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DROSOPHILID DIVERSITY (DIPTERA: DROSOPHILIDAE) FROM SHIMLA DISTRICT, HIMACHAL PRADESH

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ABSTRACT

The present study is the first to explore the diversity of drosophilids from Shimla district of Himachal Pradesh. A total 47 species under eleven genera viz., *Drosophila*, *Hirtodrosophila, Stegana*, *Lordiphosa*, *Leucophenga*, *Mycodrosophila*, *Scaptomyza*, *Scaptodrosophila*, *Impatiophila, Zaprionus*, and *Hypselothyrea* were collected. Abundance and species diversity were computed using Simpson (D), Shannon-Wiener (H) and Berger-Parker (1/d) indices. Simpson index was low at 0.029, Shannon-Wiener index was high at 3.669 and Berger-Parker index was also high at 0.613. Study reveals significant drosophilid diversity and favourable conditions for sustenance of several species.

Key words: Drosophilids, Shimla, diversity, species, genera, Berger-Parker index, Shannon-Wiener index, Simpson index

The Drosophilidae is a large family of order Diptera, class Insecta of worldwide distribution. *Drosophila* is one of its genera, characterized by rich species diversity. The family Drosophilidae is comparatively large and contains 6893 species classified under 76 genera and two subfamilies Steganinae and Drosophilinae (Bachli, 2018). In India, more than 350 species of the genus *Drosophila* are known (Gupta, 2005; Sati et al., 2013), but taxonomic studies on this genus are meagre.There had been attempts to collect *Drosophila* from different parts of India (Guruprasad et al., 2011), and presently it is being carried out only in Uttarakhand by B K Singh, R S Fartyal and their coworkers (Sati et al., 2013; Pradhan et al., 2014; Fartyal et al., 2017). The diversity of the habits and habitats of the members of the family Drosophilidae are varied; and different radiations use different hosts for feeding and breeding ((Kimura et al., 1977; Gupta and Gupta 1991; Fartyal, 2000; Fu et al., 2016). So far none has explored the diversity of drosophilids from Himachal Pradesh, and this paper describes the assemblage of drosophilid fauna from Shimla district.

MATERIALS AND METHODS

The study was done from 2014 to 2018, with material collected from Racholi, Gaura forest, Halog forest, Sarahan forest and Oddi-Narkanda forest from Shimla District (31°14′-31°30′ N and 77°29′-77°47′ E), situated between 1150- 3200 masl. These areas are characterized by evergreen forests of *Quercus acutissima*, *Q. floribunda, Q. semecarpifolia, Cedrus deodara, Pinus roxburghi*, and mixed forests. Some collections were made from plum (*Prunus* spp.) orchards.

Collection was made using various methods, mainly net sweeping and with aspirator; and mainly from flowers and mushrooms. The collected specimens were preserved in 70% ethanol, and external morphology of adults examined under a stereozoom microscope (Magnus MS24 model) with measurements made using an ocular micrometer. For male and female terminalia, respective organs were dissected from the adult body or whole body was cleared by warming in 10% KOH around 100°C for several minutes and then observed in a droplet of glycerol under a light compound microscope (Magnus MLX-DX model, 10x magnification).The morphological terminology and the definitions of measurements and indices mostly follow McAlpine (1981), Zhang and Toda (1992), and Hu and Toda (2001). Collected flies were identified using published monographs and guide to species identification (Gupta, 2005; Markow and O'Grady, 2006) and online

identification tools like BioCIS (2004), JDD (2014) and FlyBase (2018).

To validate the species occurrence qualitatively, the Occurrence Constancy Method (Dajoz, 1983) was used. The constancy value (*c*) was obtained by dividing the number of collections in which one species occurred by the total number of collections made, and then multiplying the result by 100. Species with index $c \geq 50$ were considered constants. Accessory species were those with $25 \leq c < 50$. Accidental species had $c < 25$. Species that occurred in only one area were considered exclusive. The abundance, richness and diversity relationship were assessed by Simpson (D), Shannon-Wiener (H), and Berger- Parker (1/d) indices (Mateus et al., 2006).

The Simpson index (D) that measures the probability of two individuals that are randomly selected from a sample that belong to the same species, was calculated using the formula: $D=\Sigma n (n-1)/N (N-1)$, where, n = the total number of organisms of a particular species and N = the total number of organisms of all populations. Shannon-Wiener index measures the value of species as a function of their frequency in the community and was calculated using the formula: $H' = -\Sigma \ln pi$, where pi is the proportion of individuals found in species i. Berger-Parker index (1/d) which shows the relative abundance was calculated using the formula: $1/d=N/NMax$, where, N = Number of individuals of all species and Nmax = Number of individuals in the most common species. Diversity indices were carried out using Pastsoftware version 2.10.

RESULTS AND DISCUSSION

Altogether 47 species under 11 genera of the family Drosophilidae were collected (Table 1). Genus *Drosophila* was the predominant one with 24 species, in which 13 species are of the subgenus *Sophophora*, one species of subgenus *Dorsilopha* and 10 species of subgenus *Drosophila*. Genus *Hirtodrosophila* was represented by five species followed by genus *Leucophenga* with four species. Genus *Lordiphosa* was represented by four species followed by genus *Mycodrosophila* with three species, in which two species could not be identified. Genus *Impatiophila* was represented by two species. Genus *Hypselothyrea*, *Scaptomyza, Stegana, Scaptodrosophila*, and *Zaprionus* were represented by one species each. Approximately 62% of the total collected species were constant. Thirteen accessory (~28%) and five accidental species (~10%) were found.

Comparison of species based on their relative abundance and rank is presented in Fig.1. *Drosophila nepalensis* was ranked first with 326 individuals (61%) followed by *D. melanogaster* with 247 individuals (46%). *D. suzukii indicus* was ranked third with 228 individuals (42%) followed by *D. punjabiensis* with 221 individuals (39%). *Lordiphosa parantillaria* was least abundant with only 23 individuals (0.43%). Constancy value (c) of species with absolute (A) and relative (r) abundance are presented in Table 1. Flies collected from the different sampling sites showed a Simpson index of 0.029, Shannon-Wiener index of 3.669 and Berger-Parker index of 0.613.

Drosophila immigrans, D. bizonata, *D. parazonata*, *D.trizonata*, *D. novazonata, D. bipectinata* and *D. neokuntzei* were collected from the entire sampling sites. Thus can be considered abundant. Whereas *Lordiphosa ayarpathaensis* and *Hypselothyrea fascipennis* were collected only from a single sampling site. Remaining species were collected from two and > two sampling sites. Species of *Hypselothyrea, Lordiphosa, Impatiophila*, *Scaptomyza,* and *Stegana* were only collected from flowers. *Mycodrosophila* species were collected from fungus. Species of genus *Scaptodrosophila* were collected only from mushroom. Whereas, species of genus *Zaprionus*, *Hirtodrosophila*, *Leucophenga* and *Drosophila* were collected from different plants (Table 2).

It is evident that diversity of drosophilid species in the present explored sites was high because of moist environment and rich vegetation, which includes many flowering plants. Maximum individuals and species were collected during monsoon season. For building larger communities of *Drosophila*, monsoon is a suitable season (Guruprasad et al., 2011). Lower Simpson index values indicate higher diversity, whereas value of 1 indicates no diversity. Reverse is true for Shannon-Wiener and Berger- Parker index (Ludwig and Reynold, 1988; Mateus et al., 2006). In the present study, higher values of Shannon- Wiener and Berger- Parker indices i.e. 3.669 and 0.613, respectively and lower value of Simpson index i.e. 0.029 indicate high diversity in the sites studied. Oddi- Narkanda forest was most diverse than remaining study sites, because of moist conditions. India possesses fairly rich species diversity in the genus *Drosophila* comprising many species radiations (Gupta, 2005; Sati et al., 2013; Pradhan et al., 2014; Fartyal et al., 2017). Diversity of ecological conditions in the Indian subcontinent is an important aspect of biodiversity in this region. This study suggests that

Table 1. Drosophilid species - Shimla district of Himachal Pradesh

S.No.	Species	Σ ♂	Σ ♀	A	r	C
Genus-*Drosophila*						
Subgenus- *Sophophora* Sturtevant						
1.	*Drosophila melanogaster* Meigen	102	145	247	0.046	100
2.	*D. nepalensis* Okada	142	184	326	0.061	100
3.	*D. kikkawai* Burla	52	89	141	0.026	100
4.	*D. jambulina* Prasad & Paika	58	69	127	0.023	100
5.	*D. suzukii indicus* Prasad & Paika	127	101	228	0.042	100
6.	*D. takahashii* Sturtevant	46	95	141	0.026	100
7.	*D. punjabiensis* Prasad & Paika	98	113	211	0.039	100
8.	*D. trapezifrons* Okada	54	24	78	0.014	50
9.	*D. malerkotliana* Parshad & Paika	37	65	102	0.019	100
10.	*D. bifasciata* Pomini	42	70	112	0.020	62.5
11.	*D.elegans* Bock & Wheeler	22	35	57	0.010	68.1
12.	*D. bipectinata* Duda	31	49	80	0.014	45.4
13.	*D. helvetica* Burla	15	08	23	0.004	22.7
Subgenus- *Drosophila* Fallén						
14.	*D. immigrans* Sturtevant	88	112	200	0.037	100
15.	*D. replete* Wollaston	94	110	204	0.038	100
16.	*D. trizonata* Okada	80	81	161	0.030	100
17.	*D. bizonata* Kikkawa & Pang	70	117	187	0.034	100
18.	*D. parazonata* Gupta & Dwivedi	59	93	152	0.028	100
19.	*D. novazonata* Gupta & Dwivedi	68	75	143	0.026	100
20.	*D. neokuntzei* Singh & Gupta	49	57	106	0.019	100
21.	*D. hubiensis* Sperlich & Watson	15	30	45	0.008	18.7
22.	*D. mukteshwarensis* Joshi, Fartyal & Singh	10	14	24	0.004	27.7
23.	*D. lacertosa* Okada	35	55	90	0.016	100
Subgenus- *Dorsilopha* Sturtevant						
24	*Drosophila busckii* Coquillett	79	82	161	0.030	81.8
Genus *Hirtodrosophila* Duda						
25.	*Hirtodrosophila sexvittata* Okada	78	89	167	0.031	75
26.	*H. longivittata* Hedge et al.	57	73	130	0.024	62.5
27.	*H. quadrivittata* Okada	45	68	113	0.021	87.5
28.	*H. fascipennis* Okada	14	19	33	0.006	31.2
29.	*H. hexaspina* Fartyal & Singh	25	29	54	0.010	36.6
Genus *Hypselothyrea* de Maijere						
30.	*Hypselothyrea fascipennis*de Meijere	19	05	24	0.004	12.5
Genus *Scaptomyza* Hardy						
31.	*Scaptomyza himalayana* Takada	60	99	159	0.029	81.2
Genus *Lordiphosa* Basden						
32.	*Lordiphosa ayarpathaensis* Kandpal & Singh	36	22	58	0.010	6.25
33.	*L. coei* Okada	18	29	47	0.008	45.4
34.	*L. parantillaria* Kumar & Gupta	08	15	23	0.004	43.7
35.	*L. srinagarensis* Sati & Fartyal	48	65	113	0.021	31.2
Genus *Leucophenga* Mik						
36.	*Leucophenga bellula* Bergroth	18	37	55	0.010	50
37.	*L. albiceps*de Meijere	17	25	42	0.007	62.5
38.	*L.confluens* Duda	19	15	34	0.006	31.8
39.	*L. angulata* Singh, Dash and Fartyal	20	27	47	0.008	31.2
Genus *Mycodrosophila* Oldenberg						
40.	*Mycodrosophila gratiosa* de Meijere	45	78	123	0.023	50
41.	*Mycodrosophila* sp. M1*	54	48	102	0.019	31.2
42.	*Mycodrosophila* sp. M2*	27	30	57	0.010	6.2
Genus *Impatiophila* Fu et Gao						
43.	*Impatiophilal imbicostata* Okada	37	24	61	0.011	37.5
44.	*I. actinia* Okada	28	39	67	0.012	25
Genus *Zaprionus* Coquillett						
45.	*Zaprionus indianus* Gupta	72	129	201	0.037	95.4
Genus *Scaptodrosophila* Duda						
46.	*Scaptodrosophila coracina* Kikkawa & Peng	76	113	189	0.035	50
Genus *Stegana* Meigen						
47.	*Stegana nainitalensis* Singh & Fartyal	32	67	99	0.018	31.2
	Total	2326	3018	5344		

Note: Species marked with * could not be identified; A-absolute and r - relative abundance; C- Constancy value

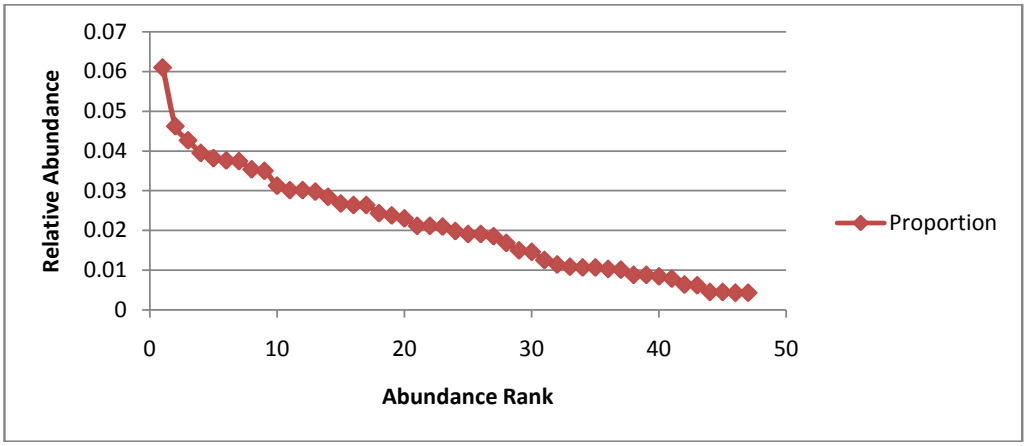

Fig. 1. Rank abundance plot of drosophilid species- Shimla district of Himachal Pradesh

Table 2. Drosophilid species collected with host/ habitats

	Host plant	*Drosophila* species
Different flowers	*Rhododendron* flower	*Hypselothyrea fascipennis, Scaptomyza himalayana*
	Hedychium spicatum	*Lordiphosa ayarpathaensis*, *Stegana nainitalensis*
	Prunus sp.,	*Drosophila helvetica*
	Agave sp., *Punica* sp., *Rubus* sp.	*Scaptomyza himalayana, Leucophenga spp.,*
	Impatiens spp.	*Impatiophila ptyonosternata, I. limbicostata, I. actinia, Lordiphosa* spp.
Fungus	*Cantharellus* spp.	*Hirtodrosophila sexvittata, H. longivittata, H. quadrivittata, Mycodrosophila gratiosa, Mycodrosophila* spp. M1*, M2*.
Mushroom	*Russula* spp., *Amanita* spp.	*Drosophila bizonata, D. trizonata, D. parazonata, D.novazonata, D. neokuntzei, D. bipectinata, Leucophenga* spp., *Scaptodrosophila coracina.*
Other hosts	Ground vegetation	*Drosophila* spp., *Hirtodrosophila fascipennis, Zaprionus indianus.*

Himachal Pradesh has significant share and favorable conditions to flourish the *Drosophila* diversity. These findings related to drosophilid diversity of Himachal Pradesh will provide an insight into the drosophilid diversity of this region that could be worth exploring further.

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