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continued on the back inside cover

Cover: Leaves and fruits of *Terminalia arjuna* in water colour artwork on cold pressed water colour paper by Bhama Sridharan.

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ARTICLE

Flies in the high for floral hike? Altitudinal variation in species diversity and composition of Diptera (Insecta) in the eastern Himalaya, India

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Abstract: Species diversity and composition enable us to understand the conservation and management of an ecosystem. There is scarcity of knowledge in understanding the diversity change across the gradients of elevation, especially in the Himalaya. Here, we focused in the eastern Himalaya to investigate the patterns of taxonomic and functional diversity of true flies with relation to variation in altitude. The study was conducted in protected area (Neora Valley National Park) in the eastern Himalaya, India and the survey was conducted at five altitudinal zones (from 500 to 3,000 m). A total of 201 species of Diptera, with 105 genera and 33 families were recorded, of which 25 species are new to the state of West Bengal and seven species are new to India. The species diversity increased with elevation (maximum was near 2,500 m) and most of the flies preferred to be close to bushes with flowers, with a substantial percentage of them being pollinator species. Flies adapt to the various vegetation and climate patterns, which was evident by the abundance of fly species at high altitudes (1,500–2,500 m). Hence, it is very important to implement appropriate actions to protect the diversity of true flies in this Himalayan landscape.

Keywords: Elevation gradient, insect diversity, pollination, species composition, West Bengal.

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Competing interests: The authors declare no competing interests.

Author details: Dr. SK Sinha has 23 years of research experience on the taxonomy and ecology of calyptrate flies. S Mahato is a PhD scholar at SACON, Coimbatore. He has been working on the taxonomy and ecology of Diptera for the last 10 years and has an interest in animal behaviour. P Hazari, N Jana and N Pandya are working with SKS on the diversity and ecology of calyptrate flies. S Ojha is pursuing her PhD in ecology and behaviour of primates and has a special interest in insects. Dr. A Hajra who studies mosquito control, has interests in parasitology and medical entomology. U Ghosh is the Additional Principal Chief Conservator of Forests, Govt. of West Bengal, and his area of interest is biodiversity conservation. Dr. S Bhattacharyya is Professor of Zoology at the West Bengal State University, and he works on ecology and conservation.

Author contributions: Study conception and design, field surveys and communication – SKS; Assistant and support in field surveys – PH, UG & SB; Lab work – SKS, PH, NJ & SM; Data compilation – SM, SO, NJ, NP & AH; Data analysis & the first draft of manuscript – SM & SO; Comments on draft of the manuscript – SKS, AH, UG & SB; All authors read and approved the final manuscript.

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INTRODUCTION

Patterns of species composition and diversity, along with environmental and elevational gradients, provide insights into our understanding of ecosystem conservation. Research trends have shifted toward a greater understanding of the elevation gradient and its impact on species diversity across various geographic regions (Terborgh 1977; Brown 2001; Sanders & Rahbek 2012; Acharya & Vijayan 2015; Marathe et al. 2021). Furthermore, changes in landscape physiology and climatic conditions due to the different gradients of elevation effects the species diversity (Sundqvist et al. 2013). Many studies have documented and described the mechanisms on patterns of diversity with respect to elevational gradient (Acharya et al. 2011a,b; Kraft et al. 2011; Sundqvist et al. 2013; Chun & Lee 2018). In harsher environments at higher elevations, niche differences and relative fitness differences may drive the presence of fewer species (HilleRisLambers et al. 2012; Kraft et al. 2015). Understanding such patterns and their underlying mechanisms is important for understanding the implications of insect conservation, particularly in the Himalayan regions that are vulnerable to climate change. The Himalaya is unique for examining such gradients and their impact on a variety of habitats with steep altitudinal gradient and unstable climate.

Biogeographical studies of multiple taxa have increased in recent years in various parts of the Himalayas. Most of the studies are focused on birds, plants, and pollinating insects such as butterflies. In the eastern Himalaya, bird species richness is greatest at intermediate elevations (Acharya et al. 2011b), whereas low elevations (<2,000 m) are important for butterfly conservation (Acharya & Vijayan 2015). When it comes to plants, elevation and high temperature have a considerable influence on the distribution and growth of trees (Acharya et al. 2011a). The reduction in tree height and richness noticed beyond 2,300 m, allows herbs to dominate due to climatic constraints (Sharma et al. 2019). In this context, a comprehensive study of true flies (Diptera) is also useful for identifying habitats with conservation value in the Himalayan mountain landscape.

The observed trends showed that most of the current studies focused on Lepidoptera (Joshi & Arya 2007; Bhardwaj et al. 2012; Acharya & Vijayan 2015; Dey et al. 2017; Sharma et al. 2020) and Hymenoptera (Bharti et al. 2013; Streinzer et al. 2019; Subedi & Budha 2020; Dewan et al. 2021; Marathe et al. 2021). Besides, Hymenoptera, Lepidoptera, and Coleoptera, Diptera is considered one of the principal orders of pollinating insects. Furthermore, flies of families such as Asilidae, Bibionidae, Muscidae, Stratiomyidae, Tabanidae, Tipulidae, Rhagionidae, Limoniidae, Sciaridae also act as bio-indicators of climate change (Frouz 1999; Bizzo et al. 2010; Mezgebu et al. 2019; Montoya et al. 2021) and the main potential pollinators (biotic vector) at high altitudes and latitudes, like in alpine, arctic and subarctic ecosystems where bees are less abundant (Elberling & Olesen 1999; Tiusanen et al. 2016; Lefebvre et al. 2018). Studies also indicate that species diversity and richness of Diptera change with elevation for example, species composition changes along the altitudinal gradient (700–2,500 m) and partitioning between seasonally dry lowland and moist montane evergreen forests on the Doi Inthanon mountain in northern Thailand (Plant et al. 2012; Chatelain et al. 2018), species richness and distribution of Hemerodromiinae and Clinocerinae are changing with the elevational gradient on the Pieniny Mountains in central Europe (Słowińska & Jaskuła 2021). Therefore, it is important to investigate their community composition across different environmental and elevational gradients in the Himalayas. The objective of this study was to investigate the variation of species composition and distribution of Diptera fauna in the eastern Himalaya between 500 m and 3,000 m elevation gradient.

MATERIALS AND METHODS

Study area

The study was conducted in the Neora Valley National Park which covers an area of 159.78 km^2. The park has diverse ecosystems with a wide range of elevation gradients (183–3,200 m), located near the ecological tri-junction of West Bengal, Sikkim (India) and Bhutan on the northeast (26.8675–27.1263 ^{0}N; 88.750–88.8333 ^{0}E). It is considered as crowning glory of the state of West Bengal (Mallick 2010). The study area is an east Himalayan moist mixed deciduous forest (Champion & Seth 1968), with lower areas (up to 1,800 m) recognized as subtropical mixed broadleaf forest, lower temperate evergreen forest, and upper areas (1,800–3,200 m) recognized as upper temperate mixed broadleaf forest and Rhododendron forest (Mallick 2012). The study area was divided into five categories based on the vegetation composition—Lower Hill Forest (<762 m), Middle Hill Forest (762–1,676 m), Broad-leaved Forest (1,676–2,133 m), Oak Forest (2,133–2,500 m) and Rhododendron Forest (>2,500 m) (Figure 1).

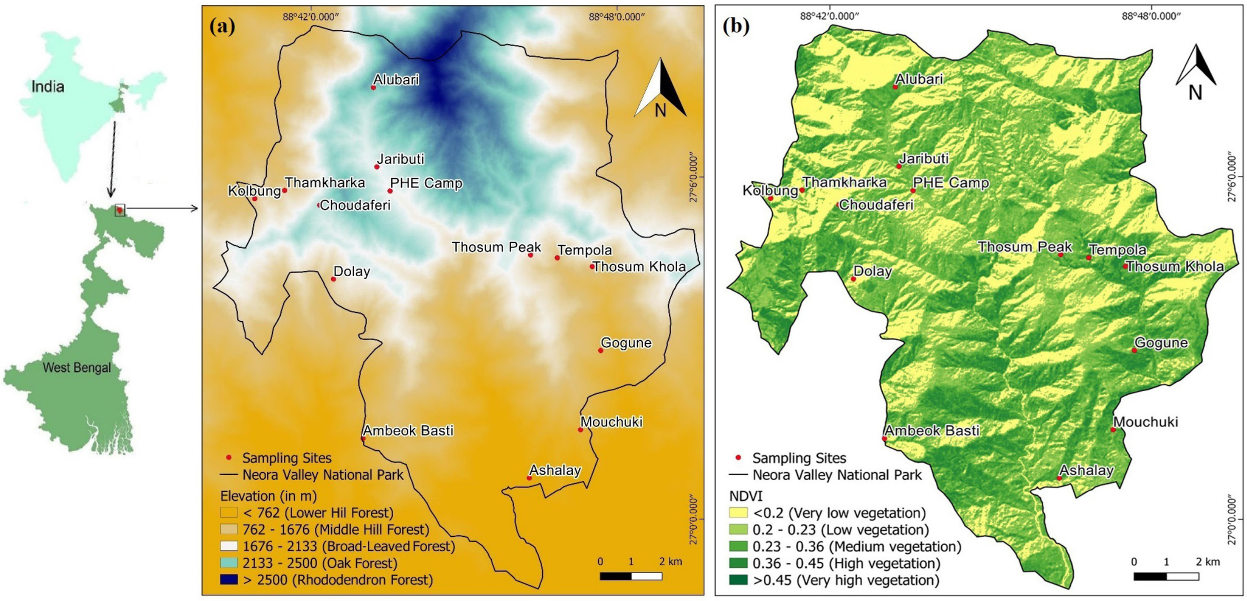

Figure 1. Sampling sites in the Neora Valley National Park, West Bengal, India: a—area with elevational gradient categorized as different forest types | b—area with normalized difference vegetation index (NDVI).

Field methods

The survey was conducted at 14 different locations (forest camps) between March 2018 and September 2021 as part of the Biodiversity Assessment Programme (organized by the Department of Forest, Government of West Bengal), using pre-set representative trail transects in representative elevations (Table 1). In each camp sites, four to five surrounding areas were surveyed from 0800 to 1500 h (7 hours). The flies in the different habitats were observed and collected by the first author, which were then classified (Table 2). During the field survey, insect collecting hand nets and one malaise trap were used to collect true flies. Average hand net collection time was 3–4 hours and malaise trap was used accordingly to the suitability of the terrains. Insect hand net specimens were paralyzed by benzene vapour in a killing jar and stored in an envelope for future use. Specimens were also pinned (No. 2) in the field and stored in an insect box. Specimens collected by malaise trap were sorted by sub-family and stored in 70% alcohol.

Identification of species

In the laboratory, collected insects were placed in a wet chamber overnight before being pinned by inserting an insect-pin slightly laterally through the pro-thoracic segment. Pinned specimens were labeled with the location of collection, date, altitude, and substances on which the flies were found. The flies were taxonomically identified using chaetotaxy key (Senior-White et al. 1940; Emden 1965; Shinonaga & Kano 1971; Crosskey 1976; Nandi 2002; Scudder & Cannings 2006; Buck et al. 2009; Joseph & Parui 2012) under a stereoscopic binocular microscope, and genitalia of male individuals were dissected in some cases for confirmation of identification. The specimens of *Culicoides* were separated and stored in different microcentrifuge tubes (1.5 ml) containing 70% ethyl alcohol. After mounting the adults on a slide using the phenol-balsam technique mentioned by Wirth & Marston (1968), the midges were identified using the identification keys used by Wirth & Hubert (1989) under a compound microscope. Following the identification keys used by Borror & Delong (1970), specimens were identified up to the suborder level, Nematoceran flies were identified up to the family level, and rest of the flies were identified up to the order level.

Analysis

A map of the study area indicating all sampling sites was prepared using QGIS software (version 3.16.11). The normalized difference vegetation index (NDVI) was calculated using a December 2019 (Landsat 8) satellite image. This month was chosen for its peak forest vegetation as it is just post-monsoon and to minimize the effect of atmospheric load on remote sensing data due to lower moisture content in the air. The remote sensing data (Landsat 8 image) was obtained from USGS Earth Explorer (https://earthexplorer.usgs.gov/). In ENVI software, the captured image was radiometrically corrected and normalized. The NDVI was employed to determine vegetation on the ground. It is used to

Table 1. Detail of the sampling sites in Neora Valley National Park, India.

Site no.	Site names	Latitude	Longitude	Elevation (m)	Forest Types
S1	Ashalay	27.013	88.769	686	Lower Hill Forest
S2	Ambeok Basti	27.025	88.713	952	Middle Hill Forest
S3	Mouchuki	27.027	88.786	1170	Middle Hill Forest
S4	Gogune	27.049	88.826	1525	Middle Hill Forest
S5	Tempola	27.077	88.779	1757	Broad-leaved Forest
S6	Kolbung	27.095	88.681	1810	Broad-leaved Forest
S7	Thosum Khola	27.074	88.791	1861	Broad-leaved Forest
S8	Thamkharka	27.098	88.691	1952	Broad-leaved Forest
S9	Thosum Peak	27.078	88.771	2043	Broad-leaved Forest
S10	Dolay	27.072	88.706	2050	Broad-leaved Forest
S11	PHE Camp	27.097	88.725	2158	Oak Forest
S12	Jaributi	27.104	88.721	2196	Oak Forest
S13	Choudaferi	27.093	88.702	2356	Oak & Rhododendron Forest
S14	Alubari	27.128	88.720	2540	Rhododendron Forest

Table 2. Types of Habitats found in the study sites.

No.	Habitat type	Codes
1	Animal, human dung, decaying fruits	AD
2	Bushes	B
3	Flowering plant	F
4	Human settlement	HS
5	Moist surface	MS
6	Near stream	NS
7	Open spaces/ Rock surface	OS
8	Shade area	S

monitor and detect changes in vegetation and land cover. The image was classified based on the NDVI value.

The indices like α-diversity index, Simpson's index and Shannon-Weiner Index were measured to understand the species richness and species evenness of flies in the study area (Krebs 1999). The correlation between the diversity indices like Shannon-Weiner Index and Simpson's Index with the elevation of all sites were done. Pearson's correlation coefficients were estimated between altitude for all the study sites and the occurrence of fly species (Bhardwaj et al. 2012). IBM SPSS Statistics 20, PAST Version 4 software and Microsoft Excel were used for analyzing the data and preparing different diagrams. A QQ-plot was done to understand the distribution pattern of all species in 14 sites. This has been done using elevation and Simpson's Index.

RESULTS

Collection and identification of 201 species belonging to 105 genera and 33 families were enumerated (Table 3). Members of the Muscidae dominated the area with 66 species followed by Syrphidae (33), Calliphoridae (17), and Tachinidae (12). A total of 25 species are reported as new records to West Bengal and seven being new to India (Table 3). Within the newly reported species in West Bengal, 13 belonged to Muscidae.

When the total number of native species (201 species) was taken into account, the accumulation curve tended to stabilize after 12 sampling efforts (Figure 2). Spatial patterns of species distribution over various habitats were observed (Figure 3). It was found that the

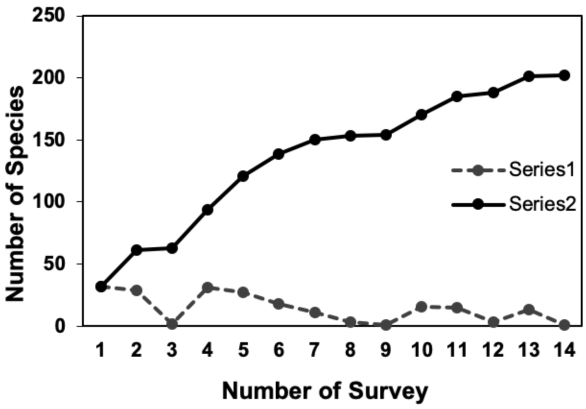

Figure 2. Temporal variation in the frequency of Diptera species in all sites: Series 1— Number of new species found in each survey | Series 2—Total number of species.

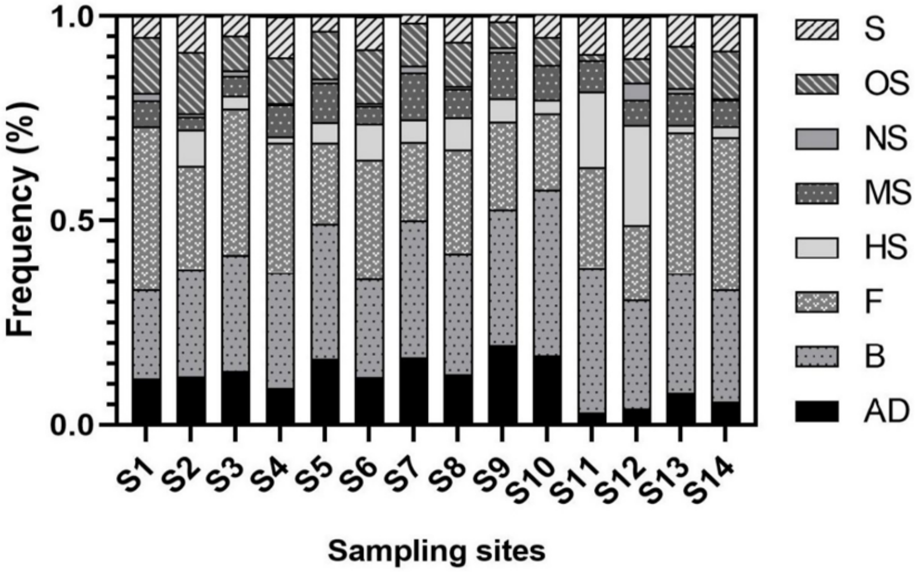

Figure 3. Distribution of species of flies in different habitats of all sampling sites: S—Shade area | OS—Open spaces/ Rock surface | NS—Near stream | MS—Moist surface | HS—Human settlements | F—Flowering plants | B—Bushes | AD—Animal, human dung, decaying fruits.

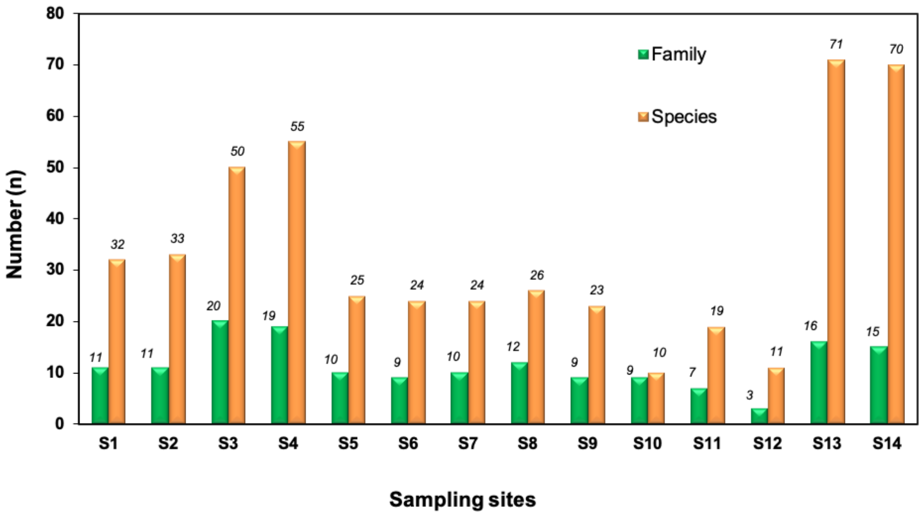

Figure 4. Distribution of the species and families across all 14 sites.

most of the flies preferred flowering plants (32.77%), followed by non-flowering plants (27.14%) throughout the region, and the least number of flies (1.41%) were found in areas near streams.

In general, comparison of distribution of species and families across all 14 sites revealed that Chaudaferi (S13) and Alubari (S14) were high in diversity with respect to families, in the higher elevation (Figure 4). On the other hand, Mouchuki has the highest number of families, having moderate number of species.

A graphical representation is made with respect to centroid position of both the variables (indices and elevation) in Figure 5. The centroid is the intersection point of means of both Simpson's index and elevation. It is the same in case of Shannon-Weiner index and elevation. It shows that, the Simpson's indices of most of the sites are near the centroid, indicating it is in a normal distribution. Here, maximum number of flies are found within the range of 1,500–2,500 m. Likewise, the Shannon-Weiner indices of most of the sites are very near to the centroid and similarly, the maximum number of flies are found within the range of 1,500–2,500 m. So, Pearson's correlation test (Figure 6) between Simpson's Index and elevation was performed which reveals

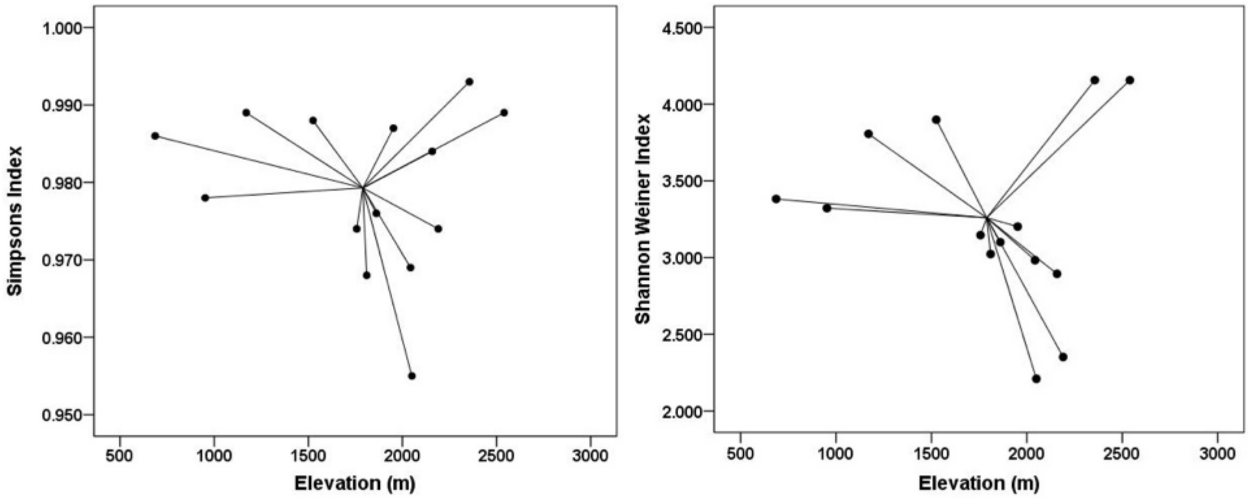

Figure 5. Scatter-plots showing the Simpson's Index and Shannon-Weiner Index of all flies on basis of elevation where most of the flies were observed in elevation ranging from 1,500–2,500 m.

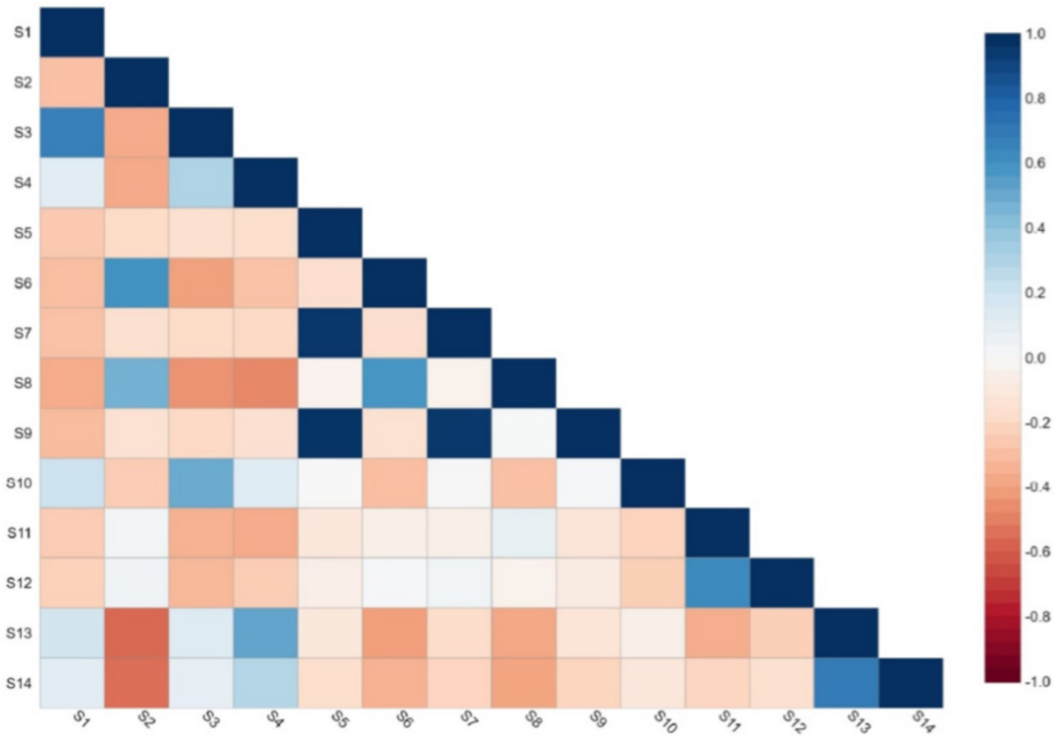

Figure 6. Correlation matrix displaying Pearson correlation analysis results. Data from the presence of fly species in 14 sampling sites were used in the analysis. Pearson correlation coefficient values and directions are color-coded: positive correlation—blue, light to dark | negative correlation—red, light to dark (see color-bar next to the matrix).

that, there is a negative correlation between them (r = -0.108). On the other hand, a correlation test between Shannon-Weiner Index and elevation reveals that there is a positive correlation but very less association between them (r = 0.092). Another correlation was done among the 14 sampling sites to find out what kind of association prevails on basis of abundance of flies. A QQ-plot showed that the observed values (estimated quantiles) were normalized (Figure 7). A rarefaction curve was generated on the basis of all 14 sites, which showed the abundance and species richness at high altitude sampling sites (Figure 8).

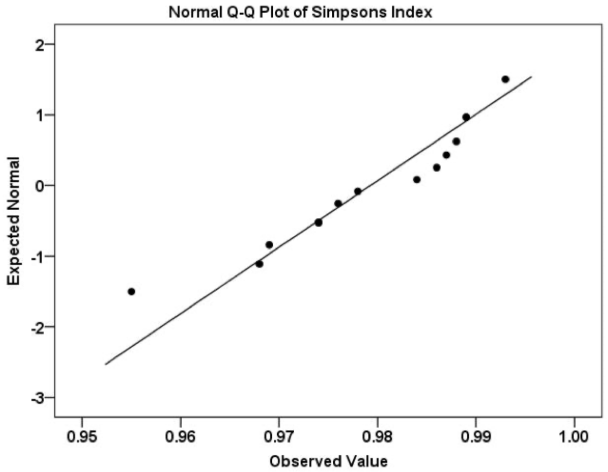

Figure 7. QQ-plot showing the distribution pattern of all Diptera species across 14 sites.

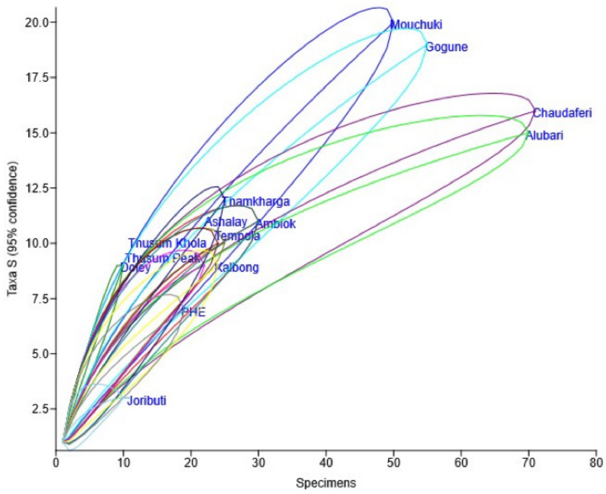

Figure 8. Rarefaction curve (taxa vs. abundance) based on 14 sites.

DISCUSSION

This is the first elaborate survey of dipteran fauna from the Neora Valley National Park along the elevation gradient. A total of 201 flies from 105 genera and 33 families were documented. Recently, Sinha et al. (2021) reported 31 species of family Muscidae from Neora Valley, including two species, *Limnophora* (*Heliographa*) *ceylanica* and *Neomyia pacifica* recorded for the first time in India. A new species, *Heligmonevra paruii* (family Asilidae) was described and illustrated from Neora Valley by Naskar et al. (2019), but it was not recorded in the present investigation.

Diptera are the primary potential pollinators at high altitudes and latitudes where bees are scarce. In the eastern Himalaya, the diversity of Syrphidae reflected the supremacy of these flies over other pollinator insects such as honeybees at the higher altitudes (Sinha et al. 2022). Studies found a similar pattern in the tropical region, such as Doi Inthanon mountain in northern Thailand (Plant et al. 2012; Chatelain et al. 2018). Even as we move farther north, the proportion of dipteran species in the total pollinator fauna grows with latitude, and they are the most common families of flower-visiting insects in the arctic (Elberling & Olesen 1999; Tiusanen et al. 2016; Lefebvre et al. 2018). In the light of this, we assessed the species richness and distribution pattern of Diptera at various elevations in the eastern Himalaya, with the highest number of flies found between 1,500 and 2,500 m. This is most likely because there are large amount flowering plants. On the contrary, in the lower elevation (1,500 m), there is dense forest with fewer fly species. Less fly species live in higher elevation areas comprising Maling bamboo forests. Furthermore, it becomes windy higher up (>2,500 m), and that area is covered with Rhododendron and wild rose plants, which reduces fly activity.

Muscidae (32.83%) and Syrphidae (16.41%) were the most abundant families at all of our sample sites. This could be due to their ability to survive in environments ranging from extremely low to extremely high elevation. Members of these families can also be found at all of the sites in a habitat that is relatively bushy and densely populated with flowering plants. Muscidae is the most common family of flower-visiting insects in the Arctic region, and they are much more abundant and widespread than the insects of other dipteran families which like to visit flowers (Elberling & Olesen 1999).

Pollinator communities are changing dramatically as a result of climate change (González-Varo et al. 2013; Rafferty 2017). However, there are large gaps in our understanding of the role of Diptera in pollination networks in the Himalaya in relation to climate change. Although our findings suggest that more sampling is required to obtain a complete picture of the study area, plant-Diptera interactions also need to be examined.

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Table 3. Detail of recorded Diptera species in Neora Valley National Park, India.

No.	Family	Subfamily	Species	Records*	Sources
1	Anthomyiidae	Anthomyiinae	*Anthomyia* sp.1		
2	Anthomyiidae	Anthomyiinae	*Anthomyia* sp.2		
3	Anthomyiidae	Anthomyiinae	*Delia platura*		
4	Anthomyiidae	Anthomyiinae	*Paregle densibarbata*		
5	Anthomyiidae	Pegomyinae	*Pegomya* sp.	WB	Suwa 1981
6	Asilidae	Laphriinae	*Maira longirostrata*		
7	Asilidae	Laphriinae	*Maira* sp.		
8	Asilidae	Laphriinae	*Nusa bengalensis*		
9	Asilidae	Laphriinae	*Nusa* sp.		
10	Asilidae	Stenopogoninae	*Microstylum* sp.		
11	Bibionidae	Pleciinae	*Penthetria japonica*		
12	Bibionidae	Pleciinae	*Plecia assamensis*	WB	Mukhopadhyay et al. 2015
13	Blephariceridae	Blepharicerinae	*Blepharocera* sp.		
14	Bombyliidae	Anthracinae	*Anthrax* sp.		
15	Bombyliidae	Anthracinae	*Villa* sp.		
16	Calliphoridae	Ameniinae	*Silbomyia asiatica*		
17	Calliphoridae	Calliphorinae	*Aldrichina grahami*		
18	Calliphoridae	Calliphorinae	*Calliphora* sp.		
19	Calliphoridae	Calliphorinae	*Calliphora pattoni*		
20	Calliphoridae	Calliphorinae	*Calliphora vicina*		
21	Calliphoridae	Calliphorinae	*Calliphora vomitoria*		
22	Calliphoridae	Chrysomyiinae	*Chrysomya pinguis*		
23	Calliphoridae	Luciliinae	*Lucilia illustris*		
24	Calliphoridae	Melanomyinae	*Melinda scutellata*		
25	Calliphoridae	Polleniini	*Dexopollenia* sp.		
26	Calliphoridae	Polleniini	*Polleniopsis pilosa*		
27	Calliphoridae	Rhiniinae	*Idiella mandarina*		
28	Calliphoridae	Rhiniinae	*Isomyia* sp.		
29	Calliphoridae	Rhiniinae	*Rhinia apicalis*		
30	Calliphoridae	Rhiniinae	*Stomorhina sp.*		
31	Calliphoridae	Rhiniinae	*Strongyloneura* sp.1	WB	Senior White et al. 1940
32	Calliphoridae	Rhiniinae	*Strongyloneura* sp.2		
33	Cecidomyiidae	Lestremiinae	*Allarete spatuliformis*		
34	Cecidomyiidae	Porricondylinae	*Camptomyia* sp.1	WB	Ahad Najam et al. 2009; Gagne & Jaschhof 2021
35	Ceratopogonidae	Ceratopogoninae	*Culicoides* sp. 1		
36	Ceratopogonidae	Ceratopogoninae	*Culicoides pararegalis*		
37	Ceratopogonidae	Ceratopogoninae	*Culicoides pseudoregalis*		
38	Ceratopogonidae	Ceratopogoninae	*Culicoides regalis*		
39	Ceratopogonidae	Ceratopogoninae	*Culicoides subregalis*		
40	Ceratopogonidae	Ceratopogoninae	*Culicoides* sp.2		
41	Chironomidae	Unidentified	Unknown		
42	Culicidae	Culicinae	*Culex* sp.1		
43	Culicidae	Culicinae	*Culex* sp.2		
44	Diopsidae	Unidentified	Unknown		

No.	Family	Subfamily	Species	Records*	Sources
45	Dolichopodidae	Diaphorinae	*Chrysotus* sp.		
46	Dolichopodidae	Diaphorinae	*Diaphorus* sp.		
47	Dolichopodidae	Dolichopodinae	*Dolichopus* sp.1		
48	Dolichopodidae	Dolichopodinae	*Dolichopus* sp.2		
49	Drosophilidae	Drosophilinae	*Drosophila* sp.		
50	Drosophilidae	Unidentified	Unknown		
51	Hybotidae	Hybotinae	*Hybos culiciformis*	IND	Shamshev et al. 2015; Zouhair & Kettani 2022
52	Lauxaniidae	Homoneurinae	*Homoneura* sp.1	IND	Miller 1976; Sasakawa 1992; Shatalkin 1996; Gao & Yang 2004; Lee & Han 2015
53	Lauxaniidae	Homoneurinae	*Homoneura* sp. 2		
54	Lonchopteridae	Unidentified	Unknown		
55	Muscidae	Atherigoninae	*Atherigona orientalis*		
56	Muscidae	Atherigoninae	*Atherigona* sp.		
57	Muscidae	Coenosiinae	*Coenosia plumiseta*	WB	Bharti 2008
58	Muscidae	Coenosiinae	*Coenosia* sp.1	WB	Rahman et al. 2017
59	Muscidae	Coenosiinae	*Coenosia* sp.2		
60	Muscidae	Coenosiinae	*Coenosia* sp.3		
61	Muscidae	Coenosiinae	*Limnophora latiseta*		
62	Muscidae	Coenosiinae	*Limnophora brunnescens*		
63	Muscidae	Lispinae	*Lispe bengalensis*		
64	Muscidae	Lispinae	*Lispe sericipalpis*		
65	Muscidae	Lispinae	*Lispe orientalis*		
66	Muscidae	Lispinae	*Lispe* sp.1		
67	Muscidae	Lispinae	*Lispe* sp.2		
68	Muscidae	Phaoniinae	*Dichaetomyia nubiana*		
69	Muscidae	Phaoniinae	*Dichaetomyia* sp.1		
70	Muscidae	Muscinae	*Morellia nigrisquama*	WB	Emden 1965; Mitra 2011; Sinha et al. 2021
71	Muscidae	Muscinae	*Morellia pectinipes*	WB	Emden 1965; Mitra 2011; Sinha et al. 2021
72	Muscidae	Muscinae	*Morellia* sp.1		
73	Muscidae	Muscinae	*Morellia* sp.2		
74	Muscidae	Muscinae	*Musca convexifrons*	WB	Mitra 2006
75	Muscidae	Muscinae	*Musca domestica*		
76	Muscidae	Muscinae	*Musca hervei*		
77	Muscidae	Muscinae	*Musca tempestiva*	WB	Emden 1965; Shina et al. 2021
78	Muscidae	Muscinae	*Musca* sp.1		
79	Muscidae	Muscinae	*Musca* sp.2		
80	Muscidae	Muscinae	*Neomyia gavisa*		
81	Muscidae	Muscinae	*Neomyia coerulea*		
82	Muscidae	Muscinae	*Neomyia claripennis*		
83	Muscidae	Muscinae	*Neomyia fletcheri*		
84	Muscidae	Phaoniinae	*Phaonia kambaitiana*	WB	Emden 1965; Mitra 2011; Sinha et al. 2021
85	Muscidae	Muscinae	*Pyrellia cadaverina*	WB	Emden 1965
86	Muscidae	Muscinae	*Rypellia flavipes*	WB	Emden 1965; Sinha et al. 2021
87	Muscidae	Muscinae	*Rypellia malaisei*	WB	Shina et al. 2021
88	Muscidae	Mydaeinae	*Brontaea ascendens*		
89	Muscidae	Mydaeinae	*Brontaea distincta*		

No.	Family	Subfamily	Species	Records*	Sources
90	Muscidae	Mydaeinae	*Brontaea lasiopa*		
91	Muscidae	Mydaeinae	*Graphomya maculata*	WB	Emden 1965; Mitra 2011; Sinha et al. 2021
92	Muscidae	Mydaeinae	*Graphomya rufitibia*		
93	Muscidae	Mydaeinae	*Hebecnema* sp.		
94	Muscidae	Mydaeinae	*Myospila bina bina*		
95	Muscidae	Mydaeinae	*Myospila tenax*		
96	Muscidae	Mydaeinae	*Myospila* sp.1		
97	Muscidae	Mydaeinae	*Brontaea* sp.1		
98	Muscidae	Mydaeinae	*Brontaea* sp.2		
99	Muscidae	Phaoniinae	*Dichaetomyia quadrata*		
100	Muscidae	Phaoniinae	*Dichaetomyia* sp.2		
101	Muscidae	Phaoniinae	*Helina appendiculata*		
102	Muscidae	Phaoniinae	*Helina iwasai*	IND	Shinonaga & Singh 1994; Sinha et al. 2021
103	Muscidae	Mydaeinae	*Myospila lenticeps*		
104	Muscidae	Phaoniinae	*Helina* sp.1		
105	Muscidae	Phaoniinae	*Helina* sp.2		
106	Muscidae	Phaoniinae	*Hydrotaea unispinosa*		
107	Muscidae	Phaoniinae	*Hydrotaea sp.*		
108	Muscidae	Coenosiinae	*Limnophora tonsa*		
109	Muscidae	Coenosiinae	*Limnophora* sp.1		
110	Muscidae	Coenosiinae	*Limnophora* sp.2		
111	Muscidae	Coenosiinae	*Limnophora* sp.3		
112	Muscidae	Mydaeinae	*Mydaea longiscutellata*		
113	Muscidae	Mydaeinae	*Myosplia meditabunda meditabunda*	WB	Jana et al. 2023
114	Muscidae	Mydaeinae	*Mydaea* sp.		
115	Muscidae	Phaoniinae	*Phaonia* sp.1		
116	Muscidae	Phaoniinae	*Phaonia* sp.2		
117	Muscidae	Phaoniinae	*Phaonia* sp.3		
118	Muscidae	Phaoniinae	*Phaonia* sp.4		
119	Muscidae	Phaoniinae	*Spilogona* sp.	WB	Emden 1965
120	Muscidae	Stomoxydinae	*Stomoxys calcitrans*		
121	Mycetophilidae	Mycetophilinae	*Rhymosia* sp.	WB	Banerjee et al. 2018
122	Phoridae	Metopinini	*Megaselia pallicornis*		
123	Phoridae	Phorinae	*Dohrniphora aequididtans*		
124	Pipunculidae	Unidentified	Unknown		
125	Psychodidae	Psychodinae	*Clogmia albipunctata*		
126	Psychodidae	Psychodinae	*Psychoda* sp.		
127	Psychodidae	Psychodinae	*Telmatoscopus lacteitarsis*		
128	Ptychopteridae	Ptychopterinae	*Ptychoptera* sp.		
129	Sarcophagidae	Sarcophaginae	*Bercaea cruentata*		
130	Sarcophagidae	Sarcophaginae	*Boettcherisca nepalensis*	WB	Sinha 2014
131	Sarcophagidae	Sarcophaginae	*Ravinia pernix*		
132	Sarcophagidae	Sarcophaginae	*Robineauella (Jantiella) kanoi*		
133	Sarcophagidae	Sarcophaginae	*Sarcophaga albiceps*		

No.	Family	Subfamily	Species	Records*	Sources
134	Sarcophagidae	Sarcophaginae	*Sarcophaga coei*		
135	Sarcophagidae	Sarcophaginae	*Sarcophaga* sp.1		
136	Sarcophagidae	Sarcophaginae	*Sarcophaga* sp.2		
137	Sarcophagidae	Sarcophaginae	*Sinonipponia baruai*	IND	Pape 1996; Nandi 2002
138	Scathophagidae	Scathophaginae	*Scathophaga* sp.		
139	Sepsidae	Nemopodatinae	*Nemopoda pectinulata*		
140	Sepsidae	Sepsinae	*Sepsis* sp.		
141	Stratiomyidae	Unidentified	Unknown		
142	Syrphidae	Eristalinae	*Cheilosia* sp.		
143	Syrphidae	Eristalinae	*Chrysogaster* sp.	IND	Dousti & Hayat 2006; Khaghaninia et al. 2012; Dousti 2023
144	Syrphidae	Eristalinae	*Eristalinus taeniops*		
145	Syrphidae	Eristalinae	*Eristalinus* sp.		
146	Syrphidae	Eristalinae	*Eristalis himalayensis*		
147	Syrphidae	Eristalinae	*Eristalis tenax*		
148	Syrphidae	Eristalinae	*Eristalis tristriatus*		
149	Syrphidae	Eristalinae	*Eristalis* sp.		
150	Syrphidae	Eristalinae	*Rhingia binotata*		
151	Syrphidae	Eristalinae	*Rhingia* sp.		
152	Syrphidae	Eristalinae	*Sphegina* sp.		
153	Syrphidae	Syrphinae	*Asarkina africana*	IND	Whittington 1998; Ssymank 2012; Smit et al. 2017; El-Hawagry & Gilbert 2019
154	Syrphidae	Syrphinae	*Asarkina* sp.1		
155	Syrphidae	Syrphinae	*Asarkina* sp.2		
156	Syrphidae	Syrphinae	*Baccha maculata*		
157	Syrphidae	Syrphinae	*Betasyrphus* sp.		
158	Syrphidae	Syrphinae	*Chrysotoxum* sp.		
159	Syrphidae	Syrphinae	*Citrogramma citrinum*		
160	Syrphidae	Syrphinae	*Episyrphus balteatus*		
161	Syrphidae	Syrphinae	*Episyrphus* sp.1		
162	Syrphidae	Syrphinae	*Episyrphus* sp.2		
163	Syrphidae	Syrphinae	*Episyrphus* sp.3		
164	Syrphidae	Syrphinae	*Episyrphus* sp.4		
165	Syrphidae	Syrphinae	*Eupeodes* sp.		
166	Syrphidae	Syrphinae	*Lycastris* sp.1		
167	Syrphidae	Syrphinae	*Lycastris* sp.2		
168	Syrphidae	Syrphinae	*Melanostoma* sp.		
169	Syrphidae	Syrphinae	*Paragus haemorrhous*	IND	Haarto 2014; Turk et al. 2014
170	Syrphidae	Syrphinae	*Paragus* sp.1		
171	Syrphidae	Syrphinae	*Paragus* sp.2		
172	Syrphidae	Syrphinae	*Spherosphoria scripta*	WB	Mitra et al. 2015; Sengupta et al. 2016
173	Syrphidae	Syrphinae	*Syrphus dalhousiae*	WB	Mitra et al. 2015; Sengupta et al. 2016
174	Syrphidae	Syrphinae	*Syrphus torvus*		
175	Tabanidae	Pangoniinae	*Philoliche longirostris*		
176	Tachinidae	Dexiinae	*Prosena* sp.		
177	Tachinidae	Dexiinae	*Thelaira solivaga*	WB	Sathe et al. 2014

No.	Family	Subfamily	Species	Records*	Sources
178	Tachinidae	Dexiinae	*Zelia* sp.		
179	Tachinidae	Tachininae	*Linnaemya* sp.		
180	Tachinidae	Tachininae	*Tothillia asiatica*	WB	O'Hara et al. 2020
181	Tachinidae	Tachininae	*Tachina* sp.1	WB	O'Hara et al. 2020
182	Tachinidae	Tachininae	*Tachina* sp.2		
183	Tachinidae	Tachininae	*Tachina* sp.3		
184	Tachinidae	Tachininae	*Tachina* sp.4		
185	Tachinidae	Tachininae	*Tachina* sp.5		
186	Tachinidae	Tachininae	*Tachina* sp.6		
187	Tachinidae	Tachininae	*Tachina* sp.7		
188	Tephritidae	Unidentified	Unknown		
189	Tipulidae	Chioneinae	*Atarba* sp.		
190	Tipulidae	Dolichopezinae	*Dolichopeza* sp.		
191	Tipulidae	Limoniinae	*Atypophthalmus* sp.		
192	Tipulidae	Limoniinae	*Geranomyia* sp.1		
193	Tipulidae	Limoniinae	*Geranomyia* sp.2		
194	Tipulidae	Limoniinae	*Toxorhina* sp.		
195	Tipulidae	Tipulinae	*Holorusia* sp.		
196	Tipulidae	Tipulinae	*Indotipula* sp.1		
197	Tipulidae	Tipulinae	*Indotipula* sp.2		
198	Trichoceridae	Trichocerinae	*Trichocera* sp.	WB	Alexander 1961
199	Ulidiidae	Otitinae	*Pseudotephritis* sp.1		
200	Ulidiidae	Otitinae	*Pseudotephritis* sp.2		
201	Ulidiidae	Otitinae	*Pseudotephritis* sp.3		

*First time recorded from the state of West Bengal (WB), or India (IND)

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Articles

Communications

Short Communications

Notes

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