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Diversity and distribution of true flies (Diptera) of Kuldiha Wildlife Sanctuary, Odisha, India: Functional roles based on ecological guilds

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ABSTRACT: Proper understanding of ecological dynamics of faunal components, whether it is a large mammal or a tiny insect of any ecosystem including forests, plays an important role in the eco-management of any eco-zone. Dipteran insects constituting a major faunal group among the entomo-diversity of any forest ecosystem portray significant functional roles in determining the stability in the ecosystem functioning of the respective ecosystem. The present paper has attempted to document the diversity of dipteran insects inhabiting a tropical deciduous forest of the extended part of Deccan Biogeographic Zone in the eastern part of India, the Kuldiha Wildlife Sanctuary alongside indicating its habitat preference and distribution patterns. A total of 34 species under 19 families of the order Diptera were recorded from different habitats of the studied forest areas, of which three species are considered new reports from the state of Odisha, India. Out of the three selected eco-zones, the deep forest area having a higher density of sal trees (*Shorea robusta*) revealed less species richness but high relative abundance, whereas the barren grazing land demonstrated higher species richness with low relative abundance. The eco-zone with wetlands and associated vegetation have shown moderate species richness and diversity of dipteran insects. Three contrasting seasons (pre-monsoon, monsoon, and post-monsoon) of this region have also demonstrated different patterns of diversity and density of this group of insects which have been segregated into several feeding guilds in tune with the seasonal availability of food resources.

KEYWORDS: Feeding guilds, habitat preference, seasonality, new records

INTRODUCTION

Kuldiha Wildlife Sanctuary (KWLS), covering an area of approximately 272.75 km^2, is one of the stable and well-protected eco-zones of India. This area was declared as a sanctuary in the year of 1984 under the territorial jurisdiction of Baripada division, comprising Tenda reserve forest, Kuldiha reserve forest, and Devgiri reserve forest intermingling with other adjoining forest land of Nilagiri sub-division extending up to Simlipal National Park, Odisha, India. Being a well-protected tropical deciduous forest, this KWLS provides shelter to a wide variety of fauna, of which insects represent the most diverse faunal group. True flies (Insecta: Diptera), being one of the major

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and the least explored faunal group of the insect community, plays a series of ecological functions within an ecosystem.

However, the faunal group of this well-protected and ecologically managed KWLS is explored by only a very few studies on mammals (Debata *et al.*, 2013; Debata and Swain, 2017, 2018a; Mohapatra *et al.*, 2013), herpetofauna (Rout *et al.*, 2016a), birds (Das and Debata, 2018; Ghosh *et al.*, 2018) and flying squirrel (Ghosh *et al.*, 2023). Overall diversity of mammals and avifauna in KWLS was earlier reported by Murmu *et al.* (2013). Some scanty studies also revealed the possibilities of use of medicinal plants among the local people (Saravanan *et al.*, 2017, 2018). Unfortunately, very few attempts have been made to explore the insects and their ecology in KWLS, except for some very recent ones by Parui *et al.* (2015) on ants, Paria *et al.* (2018) on butterflies, Debata and Swain (2018b) on Odonata, and Ganguly *et al.* (2022) on termites.

The functional diversity forming the necessary linkages among different individuals within a species population and different species within a biotic community can counterbalance the damages caused by the loss of another species in ecosystem processes and patterns and thereby ensure the ecological stability of the ecosystem. In a biotic community, different functionally similar (belonging to the same trophic level) and dissimilar species (belonging to different trophic levels) having access to the same pool of resources can compensate for the loss of one species and prohibit any reduction in the use of that resource pool because of the increasing populations of other species that are present in the same ecosystem, which will accordingly simply increase their use of that same resource. The term guild refers to the differential behavioural patterns in respect of their differential forms of feeding strategies and thereby encompasses groups of potentially competing species, not cooperating ones. The concepts of guilds rest on functional manifestations of a group of species that exploit the same class of environmental resources in a similar way depending on their phylogeny and resource requirements (Chakraborty, 2020).

Several studies on the dipteran community, including other insect groups, have been conducted in different parts of Odisha (Parui and Datta, 1987; Nandi, 1977; Joseph and Parui, 1987; Veer *et al.*, 2002; Srinivasan and Jambulingam, 2013; Shety *et al.*, 2018), but no such works have so far been reported of dipteran insects from KWLS. In such a context, the present paper has attempted to report the diversity and distributional patterns of dipteran insects from this KWLS, with ecological notes on their occurrence in different habitats, alongside highlighting the new records of three dipteran species from the state of Odisha, India.

MATERIALS AND METHODS

The KWLS (Fig. 1) is situated between $21^0 20'$ to $21^0 30'$ N; $86^0 30'$ to $86^0 45'$ E, merging with the Similipal Reserve Forest in Odisha. The vegetation of this forest fringe is characteristic of tropical deciduous forest and is dominated mostly by *Shorea robusta*, Sal trees (Champion and Seth, 1968). A recent study reveals KWLS as the home of 108 plant species, of which 38 species are trees, 38 species are shrubs, and 32 species are herbs (Rout et al. 2016b). Depending on several ecological characteristics like vegetation type, green coverage area, water bodies, and anthropogenic involvements, three categories of land cover types (LCT) were identified (Table 1, Fig. 2), which differentially support the dipteran faunal diversity of this geographical region. Two sample sites were selected in each LCT for observing and documenting the dipteran community. The climatic condition in this deciduous forest portrays three contrasting seasons, i.e., pre-monsoon (March–June), monsoon (July–October), and post-monsoon (November–February). The average temperature ranges from 8°C in post-monsoon to 42°C in pre-monsoon (Debata and Swain, 2018a).

The survey was conducted in this forest range once in each season (for three days) to explore the dipteran diversity of the area along with their ecological activities. The collection and observation of the dipteran species have been made under the canopies of forest vegetation, flowers, elephant dung, and also in the cowsheds of the local residents. Covering all kinds of habitat types during three

consecutive seasons (pre-monsoon, monsoon, and post-monsoon) between the years 2017 and 2018. The observations have been made by the simple transect walk method in each of the land cover types of the study area. The mosquito vectors were collected with the help of an aspirator. The collected insect materials were then identified up to species or genus level in the laboratory with the stereo-zoom microscope following the guidelines of standard literature (several volumes of Fauna of British India, Fauna of India, and other relevant literatures). The map of the study area has been made with the help of Google Earth.

The calculation of seasonal relative abundance of each representative dipteran families were done based on the observation of only adult dipteran insects by using the following formula:

$$Relative\ abundance = \frac{a_1}{\sum_{i-1}^{n} a_1} \times 100\ (\%)$$

Where, a_1 is the number of adults of species 1 on a particular site; $\sum_{i-1}^{n} a_1$ is the total numbers of adult observed of all species on a site.

To quantify the differences in diversity among different LCTs, some diversity indices have been deduced, like the Shannon-Weiner Index (*H'*), Simpson's Dominance Index (D), Margalef's Species Richness (R), and the Berger-Parker Index. All the statistical calculations were performed with the help of Microsoft Excel 2013 and PAST version 2.17. Cluster analysis was executed by using the paired group algorithm (UPGMA) and Jaccard Similarity measure, on the basis of presence and absence of insect species among the studied habitat types (LCTs).

RESULTS AND DISCUSSION

Diversity and ecological distribution of true flies according to habitat and resource utilization:

During the present study, a total of 328 individual dipteran insects representing 34 species under 19 families were recorded in and around Kuldiha Wildlife Sanctuary (KWLS) (Table 2). Among the different families under the order Diptera, Culicidae shares the most species (seven species, 20.59%), followed by Syrphidae (six species, 17.65%), Muscidae (three species, 8.82%), and both Stratiomyidae and Sarcophagidae (two species, 5.89%). The other insect orders possess only one representative (Table 2).

Depending on the different ecological characteristics of habitats, the study area was categorised into three LCTs. Among these, the barren grazing land mostly along the roadside (LCT-3) displayed maximum species richness with 28 species (82.35% of total dipteran species), followed by the wetland-associated vegetation (LCT-1) with 17 species (50% of total dipteran species) among 34 species. The deeper parts of the forest (LCT-2) revealed the least species richness with only 13 species, which shared about 38.24% of total dipteran species (Fig. 2). Depending on the present-absent matrix, the similarity and distance analysis (Jaccard cluster analysis) was computed according to the habitat preferences of dipteran species, which portrayed the occurrence of several groups of species (Fig. 3). It was observed that the deep forest area showed high dipteran abundance but less species diversity, mainly because of the ecological homogeneity of that studied eco-zone. At the same time, the wetland-associated vegetation shows the relatively lowest relative abundance (14.63%) but modest diversity of dipteran species because it offers higher habitat heterogeneity but less than roadside grasslands, which have maximum ecological heterogeneity coupled with higher diversity. In consideration of the relative abundance of dipteran insects in different habitats, LCT–3 (56.4%) is designated as the most abundant habitat, followed by LCT–2 (28.96%) and LCT–1 (14.63%) (Fig. 4)

The diversity indices were calculated for all three types of habitat observed in the study area (Table 3). The Shannon diversity index was found to be maximum in the LCT-3 (barren grazing land and roadside), followed by the LCT-1 (wetland-associated vegetation), and then the LCT-2 (deep forest). The species dominance and Berger-Parker index were observed to be highest in contrast to Margalef's species richness index, which was found lowest in the LCT-2 (deep forest). The species

Table 1. Different habitats or Land cover types (LCT) within Kuldiha Wild Life Sanctuary, Odisha, India, with ecological characteristics

No.	Category of LCT	Code	Characteristics
01	Wetland associated vegetation	LCT-1	There are several small waterbodies spread over the sanctuary including a large dam namely Rissia Dam. The vegetation near the waterbodies observed for the study.
02	Deep forest	LCT-2	Mostly dominated by Sal tree with other trees and shrubs.
03	Barren grazing land	LCT-3	The grazing lands of animals and the roadside area was categorized under same LCT for similar kind of anthropogenic and faunal interference. Some local people also resides within this area.

richness was calculated at its maximum in the LCT-3 (barren grazing land and roadside).

Moreover, based on the resource partitioning, all these flies tended to enjoy a particular ecological habitat with its own ecological distinctiveness, which was categorised as their feeding guild. Some of these flies are specialists, which depend on a single feeding guild, whereas several others are generalist species, which depend on more than one feeding guild to utilise resources. Twelve species were recorded from each of the two feeding guilds, i.e., flower visitors and saprophytes/decomposers. Eleven species were spotted as leaf or trunk inhabitants of different plant species across the KWLS, whereas six species were found as blood suckers or hematophagous (Table 2).

Seasonal distribution:

The seasonal distribution pattern of the dipteran insects in and around Kuldiha WLS clearly depicted the maximum abundance in the pre-monsoon, except for Culicidae and Sarcophagidae. The abundance of the culicids (mosquitoes) was very low in the pre-monsoon compared to the monsoon and post-monsoon. The sarcophagid flies were mainly abundant during the post-monsoon, while they were found in very minimal numbers during the monsoon. Another important observation was reported in the case of the dipteran species under the family Stratiomyidae (soldier flies), which were found only during the pre-monsoon in the study area (Fig. 5).

New records:

Following three dipteran species, among all the reported ones, were encountered for the first time in the state of Odisha, India: *Hermetia illucens* (Linnaeus, 1758), *Mimegralla albimana* (Doleschall, 1856), and *Dideopsis aegrota* (Fabricius, 1805), which belong to the families Stratiomyidae, Micropezidae, and Syrphidae, respectively.

Order Diptera; Sub order Brachycera

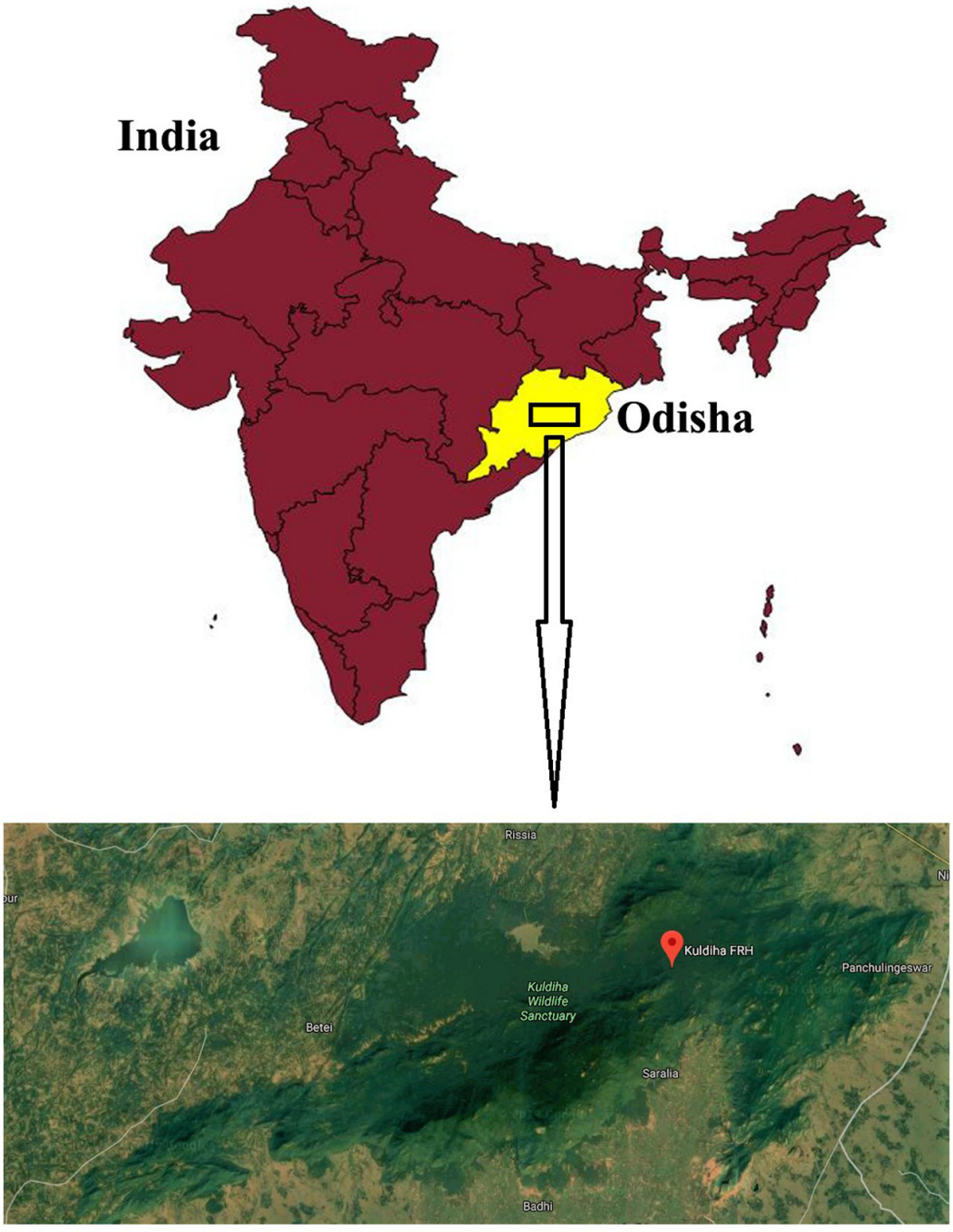
Family Stratiomyidae

1. *Hermetia illucens* (Linnaeus, 1758)*

1758. *Musca illucens* Linnaeus. *Systema naturae* Ed. 10, vol 1: 589

Type-locality: South America

Distribution: India: Assam, Odisha (Present record), Karnataka, Kerala, Maharashtra, Manipur, Punjab, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal. Elsewhere: Widespread in the World, nearly cosmopolitan.



Kuldiha Wildlife Sanctuary

Fig. 1: Map of the Study Area

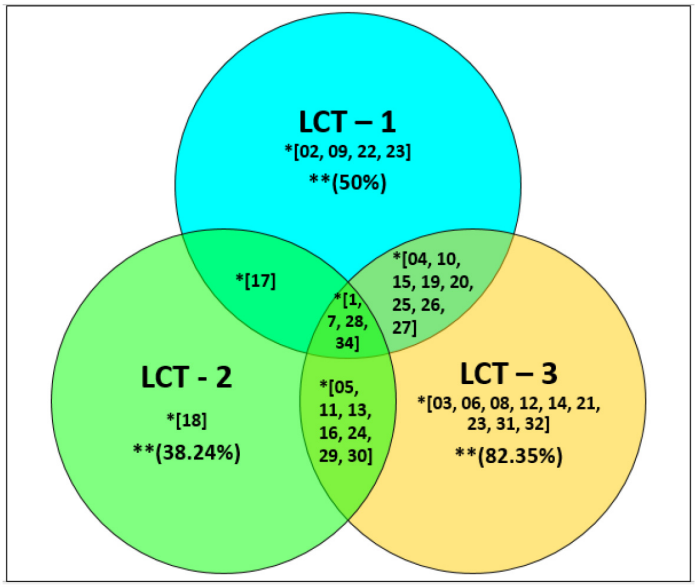


Fig. 2 Species distribution in different land cover types in and around KuldihaWLS [*numbers within third parentheses refer the species serial numbers mentioned in the Table no. 2 and
**percentages within the first parentheses refer the percentage of species composition in each LCTs among the total dipteran species]

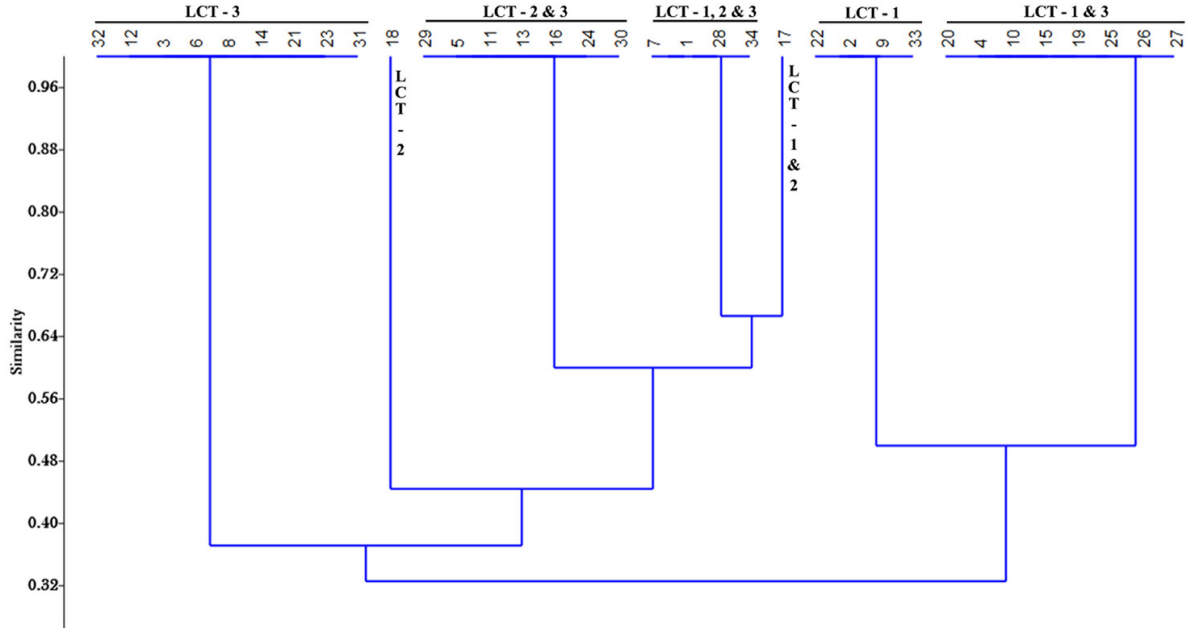


Fig. 3 Cluster analysis (Jaccardsimilarity measure with UPGMA method) of the dipteran species on the basis of their habitat preferences, where '1' indicates maximum similarity and '0' indicates no similarity [the numeric digits, i.e. 1-34 in the figure refers to the serial numbers of dipteran species in the Table no. 2]

Table 2. List of the dipteran species from different land cover types of Kuldiha Wild Life Santuary, Odisha, India ['+' denotes present and '-' denotes absent]

Sl. No.	Name of the species	LCT-1	LCT-2	LCT-3
	Family Tipulidae			
01	*Pselliophora* sp.	+	+	+
	Family Limoniidae			
02	*Limonia* sp.	+	-	-
	Family Culicidae			
03	*Anopheles (Cellia) culifacies* Giles, 1902	-	-	+
04	*Anopheles (Cellia) subpictus* Grassi, 1899	+	-	+
05	*Anopheles (Cellia) fluviatilis* James, 1902	-	+	+
06	*Aedes (Stegomyia) albopictus* (Skuse, 1895)	-	-	+
07	*Armigeres* sp.	+	+	+
08	*Culex* sp.	-	-	+
09	*Mansonia(Mansonoides) annulifera* Theobald, 1901	+	-	-
	Family Chironomidae			
10	*Chironomus* sp.	+	-	+
	Family Stratiomyidae			
11	*Sargus metallinus* Fabricius, 1805	-	+	+
12	*Hermetia illucens* (Linnaeus, 1758)*	-	-	+
	Family Tabanidae			
13	*Tabanus (Tabanus) rubidus* Wiedemann, 1821	-	+	+
	Family Muscidae			
14	*Musca (Musca) domestica* Linnaeus, 1758	-	-	+
15	*Neomyia* sp.	+		+
16	*Atherigona (Acritochaeta) orientalis* Schiner, 1868	-	+	+
	Family Micropezidae			
17	*Mimegralla albimana* (Doleschall, 1856)*	+	+	-

	Family Syrphidae			
18	*Dideopsis aegrota* (Fabricius, 1805)	-	+	-
19	*Eristalinus (Eristalinus) polychromata* (Brunetti, 1923)*	+	-	+
20	*Eristalinus (Eristalinus) arvorum* (Fabricius, 1787)	+	-	+
21	*Paragus (Paragus) serratus* (Fabricius, 1805)	-	-	+
22	*Ischiodon scutellaris* (Fabricius, 1805)	+	-	-
23	*Episyrphus (Episyrphus) balteatus* (De Geer, 1776)	-	-	+
	Family Calliphoridae			
24	*Chrysomya megacephala* (Fabricius, 1794)	-	+	+
	Family Rhiniidae			
25	*Idiella mandarina* (Wiedemann, 1830)	+	-	+
	Family Ulididae			
26	*Physiphora aenea* (Fabricius, 1794)	+	-	+
	Family Phoridae			
27	*Megaselia (Megaselia) scalaris* (Loew, 1866)	+	-	+
	Family Tephritidae			
28	*Bactrocera (Zeugodacus) cucurbitae* (Coquillett, 1899)	+	+	+
	Family Sarcophagidae			
29	*Sarcophaga (Liosarcophaga) dux* Thomson, 1869	-	+	+
30	*Sarcophaga (Liosarcophaga) brevicornis* Ho, 1934	-	+	+
	Family Drosophilidae			
31	*Drosophila* sp.	-	-	+
	Family Sepsidae			
32	*Sepsis* sp.	-	-	+
	Family Asilidae			
33	*Philodicus femoralis* Ricardo, 1921	+	-	-
	Family Dolichopodidae			
34	*Chrysosoma* sp.	+	+	+

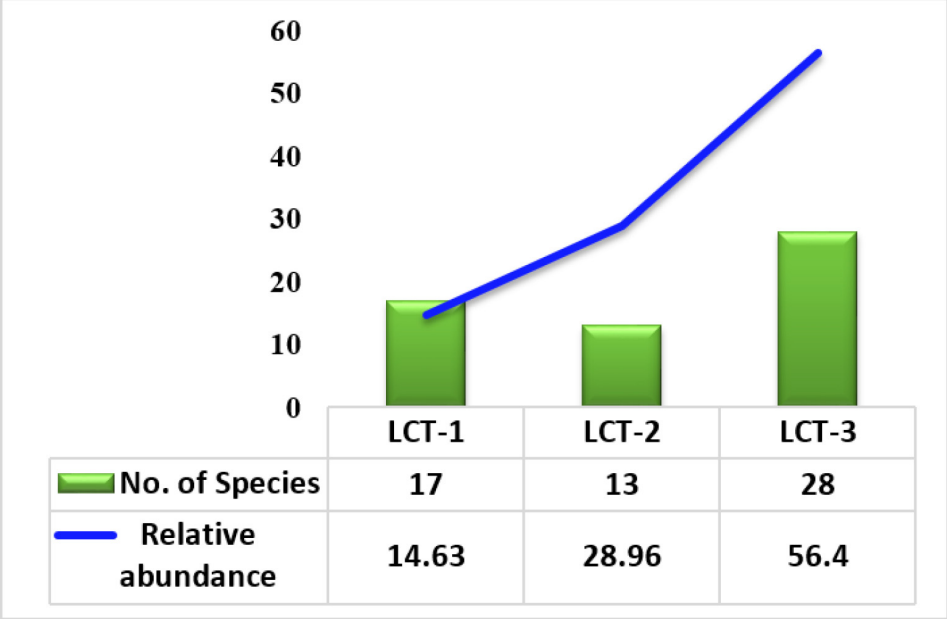


Fig. 4 Dipteran species diversity and relative abundance in different Land cover types (LCT-s) across the KuldihaWild Life sanctuary, Odisha, India

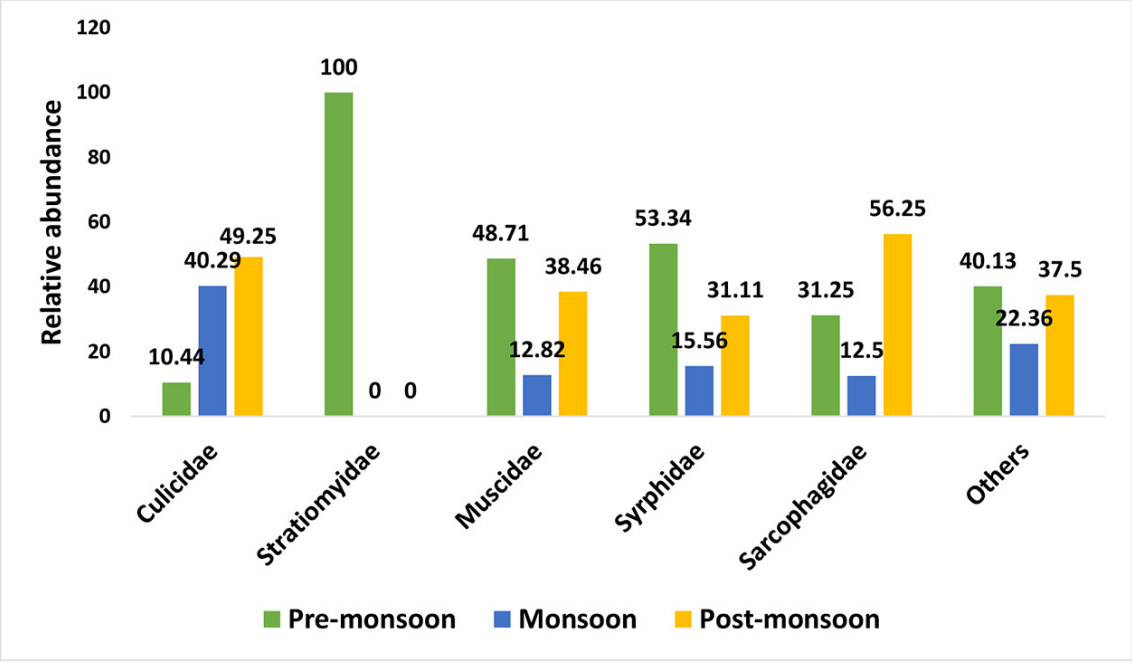


Fig. 5 Seasonal distribution of different dipteran species in and around KuldihaWild Life Sanctuary, Odisha, India

Remarks: Though it is native to the New World, but has been distributed throughout the World by anthropogenic commercial activities. The larvae of this species are utilized in processing of swine and hen manure, and food supplement of chicken which seems much cost effective (Diener *et al.,* 2011; Roy *et al.,* 2018). This species recorded here for the first time from the state of Odisha.

Family Micropezidae

2. *Mimegralla albimana* (Doleschall, 1856)*

1856. *Taenioptera albimana* Doleschall. *Eerste bijdrage tot dekennis der dipterologische fauna van Nederlandsch Indie. Natuurkd.Tijdschr. Ned.-Indie* 10: 413.

Type-locality: Indonesia: Java: Djokjakarta

Distribution: India: Assam, Mizoram, Odisha (Present record), Tripura, West Bengal. Elsewhere: Bangladesh, Java, Malaysia, Borneo, Japan, Belau, Guam, Micronesia, Myanmar, Northern Marianas, Papua New Guinea, Ryukus.

Remarks: Only eight species were reported of the family Micropezidae from India, of which 6 species were under the genus *Mimegralla* (Mitra et al. 2015c). This species also shows its distribution in other protected areas like, Sundarban Biosphere reserve (Mitra *et al.,* 2015a) and Bibhuti Bhusan Wildlife Sanctuary (Mitra *et al.,* 2015b). This is a new record for this state, Odisha.

Family Syrphidae

3. *Dideopsis aegrota* (Fabricius, 1805)

1805. *Eristalis aegrota* Fabricius, *Systema antliatorum secundum ordines, genera, species*. Xiv: 243.

Type-locality: India. Tamil Nadu: Tharangambadi

Distribution: India: Andaman and Nicobar islands, Arunachal Pradesh, Assam, Himachal Pradesh, Kerala, Karnataka, Meghalaya, Maharashtra, Madhya Pradesh, Odisha (Present record), Sikkim, Tamil Nadu, Uttarakhand and West Bengal. Elsewhere: Australia, Nepal, New Guinea.

Remarks: A widely distributed flower fly has been recorded for the first time from the state of Odisha.

The true flies are one of the most diverse insect orders, comprising about 1,59,294 described species (Pape *et al.,* 2011). However, the actual total number of extant fly species is many fold, most of which are still unexplored. The living dipteran species have been categorised into about 10,000 genera, 150 families, 22–32 super-families, 8–10 infra-orders, and 2 sub-orders (McAlpine and Wood 1989), and around 3100 fossil species have so far been described (Evenhuis 1994). Among the 150 families of the order Diptera, 85 families have been reported so far from India. These vast insect groups possess various types of ecological roles. Some of them are turning harmful to human and animal society, while some of them are beneficial to human society because of their functional contributions as pollinators, decomposers, bio-indicators, vectors, predators, and prey in the food chain and food web dynamics of the ecosystem. From the present study, 34 species under 19 families have been recorded from this KWLS, of which families Culicidae and Syrphidae have been reported as major groups in terms of species numbers as well as abundance.

Among the two major groups of dipteran insects from the study area, the family Culicidae includes some vector species, namely, *Anopheles (Cellia) culifacies* and *Anopheles (Cellia) fluviatilis* (Malaria vectors), *Aedes (Stegomyia) albopictus* (Dengue and Chikungunya vector), and *Mansonia (Mansonoides) annulifera* (Japanese Encephalitis vector) which are responsible for several deadly diseases in India (Tyagi *et al.,* 2015). Because of the favourable environmental conditions, members of the Culicidae family were most abundant during the post-monsoon season, followed by the monsoon season. Being ectotherms, the environmental factors like average temperature, relative humidity, and precipitation rates of any given area impart considerable impacts on eco-biology, especially on the development and life cycles of this insect fauna. Though only 1–10 per cent of the laid eggs emerge as adults (Aniedu *et al.,* 1993; Okogun, 2005), each life stage of these mosquitoes (egg, larva, pupa, and adult) is dependent on the temperature for its

developmental and mortality rates (Beck-Johnson *et al.,* 2013). As the temperature range during the post-monsoon and monsoon has appeared to be most favourable for the development of dipteran species, the relative abundance of this group was observed to be specifically higher compared to other dipteran groups from this area. One dipteran species, *Tabanus rubidus*, a tabanid fly in the family Tabanidae and notorious carrier of Surra disease in India, has also been reported from this KWLS, India (Basu *et al.,* 1952; Veer *et al.,* 2002).

Besides the deadly dipteran creatures that act as public health nuisances, some beneficial groups of dipteran insects were found in KWLS. The members of the family Syrphidae are one of those ecosystem service providers that, besides the honeybees, play a crucial role as pollinators (Mitra and Banerjee, 2007; Orford et al., 2015). Different species of flower flies (Syrphidae) were recorded in and around the KWLS from several plants as flower-visiting insects. They mainly visited flowers to feed themselves with nectar (myophily), which in turn enabled them to act as potential secondary or accidental pollinators. The flower flies or hover flies (Family Syrphidae) used to display their peak abundance during the pre-monsoon, while their abundance started declining drastically during the post-monsoon and monsoon. Hover flies are one of the major groups of flower-visiting insects and also act as pollinators for several wild plants, agricultural plants, ornamental plants, medicinal plants, etc. (Mitra and Banerjee, 2007; Klecka *et al.,* 2018). However, the fact remains that the roles in plant–pollinator interactions rendered by syrphid and some non-syrphid groups are often underappreciated (Inouye *et al.,* 2015). A detailed account of the roles of syrphid and non-syrphid dipteran groups as potential pollinators on a comparative basis is also available by studying 30 pollen-transport networks and 71 pollinator-visitation networks, which categorically indicate the importance of these forgotten flies in pollination (Orford *et al.,* 2015). The pre-monsoon season, with plenty of blooming flowers in the study area, including the flowers of the most dominant Sal trees, *Shorea robusta*, was seen to attract one syrphid fly, *Dideopsis aegrota*, in higher abundance, followed by other dipterans, hymenopteran insects, and lepidopteran insects in and around Kuldiha Wild Life Sanctuary (KWLS).

While observing the habitat-wise distribution of the dipteran species, it was noticed that the deep forest area (LCT-2) has fewer species diversity with a relatively high species abundance, which is supposed to be due to the homogeneity of the ecological conditions of the habitats, which are characterised by less penetration of sunlight, higher humidity, less availability of open space to fly, etc. Most of the dipteran insects were observed to flourish in either the blooming flowers or over the surface of the elephant dung. The elephant dungs were mostly visited by dipteran insects like *Chrysomya megacephala*, *Sarcophaga (Liosarcophaga) dux*, and *Neomyia* sp., along with several other insect groups like beetles (Coleoptera), ants (Hymenoptera), termites (Isoptera), etc. Certain species from families like Muscidae, Calliphoridae, Tabanidae, and Sarcophagidae could develop a close relation to human settlements (Chaiwong *et al.,* 2012; Valverde-Castro *et al.,* 2017), and thus their presence in high numbers and diversity were found at LCT–3. Aside from the presence of the greatest number of species and relatively higher abundance of mosquitoes in villages, it appears to be significant in terms of their availability of food as human blood, as most of them were found in LCT-1 as well.

Natural forests, specifically virgin evergreen forests, serve as the key reservoir of biodiversity, as they always signify their unique floral and faunal composition. Despite all the threats, any protected area holds rich biodiversity. Therefore, it is always essential to document the biodiversity of any ecosystem or protected area for the purposes of planning better eco-management and conservation. Increased species richness enhances the performance of entire communities but reduces the average contributions of individual species. This paper fulfils the preliminary knowledge of the dipteran diversity in and around the Kuldiha WLS along with the roles of habitat heterogeneity and favourable seasonal conditions to trigger both the diversity and abundance of dipteran flies. Moreover,

the present research study has also highlighted some functional roles of the major groups of dipterans, like the Culicidae and Syrphidae. Being an unexplored eco-zone, the biodiversity of this KWLS may attract the attention of several biodiversity experts who can explore different areas of biodiversity research in order to strengthen the biodiversity documentation process of the country, and the research outcomes from the present paper may certainly fill such a lacuna in the knowledge base by generating some baseline research information on the dipteran community of KWLS.

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