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Study on the diversity of Insects occurring on wild mushrooms in selected districts of West Bengal

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Abstract
The present paper documents the preliminary study on insect abundance and diversity of insect species in diversity through funnel trap in three selected districts of West Bengal conducted during September 2021 to April 2022. A total of 405 insects from 7 orders, 21 families were recorded. This study shows that Diptera (46%) was the most dominant order according to total number of individuals, followed by Coleoptera (27%), Hymenoptera (13%), Collembola (6%), Hemiptera (4%), Diplura (2%), and Lepidoptera (2%). The present study was also conducted to determine the abundance of insect species; species richness, dominance and evenness of insect fauna from different districts. The Simpson's Index diversity is highest in Paschim Medinipur (0.4486) and lowest in South 24-Parganas (0.2738). The species richness, evenness and diversity of insects were calculated by Margalef's Index, Pielou's Index and Shannon-Wiener Index respectively.

Keywords: wild mushroom, insects, diversity, distribution, relative abundance, diversity indices, Howrah, south 24 parganas, Paschim Medinipur, West Bengal, India

Introduction
Mushrooms, under the phylum Ascomycotina and Basidiomycotina, are spore producing fruit bodies and are important component for sustenance of ecosystems. Mushrooms are popular terms such as gilled fungi, cup fungi, bracket fungi, puffballs and truffles etc. According to ecological point of view, all the macro fungi can be placed in 3 groups such as the saprophytes, the parasites and the symbiotic (mycorrhizal) species. Some terrestrial micro fungi are plant pathogen and also shows pathogenicity towards some other fungi. Mushrooms found on woody substrate may be saprobes or plant pathogens, but most terrestrial macro fungi are saprobes or mycorrhizal symbionts [1]. Truly wild mushrooms don't grow in a controlled environment, they are foraged in the woods, in exactly the place where conditions are ideal for them to grow. Along with chanterelles, morel mushrooms are the most widely available truly wild mushrooms. Shaped like spongy cones, morels come in shades from ivory to deep black. They have a light woodsy flavor and wonderful firm yet spongy texture.

Mushrooms are seasonal fungi that occupy diverse niches in forest and territory ecosystem. The famililes viz., Ganodermataceae, Agaricaceae, Lycophyllaceae, Schizophyllaceae, Xylariaceae, Polyporaceae, Marasmiaceae, Psanthyrellaceae and Strophaniaceae showed rich Biodiversity. The families Auriculariaceae, Boletaceae, Formitopsidaceae, Mycenaceae, Tremellaceae and Tricholomataceae shows less diversity. Indian mycologists have reported many species of Agaricaceae, mostly represented by Agaricus from different states of India. Manoharachary *et al.* [2] reported different uses of medicinal mushroom viz., *Lentinus* sp., *Pleurotus* sp., *Schizophyllum* sp., *Ganoderma lucidum*, *Agaricus bisporus*, *A. campestris*, *Pleurotus* sp. and *Termitomyces heimii*. Senthilarasu and Kumaresan [3] reported 132 species in 60 genera belonging to Agaricales, Polyporales and Russulales. Xylaria species grows on a variety of substrates especially on decorticated wood, dung and nests of termites/ants [4]. The cosmopolitan *Ganoderma applanatum* or bracket fungus may be a unique woody Polyporaceae among all mushrooms because it is employed for its pharmaceuticals value instead of food [5].

Food, medicine, biocontrol agent, many bioactive and most pharmaceutical compounds also been obtained from mushrooms, which indicates its economic value towards the society [6]. Now a days, many organic pollutants are decomposed by most of the mushroom species, one of the best species is *Trametes versiocolor* [7,8]. In most of the countries, bioremediation of domestic waste, industrial waste and heavy metals from the environment is done by using microbes, especially micro fungi [9,10]. Important and remarkable antimicrobial activity has been indicated from secondary metabolites of mushrooms [11].

A good amount of work has been done on insects of cultivated mushroom but very few survey has been made earlier to explore and document the insects occurring on wild mushroom especially from the places like Ramakrishna mission, Narendrapur, South 24-Parganas; Acharya Jagadish Chandra Bose gardens, Howrah, Shibpur; Chintamoni Kar Bird Sanctuary, Narendrapur, South 24-Parganas; Paschim Medinipur) of West Bengal. So, to fulfill this lacuna, an attempt has been made in the present work to record different insects associated with some of the naturally occurring wild mushroom in the above-mentioned places under 3 different districts of West Bengal, during October to April, 2021-2022.

Materials and Method
Sites of collection
The survey was conducted to study the diversity of insects associated with wild mushrooms occurring in 3 districts of West Bengal viz. South 24 Parganas (Ramakrishna mission, Narendrapur; Chintamani Kar Bird Sanctuary), Howrah (Acharya Jagadish Chandra Bose gardens), Paschim Medinipur (Belda) during October to April, 2021-2022 for occurrence of insects.

Methodology adopted for collection and preservation of Insects

The wild mushrooms (*Polyporus* sp., *Mycorrhaphoides stalpersii*, *Amanita* sp., *Lentinus squarrosulus*, *Pleurotus ostreatus* etc.) were collected from forests, medicinal plant gardens, under logs and fallen tree trunks, etc. The mushroom samples were brought to the laboratory by putting those in a box to keep those undamaged. The mushroom samples were put into Tullgren funnel using a 60W electric bulb and maintaining a distance of 15cm between the bulb and the sample.

The insects were collected in a receiver containing 70% alcohol fitted with the stem of the funnel. It took about 2-3 days for complete extraction of insects. After extraction, the extracted materials were sorted out under a stereo binocular microscope into different groups.

Most of the mushroom species were identified taking the help of publication by Acharya and Pradhan [12].

Data analysis

For Statistical Analysis of data, identified insect's species observed from wild mushrooms in the study area were analysed by using various diversity indices, which are as follows:

The following formula is used to calculate the relative abundance of species in an area:

$$RA = TD/TP \times 100$$

Where, RA= The relative abundance of species (%)
TS= The total number of species in an area
TP= The total sum of the populations of all species in the area

The Simpson index of diversity mathematical formula is giving as follows:

$$(D) = 1 - [\Sigma n_i(n_i-1) / N(N-1)]$$

Where, Σ = Sum of (Total)
n_i =The number of individuals of each different species
N = The total number of individuals of all the species

The Shannon-Weiner index of diversity mathematical formula is giving as follows:

$$(H) = -[\Sigma(n_i/N) \times \ln(n_i/N)]$$

Where, Σ = Sum of (Total)
n_i = The number of individuals of each different species
N = The total number of individuals of all the species

The Evenness of diversity mathematical formula is giving as follows:

$$(E) = H/ \ln(S)$$

Where, H = Shannon's diversity index
Ln (S) = Natural logarithm of species richness

The Margalef's diversity index expressed as 'd' can be calculated in a spreadsheet by using the formula.

$$(d) = (S - 1)/ \log N$$

Where, S=The number of species
N= The total number of individuals in the sample

Result

Survey and documentation of different insects

Different types of insect orders and families which were collected from different types of mushrooms of 3 different districts (South 24- Parganas, Howrah and Paschim Medinipur) and identified has been listed in Table.1, Table.2, Table.3 and abundance of insect orders and families in the study areas has been listed in Table.4.

As perusal Table.1 indicates that 17 families of insects which belongs to 6 orders were collected from different types of host mushrooms (*Polyporus* sp., *Pleurotus ostreatus*, *Lentinus squarrosulus*, *Ganoderma* sp., *Letinus* sp. and *Amanita* sp.) present in South 24-Parganas district. Of those, there were 5 families (Phoridae, Sciaridae, Drosophilidae, Mycetophilidae and Muscidae) which belongs to the order Diptera which are found from *Polyporus* sp., *Pleurotus ostreatus*, *Ganoderma* sp. and *Lentinus squarrosulus* mushrooms; 7 families (Curculionidae, Erotylidae, Tenebrionidae, Staphylinidae, Nitidulidae and Scarabaeidae) which belongs to the order Coleoptera which are found from *Polyporus* sp., *Pleurotus ostreatus*, *Ganoderma* sp., *Lentinus* sp. and *Amanita* sp. mushrooms; 1 family Formicidae which belongs to the order Hymenoptera which is found from *Letinus* sp., *Pleurotus ostreatus* mushrooms; 2 families (Lygaeidae and Cicadidae) which belongs to the order Hemiptera which are found from *Ganoderma* sp. and *Polyporus* sp. mushrooms; 2 families (Isotomidae and Entomobryidae) which belongs to the order Collembola which are found from *Ganoderma* sp. and *Letinus* sp. mushrooms; 1 family Campodeidae which belongs to the order Diplura which is found from *Letinus* sp., *Pleurotus ostreatus* mushrooms.

Table.2 indicates that 11 families of insects which belongs to 5 orders were collected from different types of host mushrooms (*Polyporus* sp., *Mycorrhaphoides stalpersii*) present in Howrah district. Of those, there were 4 families (Phoridae, Sciaridae, Cecidomyiidae and Muscidae) which belongs to the order Diptera and 4 families (Curculionidae, Tenebrionidae, Erotylidae and Staphylinidae) which belongs to the order Coleoptera which are found from *Polyporus* sp. and *Mycorrhaphoides stalpersii* mushrooms; 1 family Formicidae which belongs to the order Hymenoptera and 1 family Isotomidae which belongs to the order Collembola are found from *Polyporus* sp. mushroom; 1 family Noctuidae which belongs to the order Lepidoptera is found from *Mycorrhaphoides stalpersii* mushroom.

Table.3 indicates that 9 families of insects which belongs to 4 orders were collected from the host mushroom (*Pleurotus ostreatus*) present in Paschim Medinipur district. Of those, there were 4 families (Phoridae, Sciaridae, Cecidomyiidae and Muscidae) which belongs to the order Diptera, 3 families (Curculionidae, Erotylidae and Carabidae) which belongs to the order Coleoptera, 1 family Formicidae which belongs to the order Hymenoptera and 1 family Reduviidae which belongs to the order Hemiptera are found from *Pleurotus ostreatus* mushroom.

In the table.4 it is seen that, in those 17 families found in South 24-Parganas district Phoridae and Sciaridae belongs to the order Diptera and Curculionidae belongs to the order Coleoptera were found in abundance from *Polyporus* sp. and *Pleurotus ostreatus* mushrooms, Tenebrionidae and

Staphylinidae belongs to the order Coleoptera were found in abundance from *Ganoderma* sp. mushroom and Formicidae belongs to the order Hymenoptera were found in abundance from *Pleurotus ostreatus* mushroom and the *Mycorrhaphoides stalpersii* mushroom sample of Howrah district has some abundance of Phoridae family belonging to Diptera order, but not as many as South 24 parganas.

The Mycetophilidae and Drosophilidae families belonging to the Diptera order were found in the *Lentinus squarrosulus* mushroom sample of Howrah district, which was not found in the mushroom sample of the other 2 districts, which distinguishes the mushroom sample of Howrah district from the mushroom sample of the other 2 districts. Similarly, the Nitidulidae and Scarabaeidae families belonging to the Coleoptera order, the Lygaeidae and Cicadidae families belonging to the Hemiptera order, the Entomobryidae family belonging to the Collembola and the Campodeidae family belonging to the Diplura were found in the *Polyporus* sp., *Ganoderna* sp., *Letinus* sp., mushroom samples of Howrah District which was not found in the mushroom samples of the other 2 districts; the Carabidae family belonging to the Coleoptera order was found in the *Pleurotus ostreatus* mushroom sample of Paschim Medinipur District, which was not found in the others; the Noctuidae family belonging to the Lepidoptera order was found in the *Mycorrhaphoides stalpersii* mushroom sample of Howrah District, which was not found in the others.

So, abundance of insect orders such as Diptera, Coleoptera, Hymenoptera, Hemiptera, Collembola is Higher in the mushroom Sample of district South 24- Parganas than Howrah and Paschim Medinipur districts. This study shows that Lepidoptera is the only insect order found in the mushroom sample of Howrah among the mushroom sample of 3 districts. Similarly, in case of insect order Diplura which is only present in the mushroom sample of South 24-Parganas district (Fig. 1).

The present study observed that the relative abundance of Order Diptera was 46.17% and significantly higher than that of Order Coleoptera (27.41%) and Order Hymenoptera (13.08%). However, the relative abundance of the orders Lepidoptera was found to be 1.48%, the lowest relative abundance. Thus, the percent relative abundance of Diptera was highest followed by Coleoptera which is again gradually followed by Hymenoptera, Collembola, Hemiptera, Diplura. Order Lepidoptera relative abundance was found to be the lowest among the seven orders (Table:5; Fig.2).

During the present study, it was observed that the Shannon index (H) is an index that seeks to measure the diversity of species, considering their uniformity. The higher the value of H, the higher the diversity of species in a particular community.

Among the Diversity indices, Simpson's index was found to be higher in Paschim Medinipur, that is 0.4486; whereas Shannon-Weiner index was higher in South 24- Parganas, that is 1.465. This difference was due to higher species richness value in South 24- Parganas which greatly influences Shannon-Weiner index.

Evenness is high if all species have similar distribution (i.e., similar population density). So, as we can see in this study, the value of Evenness is higher in South 24-Parganas district that is 0.817, which means that all the insect families in that district are equally distributed then others study areas in other two districts (Table.5, Fig.3).

Table 1: Insect Taxa associated with different host mushrooms present in South 24- Parganas

Sl. No	Order	Family	Host Mushrooms
01	Diptera	Phoridae	*Polyporus* sp., *Pleurotus ostreatus*
		Sciaridae	*Polyporus* sp., *Pleurotus ostreatus*
		Drosophilidae	*Lentinus squarrosulus*
		Mycetophilidae	*Lentinus squarrosulus*
		Muscidae	*Ganoderma* sp.
02	Coleoptera	Curculionidae	*Polyporus* sp., *Amanita* sp., *Pleurotus ostreatus*
		Erotylidae	*Polyporus* sp., *Amanita* sp., *Pleurotus ostreatus*
		Tenebrionidae	*Ganoderma* sp., *Polyporus* sp.
		Staphylinidae	*Ganoderma* sp., *Letinus* sp.
		Nitidulidae	*Polyporus* sp.
		Scarabaeidae	*Ganoderma* sp., *Letinus* sp.
03	Hymenoptera	Formicidae	*Letinus* sp., *Pleurotus ostreatus*
04	Hemiptera	Lygaeidae	*Ganoderma* sp., *Polyporus* sp.
		Cicadidae	*Ganoderma* sp.
05	Collembola	Isotomidae	*Letinus* sp., *Ganoderma* sp.
		Entomobryidae	*Ganoderma* sp.
06	Diplura	Campodeidae	*Letinus* sp.

Table 2: Insect Taxa associated with different host mushrooms present in Howrah

Sl. No	Order	Family	Host Mushrooms
01	Diptera	Phoridae	*Mycorrhaphoides stalpersii*
		Sciaridae	*Mycorrhaphoides stalpersii, Polyporus* sp.
		Cecidomyiidae	*Polyporus* sp.
		Muscidae	*Polyporus* sp.
02	Coleoptera	Curculionidae	*Mycorrhaphoides stalpersii, Polyporus* sp.
		Tenebrionidae	*Mycorrhaphoides stalpersii*
		Erotylidae	*Mycorrhaphoides stalpersii*
		Staphylinidae	*Mycorrhaphoides stalpersii, Polyporus* sp.
03	Hymenoptera	Formicidae	*Polyporus* sp.
04	Lepidoptera	Noctuidae	*Mycorrhaphoides stalpersii*
05	Collembola	Isotomidae	*Polyporus* sp.

Table 3: Insect Taxa associated with different host mushrooms present in Paschim Medinipur

Sl. No	Order	Family	Host Mushrooms
01	Diptera	Phoridae	*Pleurotus ostreatus*
		Sciaridae	*Pleurotus ostreatus*
		Cecidomyiidae	*Pleurotus ostreatus*
		Muscidae	*Pleurotus ostreatus*
02	Coleoptera	Curculionidae	*Pleurotus ostreatus*
		Carabidae	*Pleurotus ostreatus*
		Erotylidae	*Pleurotus ostreatus*
03	Hymenoptera	Formicidae	*Pleurotus ostreatus*
04	Hemiptera	Reduviidae	*Pleurotus ostreatus*

Table 4: Number and types of insects identified in wild mushrooms at different study sites belonging to 3 different districts of West Bengal

Sl. No	Order	Family	Location (District)			Total
			South 24- Parganas	Howrah	Paschim Medinipur	
01	Diptera	Phoridae	44	20	10	74
		Sciaridae	27	10	8	45
		Cecidomyiidae	0	6	6	12
		Muscidae	12	18	14	44
		Drosophilidae	4	0	0	4
		Mycetophilidae	8	0	0	8
02	Coleoptera	Curculionidae	24	10	5	39
		Carabidae	0	0	3	3
		Erotylidae	7	4	2	13
		Tenebrionidae	20	3	0	23
		Staphylinidae	18	2	0	20
		Nitidulidae	11	0	0	11
		Scarabaeidae	2	0	0	2
03	Hymenoptera	Formicidae	35	8	10	53
04	Hemiptera	Reduviidae	0	0	2	2
		Lygaeidae	5	0	0	5
		Cicadidae	8	0	0	8
05	Lepidoptera	Noctuidae	0	6	0	6
06	Collembola	Isotomidae	12	6	0	18
		Entomobryidae	7	0	0	7
07	Diplura	Campodeidae	8	0	0	8
Total			252	93	60	405

Table 5: Relative abundance of insect orders recovered from the mushrooms of 3 districts

Sl. No	Order	Family	Total no.	Relative Abundance (%)
01	Diptera	Phoridae	187	46.17
		Sciaridae		
		Cecidomyiidae		
		Muscidae		
		Drosophilidae		
		Mycetophilidae		
02	Coleoptera	Curculionidae	111	27.41
		Carabidae		
		Erotylidae		
		Tenebrionidae		
		Staphylinidae		
		Nitidulidae		
		Scarabaeidae		
03	Hymenoptera	Formicidae	53	13.08
04	Hemiptera	Reduviidae	15	3.70
		Lygaeidae		
		Cicadidae		
05	Lepidoptera	Noctuidae	6	1.48
06	Collembola	Isotomidae	25	6.17
		Entomobryidae		
07	Diplura	Camodeidae	8	1.98
Total			405	99.99

Table 6: Ecological data analysis

Location (Districts)	Shannon- Weiner index (H)= -[Σ(ni/N) × ln(ni/N)]	Simpson index (D)= 1- [Σni(ni-1) / N(N-1)]	Evenness (E)= H/ ln(S)	Margalef richness index (d) = (S – 1)/ log N
South 24- Parganas	1.465	0.2738	0.817	0.9043
Howrah	1.205	0.388	0.749	0.8825
Paschim Medinipur	0.9999	0.4486	0.721	0.7327

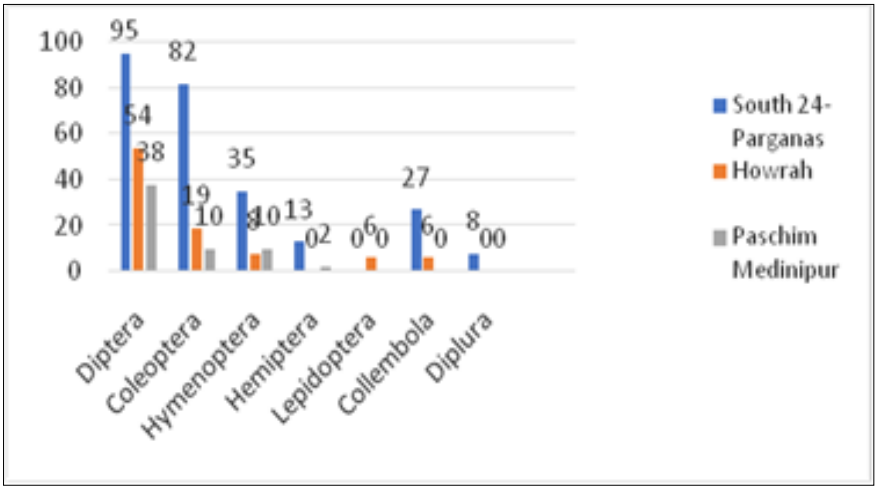

Fig 1: Number and types of insect orders observed in wild mushrooms from 3 different districts of West Bengal

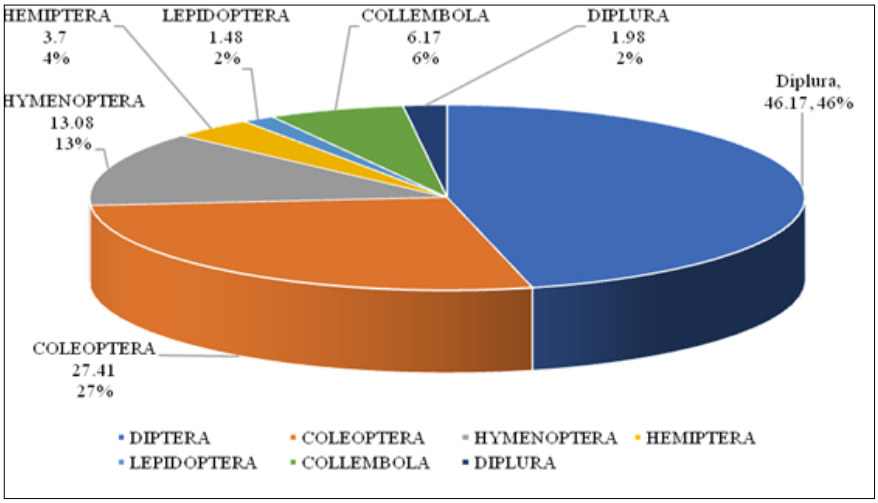

Fig 2: Relative abundance of different orders of different insects collected from mushroom of 3 districts

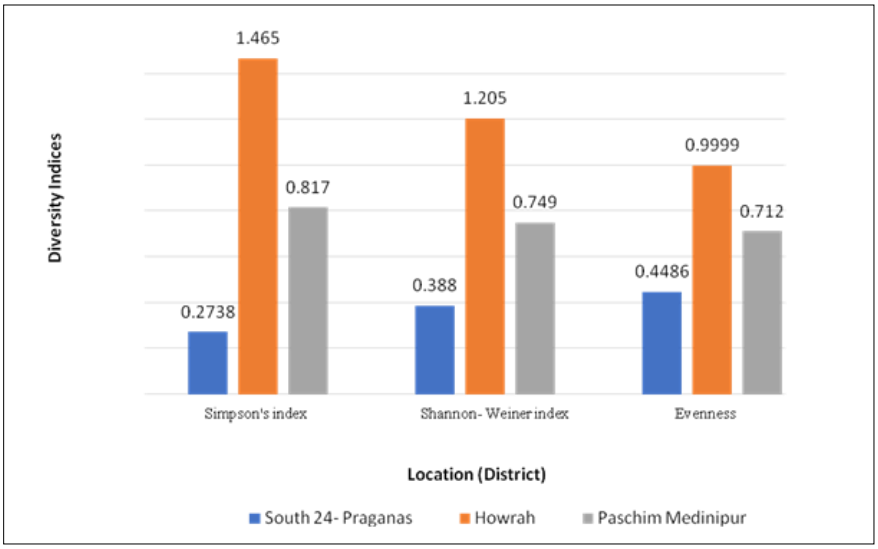

Fig 3: Bar diagram showing Diversity indices like Simpson's index(D), Shannon-Weiner index (H), Evenness (E). Index at Study site 1: South 24- Parganas, Study site 2: Howrah and Study site 3: Paschim Medinipur

Insect collection during the study
District- South 24- Parganas
(Ramakrishna Mission, Narendrapur and Chintamani Kar Bird Sanctuary)

Fig 4: Order- Diptera

Fig 5: Order- Hemiptera

Fig 6: Order- Collembola

Fig 7: Order- Diplura

Fig 8: Order- Hymenoptera

Fig 9: Order- Coleoptera

District- Howrah
(Acharya Jagadish Chandra Bose gardens)

Fig 10: Order- Diptera

Fig 11: Order- Coleoptera

Fig 12: Order- Hymenoptera

Fig 13: Order- Lepidoptera

Fig 14: Order- Collembola

District- Howrah
(Paschim Medinipur [Belda])

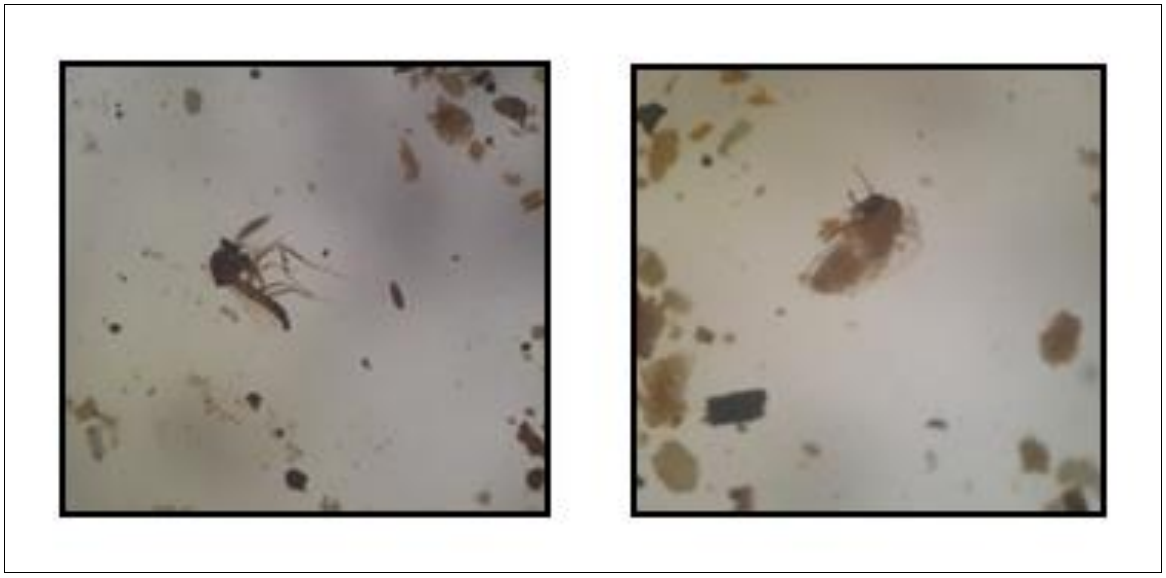

Fig 15: Order- Diptera

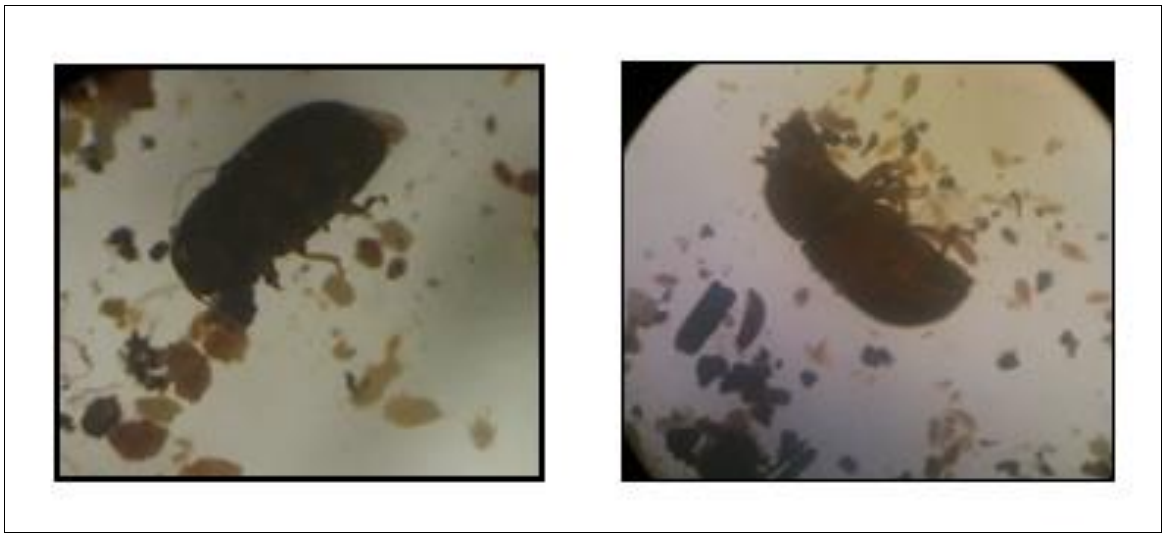

Fig 16: Order- Coleoptera

Fig 17: Order- Hymenoptera

Fig 18: Order- Hemiptera

Discussion

In the present study insect orders and families associated with wild mushrooms were collected from three districts of West Bengal (South 24 Parganas, Howrah and Paschim Medinipur). The examination of the collected specimens reveals the occurrence of 21 families of insects belonging to 7 orders. Of these, 6 families (Phoridae, Sciaridae, Cecidomyiidae, Muscidae, Drosophilidae, Mycetophilidae) belongs to the order Diptera, 7 families (Curculionidae, Carabidae, Erotylidae, Tenebrionidae, Staphylinidae, Nitidulidae, Scarabaeidae) belong to the order Coleoptera, 1 family (Formicidae) belongs to the order Hymenoptera, 3 families (Reduviidae, Lygaeidae, Cicadidae) belong to the order Hemiptera, 1 family (Noctuidae) belongs to the order Lepidoptera, 2 families (Isotomidae, Entomobryidae) belongs to the Collembola, 1 family (Campodeidae) belong to order Diplura.

The mushrooms also conform to the observations made by Jonathan *et al.* [13] who encountered Collembola and Diptera orders of insects and Oyebamijii *et al.* [14] also found Collembola and Diptera orders of insect and he also reported Araneae order. Some orders Coleoptera and Diptera reported by Tuno [15,16]; Kadowaki [17]. Diptera order also shown by Yamashita and Hijii [18]. Hosaka and Uno [19]reported verity species of maggot flies which included order of Diptera.

Some orders were shown by Nongkynrih *et al.* [20] reported various arthropods pests, viz. pleasing fungus beetles, Sciarid fly, Mycetophilid fly, Fruit fly, Noctuid moth, Springtails which belongs to Diptera, Coleoptera, Lepidoptera, Collembola. Ganeswaran and Wijayagunasekara [21] studied the same orders Diptera, Coleoptera, Collembola and Lepidoptera. Joshi *et al*. [22] and Kumar *et al.* [23]also recorded the same orders. The

Orders Hymenoptera, Diptera and Collembola were also recorded by Gupta and Mondal [24]. Gibson and Hunter [25], Vega and [26] also reported order Hemiptera from mushrooms.

From this study, the insect order Diplura was reported for the first time from the wild mushroom (present in a sample of the South 24- Parganas district, West Bengal).

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