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INSECT POLLINATOR DIVERSITY AND THEIR FLORAL PREFERENCES: A SEASONAL AND HABITAT-WISE ANALYSIS OF ABUNDANCE AND SPECIES RICHNESS

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Abstract. Insect pollinators are important in maintaining biodiversity and increasing agricultural productivity by promoting plant reproduction. Field surveys were conducted to assess insect pollinators diversity, abundance and floral preferences in the Ramnagar area of Purba Medinipur district in West Bengal, India. The scan sampling method was employed to investigate the diversity of insect pollinators across three habitats viz. agriculture fields (AF), orchards (OR), and natural vegetation (NV) for a year to capture temporal and seasonal variation in pollinator activity. A total of 44 species belonging to 18 families and 4 orders were recorded. Lepidoptera was the most abundant (1689 individuals) group followed by Hymenoptera (1211), Diptera (717) and Coleoptera (335). The highest abundance was observed in AF (1460) followed by OR (1359) and NV (1133) but NV exhibited the highest species richness (44 species) among the three habitats. Seasonal analysis of abundance exhibited the highest value during post-monsoon (1934) and the lowest value during monsoon (552). ANOVA test confirmed significant seasonal variations. Shannon and Simpson index values for diversity suggest a quite healthy diversity of insect pollinators. This study highlights the significance of habitat conservation for supporting insect pollinators, which in turn maintains ecological balance and enhances agriculture production. It presents crucial knowledge for future research on conservation of insect pollinators and their habitats.

INTRODUCTION

Although ecosystem functioning depends on insect pollinators, little is known about the ecological factors controlling the composition of native pollinator populations (Diniz-Filho et al. 2010). Spatial variance in the composition of insect pollinators can be predicted by habitat heterogeneity ((Reverté et al. 2019; Rohde and Pilliod 2021). Pollinators are influenced by the distribution of flowering plants, soil composition, and other environmental factors (Aguirre-Gutiérrez et al. 2015). Successful pollinators need abundant foraging and nesting materials within their home areas (Rands and Whitney 2011). Consequently, the initiatives to preserve pollinators depend on the establishment of superior habitats featuring a variety of host plants and microhabitats (Donaldson et al. 2002). Insect pollinator communities are understudied in most environments, although their spatial variation is crucial for agricultural and non-agricultural pollination services, as well as conservation efforts for these mobile species (Katumo et al. 2022). Insect pollination makes a major contribution to the biological functioning of every terrestrial ecosystem (Woodward and Bohan 2016).

Pollinator insects like butterflies, bees, flies, moths etc. are crucial as they support balance in natural ecosystems and agriculture productivity (Wojcik 2021). They have been reported to pollinate above 80% of wild flora and almost 75% of cultivated species (Thomann et al. 2013). Human health, agriculture and natural resources are influenced by insect ecology and diversity (Scudder 2017). The variety of pollinators reduces the risk of inadequate pollination during the critical period of crop pollination. Studies indicate that reduced pollination results from a global decline in the variety and number of insect pollinators (Polce et al. 2014).

The Ramnagar area is situated in the Purba Medinipur district of West Bengal and is characterised by various habitats like paddy fields, orchards, vegetable crops and patches of natural vegetation. Lack of previous research makes it essential to highlight the ecological significance of insect pollinators in this area. This study aims to assess the diversity and abundance of insect pollinators, their floral preferences and the influence of habitat and seasonal variations on them. Comprehending the dynamics of pollinator groups may inspire sustainable agricultural practices, sustaining vital ecosystem services that enhance crop yields and ecological integrity.

The outcomes of this study will establish a baseline for subsequent research and conservation initiatives in the field, as well as providing recommendations to augment insect pollinator diversity and abundance in agricultural environments.

MATERIALS AND METHODS

Study Site

The present study was carried out on the diversity and floral preferences of insect pollinators from the Ramnagar area. It has a latitude of 21.6745°N and a longitude of 87.5593°E. It is located in the Purba Medinipur district of West Bengal, India.

Study Design

This study employed an observational study design and was conducted between 01 October 2023 and 30 September 2024 in different habitats of the Ramnagar area. Three types of habitats were naturally prominent within the study area. The first one was natural vegetation where grasslands and stretches of native flora were present. The second one was orchards dominated by fruit plants, and the last one was agriculture fields where vegetable plants and paddy were cultivated. Field surveys were conducted during pre-monsoon (March–June), monsoon (July–September) and post-monsoon (October–February) to record seasonal variation in insect pollinator numbers and diversity. A total of 15 sites were selected (five for each habitat), and each site was visited four times per season to minimise disturbances to the pollinators. Sampling was conducted mainly between 8 am and 4 pm when pollinator activity remains high.

Data Collection

Samples were collected on bright, clear days by using pan traps, sweep nets and hand picking. White, yellow and blue pan traps were used for capturing the diversity of floral visitors (Wilson et al. 2008). The pan traps (Chinga et al. 2023) were filled with 300 ml of water and 4 ml of odourless liquid soap. The traps were installed in the chosen area in the early hours of the day and withdrawn in the afternoon to document all insect visitors. Subsequently, the soapy water in the pan traps was filtered to isolate the captured specimens by passing it through a mesh. Sealed plastic containers were used to preserve the insect specimens. Transect walks were carried out utilising sweep nets with a diameter of 30 cm and mesh size of 2.5 mm to randomly collect samples from the vegetation (Templ et al. 2019; Leung et al. 2022). Scan sampling (Koneri et al. 2020) and handpicking methods (Mattu and Nirala 2016) were also employed. To keep track of how the numbers and types of insect pollinators change over time, sampling attempts were split into three groups: pre-monsoon, monsoon, and post-monsoon. Specimens were preserved in 100% alcohol. Species identification was done with appropriate taxonomic keys (Perveen and Fazal 2013). Handbooks by Wynter Blyth (2009) and Evans (1932) were also used.

Data Analysis

Species diversity was measured with the Shannon-Wiener diversity index (H) as well as the Simpson diversity index (D). Species richness evaluates biodiversity depending on sampling size and effort to identify the number of species in an area (Hussain et al. 2021). ANOVA (one-way) was carried out in order to conclude on the significance of differences in abundance seasonally. All the tables, graphs and statistics were carried out with the help of MS-Word and MS-Excel.

RESULTS

The present study conducted in different habitats of the Ramnagar area in Purba Medinipur district of West Bengal yielded a comprehensive dataset on the abundance and diversity of pollinators and their floral connections. A total of 44 pollinator species belonging to 18 families and 4 orders were recorded during the study period (Table 1). Lepidoptera was the most abundant group with 18 species, accounting for 43% of the total pollinators observed. Hymenoptera was the second most abundant group accounting for 31% of the total pollinators observed. Coleoptera was the least abundant (8%) group with 4 species (Figure 1).

The Shannon- Wiener diversity index (H) and Simpson's diversity index (D) were used to calculate the pollinator diversity in the Ramnagar area. The values of H and D were 3.86 and 0.97, respectively. The highest H value was observed in NV (3.98) followed by AF (3.88) and OR (3.73) (Figure 2).

Among the families, Nymphalidae was most abundant (764 individuals), followed by Apidae (559), Papilonidae (388), Formicidae (301), Pieridae (289), Drossophilidae (234) and Muscidae (204). In contrast, Megachilidae and Halictidae were the two least abundant (39 and 47 individuals, respectively) families (Figure 3).

Species richness was the highest in natural vegetation (NV) with 44 species, whereas orchards (OR) and agriculture fields (AF) were found to be inhabited by 42 species of pollinators each (Figure 4). Variable pollinator abundance was observed across habitat types. A total of 1460 individuals were recorded from AF, OR supported

1359 individuals, and in NV the abundance was 1133, which is the lowest amongst the habitats (Figure 4). Although the species richness during pre-monsoon (PRM) and post-monsoon (POM) was found to be similar (44 species) but the abundance was significantly higher during POM season. Comparatively, both abundance (552) and species richness (35) were quite low during monsoon (M) season (Figure 5).

One way ANOVA was conducted to find out if the differences in abundance across different seasons was

Table 1. Order, family, species and spatial and temporal abundance as recorded during study period in Ramnagar.

Serial No.	Order	Family	Species	Abundance (N)									
				PRM			M			POM			Total
				AF	OR	NV	AF	OR	NV	AF	OR	NV	
1	Hymenoptera	Apidae	*Apis mellifera*	29	28	18	10	7	5	19	17	10	143
2		Apidae	*Tetragonula* sp.	9	9	7	5	6	4	9	6	6	61
3		Apidae	*Xylocopa* sp.	8	7	4	4	3	1	6	4	2	39
4		Apidae	*Apis cerana indica*	25	21	17	11	8	3	17	16	12	130
5		Apidae	*Apis florea*	13	10	9	8	6	3	9	7	5	70
6		Apidae	*Apis dorsata*	12	13	10	6	5	4	10	8	7	75
7		Apidae	*Ammegillazonata*	11	10	8	0	0	0	7	3	2	41
8		Halictidae	*Halictus* sp.	13	11	9	0	0	0	4	5	5	47
9		Megachilidae	*Megachile* sp.	0	5	7	0	3	2	7	9	6	39
10		Scoliidae	*Scolia affinis*	12	12	10	6	7	3	9	8	5	72
11		Vespidae	*Vespa* sp.	9	8	8	6	3	3	8	8	7	60
12		Vespidae	*Polistes sagittarius*	9	11	13	7	3	4	9	9	5	70
13		Vespidae	*Polistes wattii*	13	13	8	4	2	2	7	8	6	63
14		Formicidae	*Camponotus* sp.	8	6	4	0	0	0	7	8	6	39
15		Formicidae	*Myrmicaria brunnea*	0	0	4	0	0	0	0	0	6	10
16		Formicidae	*Iridomyrmex anceps*	0	0	8	0	0	0	0	0	9	17
17		Formicidae	*Oecophylla smaragdina*	21	25	20	8	7	7	13	12	11	124
18		Formicidae	*Lasius niger*	19	24	18	9	0	0	17	9	15	111
		Subtotal		**211**	**213**	**182**	**84**	**60**	**41**	**158**	**137**	**125**	**1211**
19	Diptera	Syrphidae	*Phytomia* sp.	21	23	19	14	12	10	13	17	14	143
20		Bombyliidae	*Bombylius major*	19	12	10	17	17	14	19	15	13	136
21		Muscidae	*Musca domestica*	29	19	20	27	22	15	27	25	20	204
22		Drosophilidae	*Drosophila melanogaster*	32	41	18	25	31	19	25	27	16	234
		Subtotal		**101**	**95**	**67**	**83**	**82**	**58**	**84**	**84**	**63**	**717**
23	Coleoptera	Coccinellidae	*Coccinella transversalis*	9	9	9	8	8	5	10	12	9	79
24			*Epilachna vigintioctopunctata*	8	9	7	9	9	7	13	14	11	87
25		Cantharidae	*Cantharis* sp.	6	8	5	7	5	5	16	13	12	77
26		Chrysomelidae	*Aulacophora foevicollis*	9	5	8	9	7	5	17	18	14	92
		Subtotal		**32**	**31**	**29**	**33**	**29**	**22**	**56**	**57**	**46**	**335**
27	Lepidoptera	Nymphalidae	*Danaus melanippus hegesippus*	9	7	7	0	0	0	29	27	25	104
28		Nymphalidae	*Euploea klugii*	12	12	9	2	1	0	27	23	20	106
29		Nymphalidae	*Junonia almanac*	11	10	10	1	1	3	22	24	21	103
30		Nymphalidae	*Danaus genutia*	14	12	7	0	0	0	23	20	25	101
31		Nymphalidae	*Phalanta phalanta*	11	13	9	2	4	2	26	18	20	105
32		Nymphalidae	*Junonia atlites*	10	9	12	3	3	1	19	17	14	88
33		Nymphalidae	*Precis iphita*	8	10	8	0	0	0	15	17	12	70
34		Nymphalidae	*Danaus chrysippus*	9	10	7	2	0	1	19	21	18	87
35		Pieridae	*Eurema hecabe*	12	13	9	0	0	4	21	21	20	100
36		Pieridae	*Pareronia hippia*	10	8	8	1	1	2	23	20	18	91
37		Pieridae	*Catopsilia pomona*	13	11	9	0	1	2	21	22	19	98
38		Papilonidae	*Graphium agamemnon*	9	9	6	1	0	3	25	18	21	92
39		Papilonidae	*Graphium doson*	10	11	9	1	0	0	29	26	20	106
40		Papilonidae	*Papilio demoleus*	13	9	9	3	0	1	27	20	19	101
41		Papilonidae	*Papilio memnon*	8	7	7	2	2	1	24	23	15	89
42		Hesperiidae	*Borbo cinnara*	9	9	8	1	3	1	22	21	19	93
43		Erebidae	*Euchromiya polymena*	9	8	5	2	2	0	21	19	16	82
44		Erebidae	*Asotacaricae*	8	9	4	0	0	0	19	19	14	73
		Subtotal		**185**	**177**	**143**	**21**	**18**	**21**	**412**	**376**	**336**	**1689**

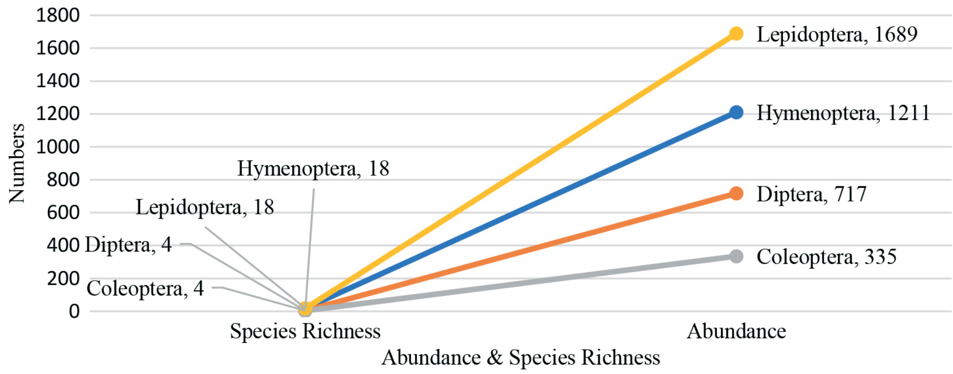

Figure 1. Order-wise abundance and species richness of pollinators.

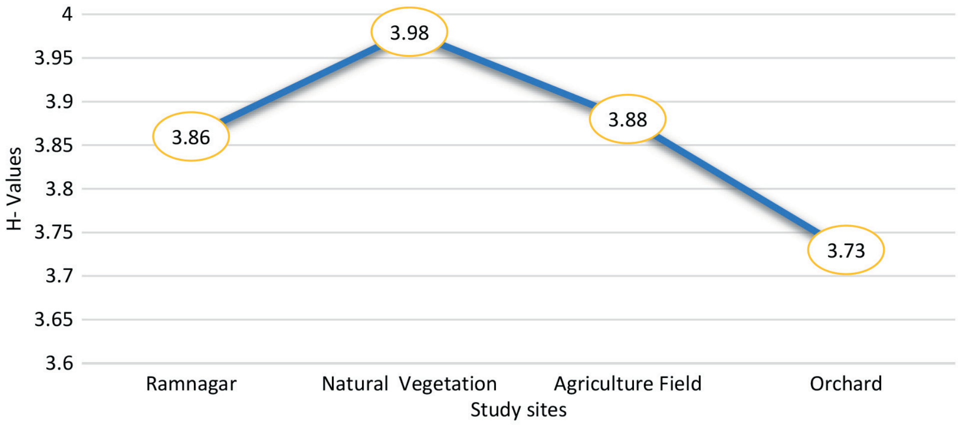

Figure 2. Species diversity in Ramnagar overall and throughout individual sites.

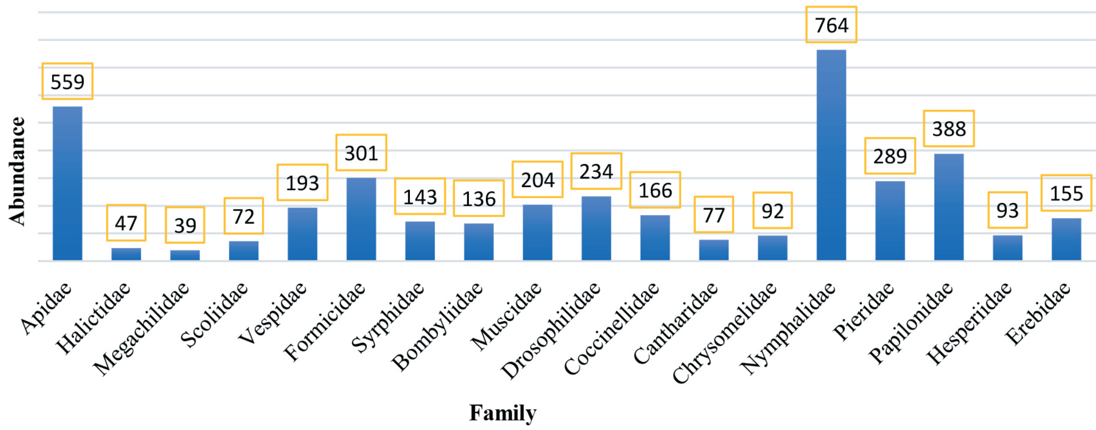

Figure 3. Family-wise abundance of pollinators.

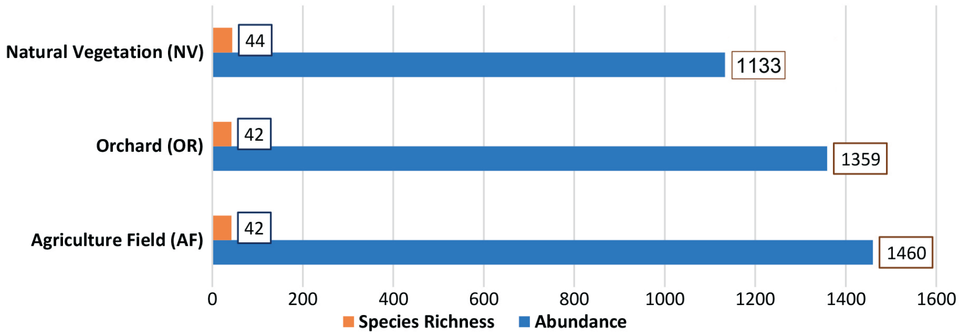

Figure 4. Habitat-wise total abundance and species richness.

Table 2. ANOVA table for seasonal variation in abundance.

Source of variation	SS	df	MS	F	*p*-value	F crit
Between groups	2472984	1	2472984	10.004	0.034	7.708
Within groups	988747.333	4	247186.833			
Total	3461731.333	5				

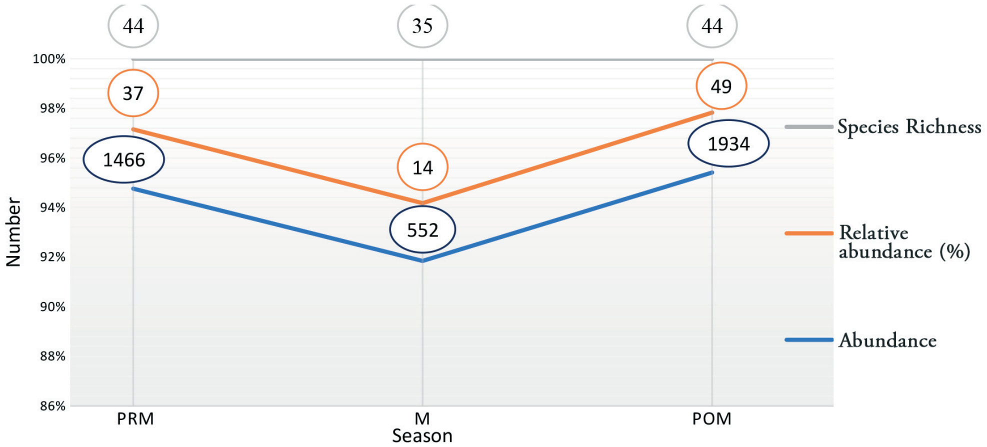

Figure 5. Seasonal variation in abundance, relative abundance and species richness (PRM – pre-monsoon, M – monsoon, POM – post-monsoon).

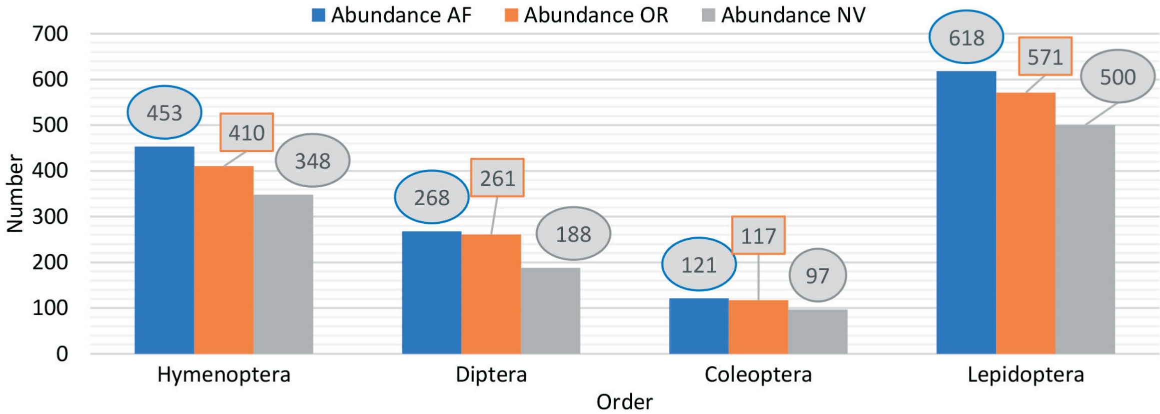

Figure 6. Order-wise abundance across various habitats.

significant or not. The calculated F value was 10.004 with a *p*-value of 0.034 (Table 2), thus differences were significant.

In all three types of habitats a similar trend was observed where Lepidoptera was most prevalent in number followed by Hymenoptera, Diptera and Coleoptera (Figure 6).

Among the pollinator species, *Drosophila melanogaster* (234), *Musca domestica* (204), *Phytomia sp.* (143), *Apis mellifera* (143) and *A. cerana indica* (130) were mostly encountered. *Euploea klugii* (106), *Graphium doson* (106), *Phalanta phalanta* (105), and *Danaus melanippushagesippus* (104) were most abundant butterflies of this region (Table 3).

Generalist pollinators like *Apis mellifera*, *Apis cerana indica* etc. favoured diverse families like Fabaceae, Asteraceae, Arecaceae, Myrtaceae etc., while specialized pollinators like *Aulacophora foevicollis* favoured only the Cucurbitaceae family. Some pollinators like *Apis mellifera*, *Tetragonula* sp. were seen to visit 11 plant species (Table 3) showcasing their broader ecological role.

DISCUSSION

The results of the current study provide important insights into the diversity and abundance of insect pollinators in the Ramnagar area of Purba Medinipur district in West Bengal. Although pollinator abundance was lowest in natural vegetation (NV), the species richness was similar to that of agricultural field (AF). This emphasizes the critical role that diverse, undisturbed habitats play

Table 3. Species (and their abundance), common name and their floral preferences (family and species) as recorded during study period in Ramnagar.

Pollinators				Visited flora	
Order	Family	Species (abundance)	Common name	Family	Species
Hymenoptera	Apidae	*Apis mellifera* (143)	European bee	Fabaceae	*Acacia auriculiformis*
				Cucurbitaceae	*Cucurbita maxima*
				Brassicaceae	*Brassica nigra* *Raphanus sativus*
				Asteraceae	*Helianthus annuus* *Chrysanthemum indicum*
				Arecaceae	*Borassus flabellifer* *Cocos nucifera*
				Apiaceae	*Coriandrum sativum* *Foeniculum vulgare*
				Myrtaceae	*Eucalyptus* sp.
		Tetragonula sp. (61)	Stingless bee	Anacardiaceae	*Mangifera indica*
				Apiaceae	*Coriandrum sativum*
				Arecaceae	*Borassus flabellifer* *Cocos nucifera*
				Asteraceae	*Chrysanthemum indicum*
				Brassicaceae	*Brassica* sp.
				Rhamnaceae	*Ziziphus mauritiana*
				Meliaceae	*Azadirachta indica*
				Myrtaceae	*Eucalyptus* sp.
				Lamiaceae	*Ocimum tenuiflorum*
				Fabaceae	*Acacia auriculiformis*
		Xylocopa sp. (39)	Carpenter bee	Asteraceae	*Helianthus annuus* *Parthenium hysterophorus*
				Myrtaceae	*Eucalyptus* sp.
				Convolvulaceae	*Ipomoea* sp.
		Apis cerana indica (130)	Indian honey bee	Myrtaceae	*Eucalyptus* sp. *Psidium guajava*
				Brassicaceae	*Brassica* sp.
				Arecaceae	*Cocos nucifera*
				Fabaceae	*Acacia auriculiformis*
		Apis florea (70)	Little honey bee	Brassicaceae	*Brassica* sp.
				Myrtaceae	*Eucalyptus* sp.
				Apiaceae	*Coriandrum sativum*
				Asteraceae	*Helianthus annuus* *Chrysanthemum indicum*
				Arecaceae	*Borassus flabellifer* *Phoenix sylvestris*
				Rutaceae	*Citrus grandis*
		Apis dorsata (75)	Rock bee	Brassicaceae	*Brassica* sp.
				Myrtaceae	*Eucalyptus* sp.
				Arecaceae	*Borassus flabellifer*
				combretaceae	*Terminalia arjuna*
				Apiaceae	*Foeniculum vulgare*
		Ammegilla zonata (41)	Blue banded bee	Fabaceae	*Butea monosperma* *Delonix regia* *Albizia procera*
				Bombacaceae	*Bombax ceiba*
				Malvaceae	*Hibiscus rosa sinensis*
				Apocynaceae	*Alstonia schloris*
	Halictidae	*Halictus* sp. (47)	Sweat bee	Brassicaceae	*Brassica* sp.
				Rutaceae	*Citrus limon*
				Cucurbitaceae	*Citrullus lanatus*
				Anacardiaceae	*Anacardium occidentale*
	Megachilidae	*Megachile* sp. (39)	Leaf cutter bees	Asteraceae	*Helianthus annuus* *Tagetes* sp.
				Verbenaceae	*Lantana camara*
				Pedaliaceae	*Sesamum indicum*
				Brassicaceae	*Brassica* sp.
				Lamiaceae	*Ocimum* sp.

Pollinators				Visited flora	
Order	Family	Species (abundance)	Common name	Family	Species
Hymenoptera	Scoliidae	*Scolia affinis* (72)	Solitary mammoth wasp	Verbenaceae	*Lantana camara*
				Fabaceae	*Crotalaria* sp.
				Apocynaceae	*Calotropis gigantea*
				Asteraceae	*Bidens Pilosa* *Tridax procumbens*
	Vespidae	*Vespa* sp. (60)	hornets	Anacardiaceae	*Mangifera indica*
				Verbenaceae	*Lantana camara*
				Myrtaceae	*Eucalyptus* sp. *Psidium guajava* *Syzygium cumini*
				Brassicaceae	*Brassica* sp.
				Caricaceae	*Carica papaya*
		Polistes Sagittarius (70)	Banded paper wasp	Verbenaceae	*Lantana camara*
				Asteraceae	*Tridax procumbens*
				Lamiaceae	*Clerodendrum indicum*
				Convolvulaceae	*Ipomoea indica*
		Polistes wattii (63)	Yellow paper wasp	Verbenaceae	*Lantana camara*
				Asteraceae	*Tridax procumbens* *Parthenium hysterophorus*
				Lamiaceae	*Clerodendrum indicum*
				Apocynaceae	*Calotropis gigantea*
	Formicidae	*Camponotus* sp. (39)	Carpenter ant	Anacardiaceae	*Mangifera indica*
				Lamiaceae	*Tectona grandis*
				Moraceae	*Artocarpus heterophyllus*
				Fabaceae	*Tamarindus indica* *Acacia auriculiformis*
				Myrtaceae	*Psidium guajava*
				Verbenaceae	*Lantana camara*
		Myrmicaria brunnea (10)	Hunchback ant	Fabaceae	*Crotalaria juncea* *Mimosa pudica*
				Moringaceae	*Moringa oleifera*
				Verbenaceae	*Lantana camara*
				Asteraceae	*Tridax procumbens*
		Iridomyrmex anceps (17)	Asian tyrant ant	Anacardiaceae,	*Mangifera indica*
				Cucurbitaceae	*Cucumis sativus*
				Brassicaceae	*Brassica oleracea var. capitata*
				Zingiberaceae	*Zingiber officinale*
				Asteraceae	*Helianthus annuus*
		Oecophylla smaragdina (124)	Red ant	Anacardiaceae	*Mangifera indica*
				Rutaceae	*Citrus limon*
				Meliaceae	*Azadirachta indica*
				Moraceae	*Ficus carica*
		Lasius niger (111)	Black ant	Anacardiaceae	*Mangifera indica*
				Cucurbitaceae	*Cucumis sativus*
				Brassicacea	*Brassica oleracea var. capitata*
				Lamiacea	*Ocimum sanctum*
				Asteraceae	*Helianthus annuus*
Diptera	Syrphidae	*Phytomia* sp. (143)	Hover fly	Apiaceae	*Coriandrum sativum*
				Brassicaceae	*Brassica oleracea var. capitata*
				Asteraceae	*Helianthus annuus* *Tagetes erecta*
				Verbenaceae	*Lantana camara*
	Bombyliidae	*Bombylius major* (136)	Bee flies	Malvaceae	*Hibiscus rosa sinensis*
				Asteraceae	*Tagetes erecta* *Zinnia elegans* *Cosmos bipinnatus*
				Verbenaceae	*Lantana camara*
	Muscidae	*Musca domestica* (204)	House fly	Asteraceae	*Tagetes erecta* *Helianthus annuus*
				Verbenaceae	*Lantana camara*
				Convolvulaceae	*Ipomoea carnea*
				Cucurbitaceae	*Cucurbita maxima*
				Anacardiaceae	*Mangifera indica*

Pollinators				Visited flora	
Order	Family	Species (abundance)	Common name	Family	Species
Diptera	Drosophilidae	*Drosophila melanogaster* (234)	Fruit fly	Anacardiaceae	*Mangifera indica*
				Rutaceae	*Citrus limon*
				Cucurbitaceae	*Cucumis melo*
				Bromeliaceae	*Ananas comosus*
				Solanaceae	*Solanum lycopersicum*
				Moraceae	*Ficus carica*
Coleoptera	Coccinellidae	*Coccinella transversalis* (79)	Lady bird beetle	Anacardiaceae	*Mangifera indica*
				Rutaceae	*Citrus limon*
				Brassicaceae	*Brassica oleracea var. capitata*
				Solanaceae	*Solanum melongena*
		Epilachna vigintioctopunctata (87)	Hadda beetle	Solanaceae	*Solanum melongena* *Solanum lycopersicum* *Solanum tuberosum*
				Cucurbitaceae	*Cucumis sativus* *Cucurbita maxima* *Luffa acutangula*
	Cantharidae	*Cantharis* sp. (77)	Soldier beetle	Asteraceae	*Tagetes erecta* *Zinnia elegans* *Dahlia pinnata* *Helianthus annuus*
				Verbenaceae	*Lantana camara*
	Chrysomelidae	*Aulacophora foevicollis* (92)	Pumpkin beetle	Cucurbitaceae	*Cucumis sativus* *Cucurbita maxima* *Cucurbita pepo* *Cucumis melo* *Lagenaria siceraria* *Momordica charantia*
Lepidoptera	Nymphalidae	*Danaus melanippus hegesippus* (104)	Black veined tiger	Verbenaceae	*Lantana camara*
				Lamiaceae	*Clerodendrum infortunatum*
				Apocynaceae	*Asclepias* spp.
				Asteraceae	*Eupatorium odoratum*
				Rubiaceae	*Ixora coccinea*
		Euploea klugii (106)	Brown King Crow/King Crow	Asteraceae	*Ageratum conyzoides*
				Verbenaceae	*Lantana camara*
				Lamiaceae	*Clerodendrum infortunatum*
				Fabaceae	*Crotalaria* sp.
				Apocynaceae	*Asclepias* spp.
		Junonia almanac (103)	Peacock Pansy	Verbenaceae	*Lantana camara*
				Asteraceae	*Tagetes erecta* *Ageratum conyzoides* *Zinnia elegans* *Helianthus annuus*
				Rubiaceae	*Ixora coccinea*
				Apocynaceae	*Calotropis gigantea*
				Lamiaceae	*Clerodendrum infortunatum*
		Danaus genutia (101)	Striped tiger / Common tiger	Verbenaceae	*Lantana camara*
				Apocynaceae	*Asclepias* spp. *Catharanthus roseus* *Calotropis* spp.
				Asteraceae	*Cosmos bipinnatus*
		Phalanta phalanta (105)	Common leopard butterfly	Verbenaceae	*Lantana camara*
				Solanaceae	*Cestrum nocturnum*
				Apocynaceae	*Asclepias* spp.
				Lamiaceae	*Clerodendrum infortunatum*
				Rubiaceae	*Ixora coccinea*
				Asteraceae	*Zinnia elegans*
		Junonia atlites (88)	Grey pansy	Verbenaceae	*Lantana camara* *Stachytarpheta indica*
				Asteraceae	*Ageratum conyzoides* *Eupatorium odoratum*
				Acanthaceae	*Barleria* spp. *Asystasiagangetica*
		Precis iphita (70)	Chocolate pansy	Verbenaceae	*Lantana camara* *Duranta repens*
				Asteraceae	*Ageratum conyzoides* *Eupatorium odoratum*
				Apocynaceae	*Catharanthus roseus*
				Anacardiaceae	*Anacardium occidentale*
				Polygonaceae	*Antigonon leptopus*

Pollinators				Visited flora	
Order	Family	Species (abundance)	Common name	Family	Species
Lepidoptera	Nymphalidae	*Danaus chrysippus* (87)	The plain tiger	Verbenaceae	*Lantana camara*
				Apocynaceae	*Catharanthus roseus* *Calotropis* spp. *Asclepias* spp.
				Rubiaceae	*Ixora coccinea*
				Asteraceae	*Tridax procumbens*
	Pieridae	*Eurema hecabe* (100)	Common grass yellow	Fabaceae	*Trifolium* sp.
				Verbenaceae	*Lantana camara*
				Apiaceae	*Coriandrum sativum*
				Asteraceae	*Taraxacum* sp.
		Pareronia hippia (91)	Common wanderer / Indian wanderer	Verbenaceae	*Lantana camara*
				Asteraceae	*Aster* spp. *Zinnia* spp. *Tagetes erecta* *Dahlia* spp.
		Catopsilia pomona (98)	Common emigrant	Tropaeolaceae	*Tropaeolum majus*
				Acanthaceae	*Acanthus* sp.
				Fabaceae	*Cassia* sp.
				Verbenaceae	*Lantana camara*
				Malvaceae	*Hibiscus rosa sinensis*
	Papilonidae	*Graphium agamemnon* (92)	Tailed jay	Apocynaceae	*Nerium oleander* *Asclepias* spp.
				Asteraceae	*Eupatorium odoratum* *Zinnia* spp. *Tagetes erecta*
				Rutaceae	*Murraya koenigii*
				Verbenaceae	*Lantana camara*
		Graphium doson (106)	Common jay	Malvaceae	*Hibiscus rosa sinensis*
				Verbenaceae	*Lantana camara*
				Asteraceae	*Zinnia* spp.
				Apocynaceae	*Nerium oleander*
				Rubiaceae	*Mussaenda frondosa*
				Euphorbiaceae	*Euphorbia milii*
				Lamiaceae	*Clerodendrum thomsoniae*
		Papilio demoleus (101)	Citrus butterfly	Rutaceae	*Citrus limon* *Murrayakoenigii*
				Euphorbiaceae	*Euphorbia milii*
				Asteraceae	*Tagetes erecta*
				Verbenaceae	*Lantana camara*
		Papilio memnon (89)	Great Mormon	Malvaceae	*Hibiscus rosa sinensis*
				Asteraceae	*Tagetes erecta* *Zinnia* spp.
				Verbenaceae	*Lantana camara*
				Apocynaceae	*Asclepias* spp.
				Oleaceae	*Jasminum sambac*
	Hesperiidae	*Borbo cinnara* (93)	Rice swift	Poaceae	*Oryza sativa*
				Brassicaceae	*Brassica* spp.
				Apiaceae	*Coriandrum sativum*
				Asteraceae	*Helianthus annuus*
	Erebidae	*Euchromiya polymena* (82)	Wasp moth	Euphorbiaceae	*Euphorbia milii*
				Fabaceae	*Trifolium* sp. *Cassia* sp.
				Lamiaceae	*Clerodendrum infortunatum* *Ocimum sanctum* *Tectona grandis*
				Asteraceae	*Helianthus annuus* *Tagetes erecta* *Zinnia* spp. *Eupatorium odoratum*
		Asota caricae (73)	Tropical tiger moth	Solanaceae	*Cestrum nocturnum* *Datura* spp. *Brugmansia* sp.
				Arecaceae	*Cocos nucifera*
				Caricaceae	*Carica papaya*
				Myrtaceae	*Psidium guajava*
				Asteraceae	*Tagetes erecta* *Zinnia* spp. *Helianthus annuus*

Figure 7. Some pollinators observed during the survey: A) *Euploea klugii*, B) *Junonia atlites*, C) *Junonia almana*, D) *Danaus genutia*, E) *Catopsilia pomona*, F) *Danaus chrysippus*, G) *Apis mellifera*, H) *Phytomia* sp., I) *Amegilla zonata*, J) *Vespa* sp., K) *Halictus* sp., L) *Camponotus* sp., M) *Apis dorsata*, N) *Musca domestica*, O) *Xylocopa* sp.

in maintaining pollinator diversity (Vujanović et al. 2023). Despite supporting lower pollinator abundance, it harbours a wide range of pollinator species including solitary bees and some butterflies, which are often found less frequently in AF. This finding corresponds with earlier research which suggested that NV are important for sustaining pollinator populations as they provide a variety of floral resources, nesting sites and shelter throughout the year (Kennedy et al. 2013). On the other hand, AF exhibited the highest abundance because crops with extensive floral resources such as mustard, pumpkin, sunflower, paddy etc. attract a significant number of pollinators particularly bees and flies. It supports a more homogenous pollinator community dominated by generalist species like *Apis mellifera*, *Apis cerana indica*, *Tetragonula* sp. etc. (Indhu et al. 2022). This result aligns with a previous study that indicates intensive agriculture tends to favour a few dominant pollinator species often in the expense of specialized or less competitive pollinators (Kremen et al. 2007). The significant seasonal fluctuation in pollinator abundance and species richness reflects the impact of floral resource availability and climatic condition on pollinators activity. The lowest pollinator activity across all habitat types was observed during monsoon (M) season, most probably due to high rainfall and a reduction in floral supply. This seasonal pause in pollinator activity is a well-documented phenomenon in tropical and subtropical regions where foraging behaviour and access to floral resources were interrupted by monsoon rain (Lawson and Rands 2019). The pollinator abundance was significantly higher during pre-monsoon (PRM) season, which coincides with the flowering of key crops of this region. This may be due to the profusion of pollen and nectar resources especially in agricultural settings. Pollinator activity can surge specially when large flowering crops are available, as earlier research has shown, although this effect is frequently transient and restricted to the time when the crop blooms (Westphal et al. 2003). After monsoon, pollinator activity increased tremendously, especially in orchards, when fruit trees like guava, mango, custard apple, java plum etc. started to bloom and provide pollinators a new supply of nectars. In contrast to annual crops that provide floral resources only temporarily, orchards are a reliable source of nectar and pollen, especially during post-monsoon. A relatively high species richness and abundance recorded from orchards indicate that they are important habitats for foraging particularly for butterflies, bees and ants. This result is in line with research demonstrating that, in comparison to monoculture crops, orchards can increase pollinator variety and number by offering a more stable and varied range of floral supply (Klein et al. 2006). The ANOVA test also suggested that the variation in pollinator abundance across different seasons was statistically significant (as the calculated F value of 10.004 exceeds the critical F value of 7.708).

For assessing pollinator diversity in the study area, the Shannon-Wiener diversity index (H) and Simpson index (D) were used. Both indexes take into account species richness as well as evenness (Magurran 2003). The estimated H- value of 3.86 indicates that insect pollinator diversity is quite high in the Ramnagar area. The Simpson's index value or D = 0.97 in the study area. As it is closer to 1, so it also implies a high diversity of insect pollinators. The two values complement each other. The calculated H- value in NV was 3.98, which suggests that it harbours the most diverse insect pollinators most likely due to a lack of anthropogenic activities, the presence of a wide range of floral resources and habitat structure (Kevan and Viana 2003). AF with an H- value of 3.88 also supports rich pollinator diversity, which may correspond to its crop variety or presence nearer to NV. Conversely, OR exhibited a slightly lower H- value of 3.73, which may be due to some monoculture practices, pesticide uses or less structural diversity (Tscharntke et al. 2005).

Lepidopteran insects are vital for pollinating plant species in every terrestrial ecosystem worldwide (Macgregor et al. 2014). The present study also reported Lepidoptera as the dominant order. Lepidopterans like bright colours. The floral diversity within the study sites provided a wide range of colour variation of flowers, which may be the cause of their higher abundance than others (Shakeel et al. 2018). The current study also recorded Hymenoptera as the second dominant order. It has also been reported that flowers with a lot of nectars as found in *Brassica* spp. and other wild plants attract hymenopterans. Wild plants and cultivated crops (*Brassica* spp.) secret a huge amount of nectars. This may be the reason of their high abundance (Silva and Dean 2000). Dipterans are important in pollinating crops and natural vegetation. They are vital pollinators for agroand plant biodiversity (Ssymank et al. 2008). They greatly increased insect pollinator abundance in the current study. Significantly, only 8% coleopterans were reported during the present study. Hussain et al. (2023), while studying distribution mechanism of insect pollinators, obtained identical results. The Nymphalidae family may be abundant since they collect pollen and nectar from Verbenaceae, Lamiaceae, Apocynaceae, Asteraceae, Rubiaceae, Fabaceae and other families. These generalist foragers flourish in many habitats, particularly blooming plant ecosystems. Apidae followed Nymphalidae in terms of abundance. They dominated pollination networks due to their social structure and foraging activity, mostly in agricultural settings where bees pollinate crops. A lower abundance observed in families Halictidae and Megachilidae may be due to their specialized foraging behaviour and preference for special floral resources. According to the current study, an abundant flowering plant community promotes a diverse pollinator community. Insect pollinator diversity facilitates floral health and sustains ecosystems. That is why floral diversity and pollinator habitats should be conserved.

CONCLUSION

The findings of the present study represent the first quantitative survey of insect pollinators in the Ramnagar area of Purba Medinipur district in West Bengal. This study revealed the existence of a wide and rich diversity of insect pollinators. Hymenopterans and nymphalids were the most abundant flower visitors. Among various habitats, natural vegetation exhibited the highest species diversity and species richness but abundance was maximum in agriculture fields. A wide variety of floral resources (both family and species) enriched the study area. Agricultural fields deliver rich floral supplies during crop flowering, whereas natural vegetation and orchards are essential for sustaining pollinator species year-round, especially when crop fields provide limited resources. This study suggests that if habitats are managed properly, they could protect insect pollinators, which in turn enhance agriculture production. To sustain insect pollinator populations, this study recommends biodiversity-friendly agricultural strategies like crop diversification, pesticide reduction and plant conservation.

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