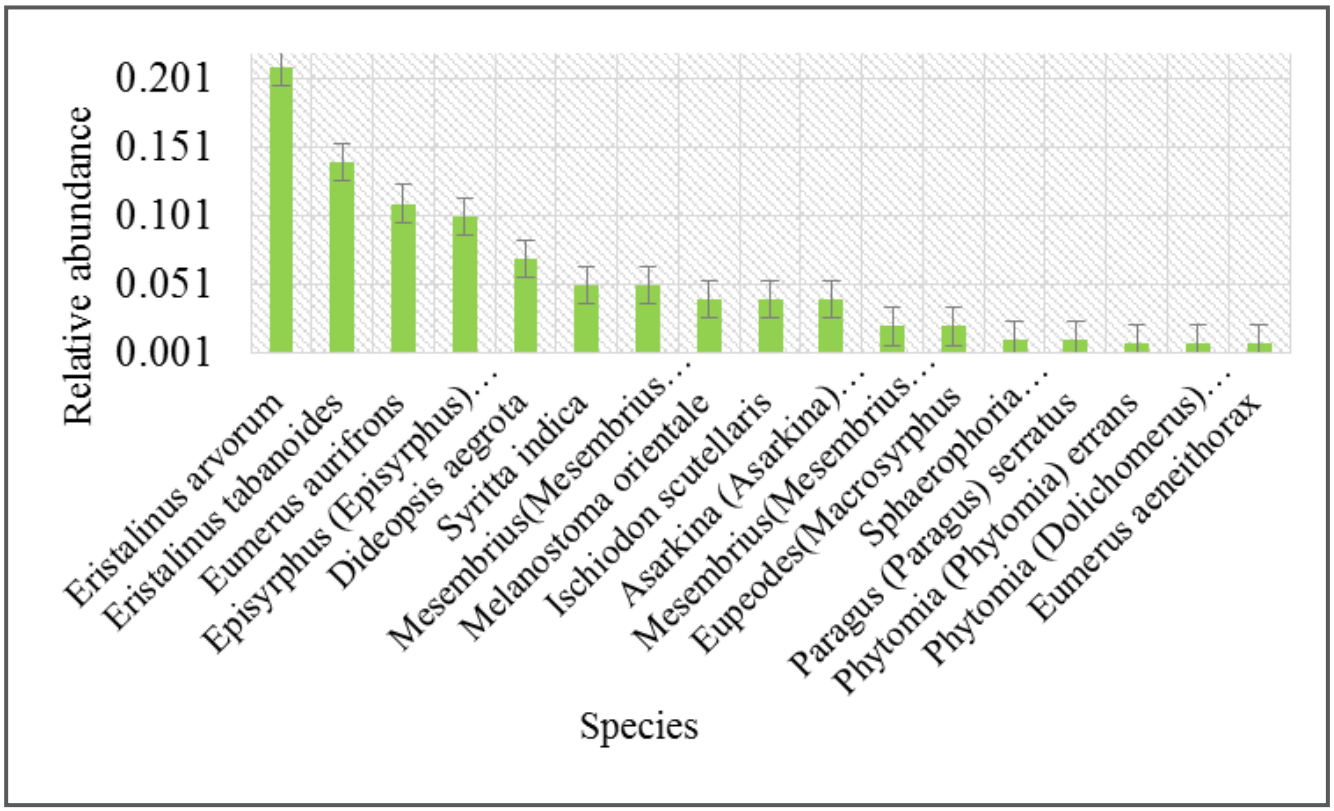


Figure 10: Relative abundance scenario of species collected from study area during Pre monsoon season

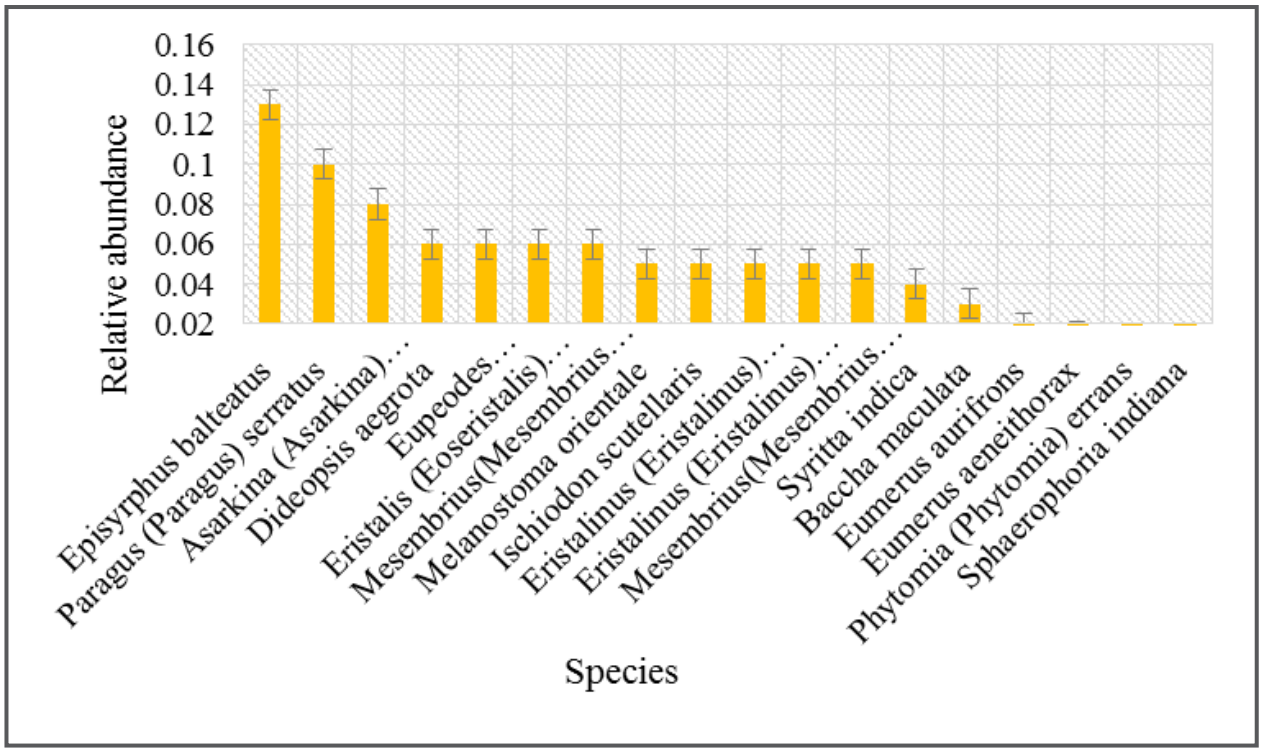


Figure 11: Relative abundance scenario of species collected from study area during monsoon season

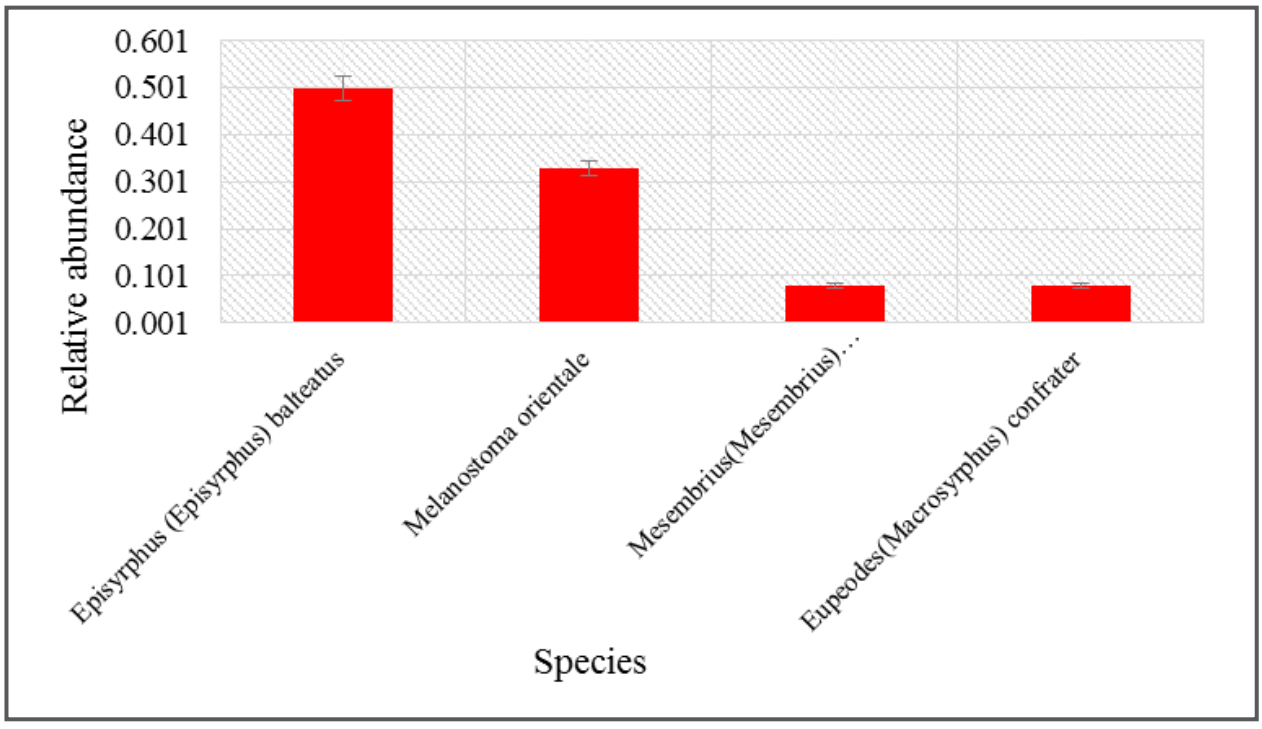


Figure 12: Relative abundance scenario of species collected from study area during post monsoon season

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References

Bhatia, H.L. and Shaffi, M. 1933. Life histories of some Indian Syrphidae. Indian Journal of Agricultural Science, 2: 543-570.

Ghorpadé, K. 2014. On the Hover-flies (Diptera–Syrphidae) preserved in the collection of the Panjab University, Chandigarh, and further notes on those from the Indian Punjab and NW. India. Colemania, 46: 1-17.

Hegland, S.J. and Boeke, L. 2006. Relationships between the density and diversity of floral resources and flower visitor activity in a temperate grassland community. Ecological Entomology, 31(5): 532-538.

Kearns, C.A. 2001. North American dipteran pollinators: assessing their value and conservation status. Conservation Ecology, 5(1).

Mengual, X. 2012. The flower fly genus Citrogramma Vockeroth (Diptera: Syrphidae): illustrated revision with descriptions of new species. Zoological Journal of the Linnean Society, 164(1): 99-172.

Owen, J. and Gilbert, F.S. 1989. On the abundance of hoverflies (Syrphidae). Oikos, pp.183-193.

Ali, H., Alqarni, A.S., Shebl, M. and Engel, M.S. 2016. Notes on the nesting biology of the small carpenter bee Ceratina smaragdula (Hymenoptera: Apidae) in northwestern Pakistan. Florida Entomologist, 99(1): 89-93.

Chain-Guadarrama, A., Martínez-Salinas, A., Aristizábal, N., & Ricketts, T. H. (2019). Ecosystem services by birds and bees to coffee in a changing climate: A review of coffee berry borer control and pollination. *Agriculture, Ecosystems & Environment*, 280: 53-67.

Coe, R.L. 1964. Diptera from Nepal: Syrphidae.

Colley, M.R. and Luna, J.M. 2000. Relative attractiveness of potential beneficial insectary plants to aphidophagous hoverflies (Diptera: Syrphidae). Environmental Entomology, 29(5): 1054-1059.

De Silva, M.D., 1961. A preliminary list of the native parasites and predators of insect pests in Ceylon. Tropical agriculture, 117: 115-141.

Decourtye, Axel & Alaux, Cédric & Le Conte, Yves & Henry, Mickaël. (2019). Toward the protection of bees and pollination under global change: Present and future perspectives in a challenging applied science. *Current Opinion in Insect Science*. 35:123-131 DOI: http://10.1016/j.cois.2019.07.008.

Delfiando, M.D and Hardy, D.E. (eds.) 1977. A Catalogue of Diptera of the Oriental region. Vol. III (Nematocera). University of Hawaii, Honolulu.

Delfinado, M.D. and Hardy, D.E. eds. 1975. A Catalog of the Diptera of the Oriental Region: Volume II—Suborder Brachycera; through Division Aschiza, Suborder Cyclorrhapha. University of Hawaii Press.

Evenhuis, N.L. 2014. Catalog of the fossil flies of the world (Insecta: Diptera) website. Version, 2: 18.

Gahari, H., Ostovan, H., Kamali, K. and Tabari, M. 2008. Arthropod predators of rice fields in central parts of Mazandaran. Journal of Agricultural Science (Islamic Azad University), 14(1): 63-74.

Ghorpadé, K. 2014. An updated Check-list of the Hover-flies (Diptera-Syrphidae) recorded in the Indian subcontinent. Colemania, 44: 1-30.

Gilbert, F., 2005, September. The evolution of imperfect mimicry. In Symposium-Royal Entomological Society of London (Vol. 22, p. 231).

Gottschalk, M.S., De Toni, D.C., Valente, V.L. and Hofmann, P.R. 2007. Changes in Brazilian Drosophilidae (Diptera) assemblages across an urbanisation gradient. Neotropical entomology, 36: 848-862.

Hegland, S.J., Grytnes, J.A. and Totland, Ø. 2009. The relative importance of positive and negative interactions for pollinator attraction in a plant community. Ecological Research, 24: 929-936.

Herve-Bazin, J. 1923. Diagnoses de Syrphides [Dipt.] nouveaux du Laos (Indo-Chine francaise). Bulletin de la Société entomologique de France, 28(2): 25-28.

Hull, F.M. 1945. A revisional study of the fossil Syrphidae. éditeur non identifié.

J.R. Vockeroth. 2001. The flower flies of the subfamily Syrphinae of Canada, AJaska, and Greenland: Diptera, Syrphidae.The Insects and Arachnids of Canada. 1:12-16.

Janzen, D.H., 1986. Management of habitat fragments in a tropical dry forest: growth. Manejo de fragmentos de hábitat en un bosque seco tropical: crecimiento. In Annual Systematics Symposium of the Missouri Botanical Garden. 33rd. Species diversity, St. Louis, MO, US, 10-11 Oct. 1986, 1986-10-10.

Jauker, F., Jauker, B., Grass, I., Steffan-Dewenter, I., & Wolters, V. (2019). Partitioning wild bee and hoverfly contributions to plant–pollinator network structure in fragmented habitats. *Ecology*, 100(2):e02569.

Joseph, A.N.T. 1967a. A new Indian species of Sphaerophoria St. Fargeau and Serville, 1825 (Diptera: Syrphidae). Bull. Ent, 8(2): 79-80.

Joseph, A.N.T. 1967b. On the 'forms' of Sphaerophoria St. Fargeau and Serville (Diptera: Syrphide) described by Brunetti from India. Oriental Insects, 1(3-4): 243-248.

Kearns, C.A., 2001. North American dipteran pollinators: assessing their value and conservation status. Conservation Ecology, 5(1).

Knutson, L. V., Thompson, F. C. & Vockeroth, J. R. 1975. Family Syrphidae. A catalog of the Diptera of the oriental region, 2: 307-374

Mengual, J. and Ghorpadé, K. 2010. The flower fly genus Eosphaerophoria Frey (Diptera, Syrphidae). ZooKeys.

Miličić, M., Vujić, A., Jurca, T., & Cardoso, P. (2017). Designating conservation priorities for Southeast European hoverflies (Diptera: Syrphidae) based on species distribution models and species vulnerability. *Insect Conservation and Diversity*, 10(4): 354-366.

Nayar, J.L., 1968. A contribution to our knowledge of high altitude Syrphidae (Cyclorrhapha: Diptera) from NW Himalaya. Part I–Subfamily Syrphinae. Agra University Journal of Research (Science), 16(2): 121-131.

Pape, T. and Evenhuis, N.L., 2018. Systema Dipterorum, Version 1.5. 67 records.

Parui, P., Mitra, B. and Sharma, R.M. 2006. Diptera Fauna of Punjab and Himachal Shiwalik Hills. Records of the Zoological Survey of India, 106(1): 83-108.

Pascal, J.P. and Pelissier, R. 1996. Structure and floristic composition of a tropical evergreen forest in south-west India. Journal of Tropical Ecology, 12(2): 191-214.

Petty, Deryn. "A veterinary guide to the parasites of reptiles. Volume 2: Arthropods (excluding mites), Susan M. Barnard & Lance A. Durden: book review." African Journal of Herpetology 49.2 (2000): 175.

Potts, S.G., Vulliamy, B., Dafni, A., Ne'eman, G. and Willmer, P. 2003. Linking bees and flowers: how do floral communities structure pollinator communities?. Ecology, 84(10): 2628-2642.

Reemer, M. and Ståhls, G. 2013. Generic revision and species classification of the Microdontinae (Diptera, Syrphidae). ZooKeys, (288): 1.

Rhodes CJ. (2019). Are insect species imperilled? Critical factors and prevailing evidence for a potential global loss of the entomofauna: A current commentary. Science Progress, 102(2):181-196.

Rotheray GE. 1981. Host searching and oviposition behavior of some parasitoids of aphidophagous Syrphidae. *Ecol Entomol*. 6:79–87.

Sahayaraj, K. 2004. Indian insect predators in biological control. Daya Books.

Sajjad, A., Saeed, S. and Ashfaq, M. 2010. Seasonal variation in abundance and composition of hoverfly (Diptera: Syrphidae) communities in Multan, Pakistan. Pakistan Journal of Zoology, 42(2): 105-115.

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

Sengupta, J., Naskar, A., Maity, A., Homechaudhuri, S. and Banerjee, D., 2018. Distributional scenario of hover flies (Diptera: Syrphidae) from the state of West Bengal. Munis Entomol. Zool, 13, pp.447-457.

Shah, G.M., Jan, U. and Wachkoo, A.A. 2014. A checklist of hoverflies (Diptera: Syrphidae) in the western Himalaya, India. Acta Zoologica Hungarica, 60(4): 283-305.

SHEBL, M.A., KAMEL, S.M., ABUHASHESH, T.A. AND OSMAN, M.A., 2008. Seasonal abundance of leafcutting bees (Megachile minutissima, Megachilida Hymenoptera). World Journal of agricultural Science., 4: 280-287.

Souza-Silva, M., Fontenelle, J.C. and MARTINS, R.P., 2001. Seasonal abundance and species composition of flower-visiting flies. Neotropical Entomology, 30: 351-359.

Ssymank, A., Kearns, C.A., Pape, T. and Thompson, F.C. 2008. Pollinating flies (Diptera): a major contribution to plant diversity and agricultural production. Biodiversity, 9(1-2): 86-89.

Steffan-Dewenter, I. 2002. Landscape context affects trap-nesting bees, wasps, and their natural enemies. Ecological Entomology, 27(5): 631-637.

Sutherland, J.P., Sullivan, M.S. and Poppy, G.M. 2001. Distribution and abundance of aphidophagous hoverflies (Diptera: Syrphidae) in wildflower patches and field margin habitats. Agricultural and forest Entomology, 3(1): 57-64.

Thompson, F.C. and Ghorpade, K., 1992. A new coffee aphid predator, with notes on other Oriental species of Paragus (Diptera: Syrphidae). Colemania.

Thompson, F.C., 1969. A new genus of Microdontine flies (Diptera: Syrphidae) with notes on the placement of the subfamily. Psyche, 76(1): 74-85.

Thomson Reuters, U.K., 2013. Insecta. Part-C Diptera. Family Syrphidae. Zoological Record, 149(13C): 383-398.

Vockeroth, J.R., 1958. Two New Nearctic Species of Spilomyia (Diptera: Syrphidae), with a Note on the Taxonomic Value of Wing Microtrichia in the Syrphidae1. The Canadian Entomologist, 90(5): 284-291.

Winder JA (1978). The role of non-dipterous insects in the pollination of cocoa in Brazil. *Bulletin of Entomological Research*, 68(4):559-574.

Woodcock, T. S., Larson, B. M., Kevan, P. G., Inouye, D. W., & Lunau, K. (2014). Flies and flowers II: Floral attractants and rewards. Journal of Pollination Ecology, 12(8):63-94.