Research Article

Density, Abundance and Diversity of Insect Pollinators at Agro-Ecosystems of Kodagu District, Karnataka, India

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ABSTRACT

Aim: Inventorying the insect pollinators and their diversity at different agro-ecosystems of Kodagu district. **Background:** Many insect species play a crucial role in the process of pollination of various flowering plant species amidst diversified agro-ecosystems. Published reports on insect pollinators are diffused and it is necessitated in Kodagu district. Hence, the study of insect pollinators was carried out at different agro-ecosystems of Kodagu district of Karnataka during 2020-2023. **Materials and Methods:** Twelve study sites were selected randomly at different habitats such as plantations, uncultivable lands, paddy fields, horticulture gardens, meadows, scrubby jungle and agriculture farms by following standard methods. **Results:** Total 79 insect species were observed on different flora which belongs to six orders, 22 families and 69 genera. *Hymenopterans* were predominant (86.3%) and it was followed by Lepidopteron (8.1%) found commonly at different agro-ecosystems of Kodagu district. However, *Coleopterans* (1.7%), *Dipterans* (1.7%), *Hemipterans* (1.0%) and *Odonates* (1.1%) were less in number and their per cent occurrence was less than 2. Interestingly, *Apidae* family members of the order *Hymenoptera* were very high and it was followed by *Nymphalidae* and *Pieridae* of the order *Lepidoptera* and *Syrphidae* of the order *Diptera* compared to other families. The diversity indices revealed considerable variations and surprisingly, 2.8% insect pollinators decline was observed at different agro-ecosystems of Kodagu district. **Conclusion:** Thus, present investigation provided an insight on commonly occurring pollinating insect species, their distribution, diversity and declining trend at agro-ecosystems of Kodagu district, Karnataka.

Keywords: Agro-ecosystems, Insect pollinators, Diversity, Kodagu, India.

INTRODUCTION

The pollination is crucial for the development of sexually reproducing plant species. It is one of the most important biological phenomenon help completes the reproductive cycle in flowering plant species. This process helps produce fruits or seeds from flowering plant species. During this process, flowering plants get exposed to a variety of pollen transmission mechanisms such as zoophily, hydrophily, anemophily etc.,[1] have reported animal pollinators of flowering plants. Of all, insects are benevolent pollinators, pollinate 80% of the flowering plants and majority of the crop plants rely on insect species. This process of cross pollination not only enhances the yielding potential but, brings genetic diversity among the plant species.[2,3] have reported on the effects of habitat isolation on pollinator communities and plant seed set. Hence, insect pollinators play a pivotal role in the ecosystem, their diversity help attend pollination of various flowering plant species that could bring propagation of diversified plant species both in human modified landscapes and in the wild.[4] Unfortunately, insect pollinators are declining around

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the world due to various reasons.[5] has highlighted the global pollination crisis and[6] have emphasized the importance of pollinators in changing landscapes for world crops. Around 40% insect pollinators have globally been under threats and their population is declining due to modern agriculture activities, use of pesticides, changes in local weather conditions, which affected the local vegetation cover and source of suitable host plant and food plant species.[7] have reported on the global pollinator declines and its impact and it develops economic consequences at different parts of the world.[8] Therefore, in order to increase the survival rate of insect pollinators, there must be a healthy living space[9] for insect species. Several researchers have recorded the positive correlation between pollinator diversity and plant functioning.[10,11] have recorded the compounded effects of climate change and habitat alteration shift of butterfly diversity. It has been estimated that 1200 species of vertebrates and 80,000 insect species which act as vital pollinators around the world. Among the 80,000 insect species, 17,533 bee species are important in the pollination of various flowering plants around the world.[12] In the nature, the reproduction and survival of many wild plants depend on insect pollination.[13] Floral resources influence the increase of insect pollinators.[14] Many insect species which belong to the order *Hymenoptera, Diptera, Coleoptera, Lepidoptera*, *Thysanoptera, Hemiptera* and *Neuroptera* are crucial to the pollination of various agricultural, horticultural, commercial, medicinal herbs, orchids, etc.,[9] Many diversified habitats, including agro-ecosystems depend on pollinator's diversity to maintain local biodiversity and benefit the society by improving food security and the livelihoods of farmers who are living amidst diversified agro-ecosystems. In this regard, several researchers[2,15-23] have reported on different insect pollinators (e.g. Carpenter bee, *Odonates*, Stingless bees, Blow flies, Flies, etc.,) pollinator efficiency, pollination biology, pollinator webs, plant communities (e.g. *Capsicum annuum, Buchanania lanzan, Coffea Arabica, Brassica napus, Paeonia ostii, Citrullus lanatus, Eruca sativa* and *Brassica rapa Citrus maxima,* Castor species, *Camelia oleifera,* etc.) at greenhouses, agricultural lands, horticultural gardens, institutional campuses and other diversified agro-ecosystems at different parts of the world.[24] Surveyed the Soybean insect pollinators.[25] has reported the environmental change and the distributions of British bumble bees.[26,27] have reported the global pollinator declines, trends and the impact on agriculture. Therefore, maintaining plant diversity is necessary to enhances bees and other insect pollinators in agro-ecosystems.[28] Similarly, in India, 633 insect species which belong to 60 genera in six families were reported as vital pollinators.[13,29-40] have reported the floral biology, floral resource constraints, pollination limitation and insect pollinators. The flies, dragonflies, damselflies, butterflies, hover flies and their population dynamics and diversity on *Carica papaya, Luffa acutangula, Terminalia belerica, Terminalia chebula, Calotropis procera, Guizoti abyssinica, Brassica campestris, Luffa acutangula, Ricinus communis, Caesalpinia cucullata* and strawberry, coriander, apple, peach, pears, citrus plantation and other selected weeds has been reported at Kolkota, Lucknow, Nainital, Uttar Pradesh, Pantnagar, West Bengal, Itanagar, Ranchi, Jammu, Chattisgarh, Gujarat, Thar, Raipur, Jorhat, Karad, Haryana and Aizawl of India. Furthermore,[10,41,42] have reported various pollinators, their diversity, pollination efficiency, foraging behaviour and abundance of honeybees and flies at different landscapes in south India. In Karnataka, only few published reports are available on the diversity, abundance of insect pollinators, pollination efficiency and foraging behaviour and dynamics of honeybees, flies and other *Hymenopterans*.[43-46] have reported the role of insect pollinators on coriander and ajwain, onion, pigeon pea, cucurbit and other crops in a traditional landscape, institutional campuses and agricultural lands at Kumta, Dharwad, Bijapur, Bagalkot, Bengaluru and other parts of north Karnataka. However, in Kodagu district, reports on pollinators at different ecosystems are sparse. Kodagu district is located midst Western Ghats, known for diversified landscape, natural vegetation with different flora and climatic conditions. The bee population decline due to the combined stress from parasites, pesticides and lack of flowers.[47] Moreover, various man-made activities also impacted the bee population in south-western Karnataka.[48] Further, crop intensification also interferes with the diversity of native pollinator communities.[49] Furthermore, various researchers[50-60] have reported the pollinators at various parts of India in general and Karnataka in particular. Inventorying of insect pollinators and their diversity at Kodagu district is scanty. Variety of flowering plants, wild plants including weeds, common fruit yielding plants and commercial crop plantations are grown at different parts of Kodagu district.[61] Published reports on insect pollinators, their distribution and diversity at different landscapes of Kodagu district are poor. Therefore, present investigation was undertaken to record and inventorying the commonly occurring insect pollinators and their diversity at different agro-ecosystems of Kodagu district.

MATERIALS AND METHODS

Study area

The investigation was conducted at randomly selected 12 study sites in Kodagu district (12.15[1]-12.45[1]N, 75.25[1]-76.14[1]E) which is located at an altitude in between 390 to 5,627 ft (Figure 1). Moreover, Kodagu district is with 4,102 square kilometer geographical area and provide birth to the River Cauvery, which drains in the greater part of Kodagu and created exceptional biodiversity.[61] In Kodagu district, the agrarian economy is mainly depended on coffee plantation and other horticultural crops. It has rich floral resources including various insect pollinators.

Methodology

Insect pollinators density, relative abundance, diversity and per cent occurrence was recorded for three years (2020 to 2023) at different study sites (Figure 1) based on the vegetation distribution, topography using Variable Width Line Transect Method (VWLTM) and Visual Count Method (VCM) as per the description of.[62] All Out Search Method (AOSM) was also employed wherever necessitated during the time of need at different agro-ecosystems of Kodagu district as per.[63] During the survey, 50 m length variable width line 500 m transect was earmarked at randomly chosen different agro-ecosystems to record the insect pollinators on various flowering plant species as per the method described by.[62-67] Insect pollinators were recorded on various flowering plant species, which were photographed using digital camera. Pollinating insect species were identified using taxonomic keys and with the help of field entomological guide, research articles and atlas of insects. Diversity indices of pollinators were calculated as per the method of.[68] Moreover, the Shannon-Wiener diversity index (H) was calculated by using H= - Σ pi ln pi. The Simpson diversity index was calculated using D=1- Σ pi and relative abundance was calculated using the formula: Abundance of the species × 100/Total abundance of all species. Analysis of variance was calculated to record the pollinator's distribution from 2021 to 2023. Collected data was

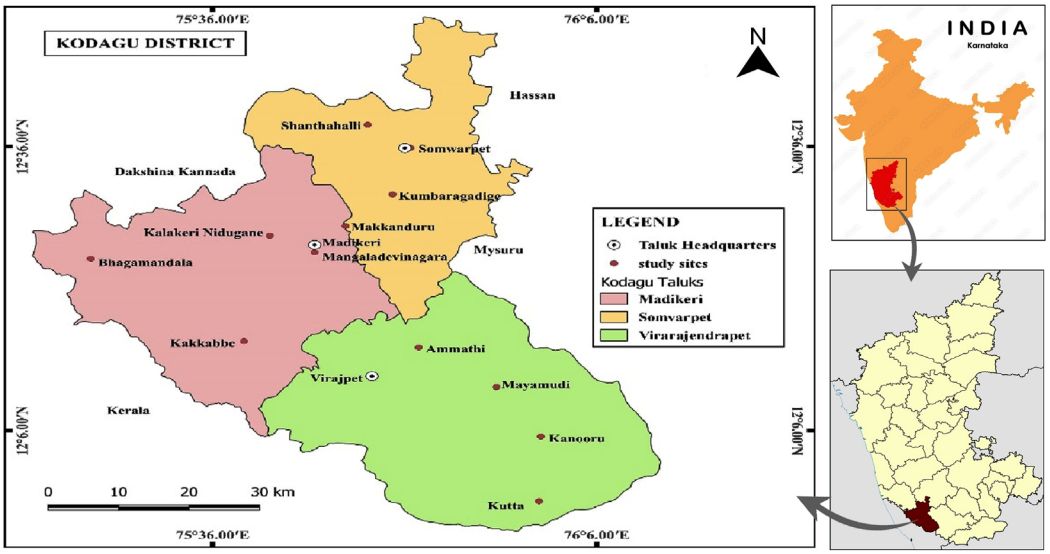

Figure 1: Map Showing the study sites in Kodagu District.

Table 1: Insect pollinators recorded in Kodagu district during 2021 to 2023.

Sl. No.	Order	No. of Families	No. of Species	% Occurrence	Pollinator Density	Relative Abundance
1.	*Coleoptera*	4	6	1.7	0.16	29.68
2.	*Diptera*	3	13	1.7	0.12	13.62
3.	*Hemiptera*	1	1	1.0	0.30	106.30
4.	*Hymenoptera*	7	26	86.3	0.32	345.14
5.	*Lepidoptera*	6	30	8.1	0.19	27.25
6.	*Odonata*	1	3	1.0	0.23	41.73
	Total	22	79	100.0	-	-
	Mean	-	-	-	0.22	93.95

Table 2: Coleopteran, *Dipteran*, *Hemipteran* and Odonate pollinators recorded in Kodagu district.

Order	Sl. No.	Family	Sl. No.	Scientific name	% Occurrence	Pollinator Density	Relative Abundance
Coleoptera	1.	Cantharidae	1.	*Chauliognathus lugubris*	0.14	0.08	15.2
	2.	Chrysomelidae	2.	*Aulacophora* sp.	0.17	0.11	17.7
			3.	*Chrysolina coerulans*	0.18	0.08	19.9
			4.	*Gastrophysa viridula*	0.036	0.08	3.79
	3.	Coccinellidae	5.	*Coccinella septempunctata*	1.02	0.47	106.3
	4.	Lycidae	6.	*Dictyoptera* sp.	0.15	0.12	15.2
Diptera	5.	Calliphoridae	7.	*Calliphora* sp.	0.085	0.03	8.86
			8.	*Chrysomya meghacephala*	0.109	0.08	11.4
			9.	*Hemipyrellia pulchra*	0.097	0.17	10.1
	6.	Muscidae	10.	*Musca domestica*	0.19	0.14	20.2
	7.	*Syrphidae*	11.	*Allograpta obliqua*	0.109	0.08	11.4
			12.	*Asarkina* sp.	0.109	0.05	11.4
			13.	*Eristalinus arvorum*	0.28	0.16	29.1
			14.	*Eristalinus* sp.	0.26	0.11	27.8
			15.	*Helophilus* sp.	0.109	0.25	11.4
			16.	*Ischiodon scutellaris*	0.12	0.12	12.6
			17.	*Lucilia cuprina*	0.133	0.12	13.9
			18.	*Sphaerophoria scripta*	0.048	0.08	5.06
			19.	Unidentified	0.036	0.17	3.79
Hemiptera	8.	Pyrrhocoridae	20.	*Dysdercus cingulatus*	1.02	0.30	106.3
Odonata	9.	*Libellulidae*	21.	*Neurothemis tullia*	0.097	0.12	10.1
			22.	*Orthetrum luzonicum*	0.207	0.16	21.5
			23.	*Sympetrum* sp.	0.90	0.41	93.6

Table 3: Hymenopteran pollinators recorded in Kodagu district.

Sl. No.	Family	Sl. No.	Scientific Name	% Occurrence	Pollinator Density	Relative Abundance
1.	Andrenidae	1.	*Andrena* sp.	0.33	0.14	34.2
2.	*Apidae*	2.	*Amegilla cingulata*	3.62	0.08	375.9
		3.	*Apis cerena*	50.9	01	5293
		4.	*Apis dorsata*	2.216	0.42	230.4
		5.	*Apis florea*	0.38	0.11	40.5
		6.	*Bombus* sp.	0.18	0.16	19.9
		7.	*Ceratina* sp.	1.94	0.55	202.5
		8.	*Heterotrigona itama*	1.035	0.36	107.6
		9.	*Melipona fasciculata*	2.52	0.5	262
		10.	*Tetragonula iridipennis*	0.219	0.08	22.7
		11.	*Tetragonula* sp.	0.060	0.08	6.33
		12.	*Trigona* sp.	1.33	0.42	137.9
		13.	*Xylocopa pubescens*	1.09	0.61	113.9
3.	Crabronidae	14.	*Cerceris* sp.	0.14	0.21	15.2

4.	*Formicidae*	15.	*Camponotus* sp.	4.34	0.27	451.8
		16.	*Lasius niger*	10.09	01	1049
		17.	*Solenopsis geminata*	0.68	0.21	70.8
		18.	*Tetraponera rufonigra*	2.03	0.53	211
5.	Halictidae	19.	*Halictus ligatus*	0.46	0.22	48.1
		20.	*Lasioglossum* sp.	1.60	0.58	167.1
6.	Megachilidae	21.	*Megachile* sp.	0.097	0.08	10.1
7.	*Vespidae*	22.	*Polistes bellicosus*	0.548	0.22	56.9
		23.	*Polistes* sp.	0.036	0.08	3.79
		24.	*Ropalidia marginata*	0.122	0.12	12.6
		25.	*Vespa* sp.	0.109	0.08	11.4
		26.	*Vespa velutina*	0.18	0.19	18.9

Table 4: Lepidopteron pollinators recorded in Kodagu district.

Sl. No.	Family	Sl. No.	Scientific Name	% Occurrence	Pollinator Density	Relative Abundance
1.	Erebidae	1.	*Eressa* sp.	0.41	0.30	43.0
2.	Hesperidae	2.	*Luthrodes pandava*	0.207	0.08	21.5
		3.	*Potanthus omaha*	0.109	0.08	11.4
		4.	*Thoressa sitala*	0.097	0.17	10.1
3.	Lycaenidae	5.	*Lampides boeticus*	0.109	0.08	11.4
		6.	*Prosotas* sp.	0.036	0.08	3.79
		7.	*Talicada nyseus*	0.84	0.38	87.3
		8.	*Zizeeria karsandra*	0.036	0.08	3.79
4.	*Nymphalidae*	9.	*Cupha erymanthis*	0.35	0.19	36.7
		10.	*Hypolimnas bolina*	0.316	0.25	32.9
		11.	*Junonia atlites*	0.073	0.08	7.59
		12.	*Junonia iphita*	0.060	0.08	6.32
		13.	*Junonia lemonias*	0.304	0.33	31.6
		14.	*Neptis hylas*	0.53	0.39	55.7
		15.	*Tirumala limniace*	0.49	0.33	51.8
		16.	*Vanessa cardui*	0.170	0.21	17.7
		17.	*Vindula erota*	0.316	0.25	32.9
		18.	*Ypthima huebneri*	0.048	0.08	5.06
5.	*Papilionidae*	19.	*Graphium sarpedon*	0.024	0.08	2.53
		20.	*Papilio buddha*	0.097	0.08	10.1
		21.	*Papilio polymnester*	0.377	0.28	39.2
		22.	*Papilio polytes*	0.328	0.25	34.2
6.	*Pieridae*	23.	*Catopsilia pomona*	0.19	0.15	20.2
		24.	*Colotis danae*	0.073	0.17	7.59
		25.	*Delias eucharis*	0.55	0.36	56.9
		26.	*Eurema hecabe*	1.20	0.33	125.3
		27.	*Hebomoia glaucippe*	0.060	0.08	6.32
		28.	*Leptosia nina*	0.569	0.27	46.8
		29.	*Pieris canidia*	0.060	0.08	6.33
		30.	*Zizula hylax*	0.060	0.08	6.32

Table 5: Insect pollinator's abundance during 2021 to 2023 in Kodagu district.

Sl. No.	Order	Sl. No.	Family	Species Abundance during		
				2020-21	2021-22	2022-23
1.	Coleoptera	1.	Cantharidae	4.54	4.76	-
		2.	Chrysomelidae	9.09	14.3	11.7
		3.	Coccinellidae	4.54	4.76	5.88
		4.	Lycidae	4.54	0	5.88
2.	*Diptera*	5.	Calliphoridae	4.54	9.52	5.88
		6.	Muscidae	4.54	4.76	5.88
		7.	*Syrphidae*	27.3	28.6	35.2
3.	*Hemiptera*	8.	Pyrrhocoridae	4.54	4.76	5.88
4.	*Hymenoptera*	9.	Andrenidae	4.54	4.76	5.88
		10.	*Apidae*	45.4	52.4	64.7
		11.	Crabronidae	4.54	4.76	-
		12.	*Formicidae*	18.2	19.0	17.6
		13.	Halictidae	9.09	9.52	11.7
		14.	Megachilidae	4.54	4.76	-
		15.	*Vespidae*	22.7	14.3	23.5
5.	*Lepidoptera*	16.	Erebidae	4.54	4.76	5.88
		17.	Hesperidae	13.6	9.52	-
		18.	Lycaenidae	13.6	19.0	-
		19.	*Nymphalidae*	36.3	33.3	58.8
		20.	*Papilionidae*	13.6	19.0	17.6
		21.	*Pieridae*	31.8	23.8	47.1
6.	*Odonata*	22.	*Libellulidae*	9.09	14.3	17.6
		Range		4.54 to 45.4	0.0 to 52.4	0.0 to 64.7
		Mean		13.45	14.51	20.39
		'F' value			1.225*	

Note: *Value is not significant.

systematically compiled and statistically analyzed as per the description of.[68]

RESULTS

Total 79 insect pollinator species which belong to 22 families in six orders were observed at different agro-ecosystems such as plantation crops, paddy fields, meadows, social/agro forests, gardens and other natural and man-made habitats (Table 1). Among the insect pollinators, Lepidopteron species were comprised highest (30) and which represented from six families and it was followed by *Hymenopterans* with 26 species represented from seven families and *Dipterans* with 13 species represented from three families (Table 1). However, the *Coleopterans*, *Odonates* and *Hemipterans* were found 6, 3 and 1 species respectively from 4 and 1 each family (Table 1). Interestingly, *Hymenopterans* predominated more (86.3%) at different agro-ecosystems and it was followed by Lepidopteron species (8.1%) (Table 1). Surprisingly, *Coleopterans* and *Dipterans*, *Hemipterans* and *Odonates* per cent occurrence was 1.7 each and 1.0 each respectively. Further, density and relative abundance of pollinators which belong to different insect orders indicated considerable variation. Pollinator's density was 0.32, 0.30, 0.23, 0.19, 0.16 and 0.12 in *Hymenopterans*, *Hemipterans*, *Odonates*, *Lepidopteran*s, *Coleopterans* and *Dipterans* respectively (Table 1). Moreover, the relative abundance was 345.14, 106.30, 41.73, 29.68, 27.25 and 13.62 in *Hymenopterans*, *Hemipterans*, *Odonates*, *Coleopterans*, *Lepidopteran*s and *Dipterans* respectively (Table 1). Further, on an average the pollinator's density and their relative abundance was respectively 0.22 and 93.95 per 10 square feet area.

Further, family name, species name, per cent occurrence, density and relative abundance of insect pollinators belong to different orders are depicted in Tables 2 to 4. The insect pollinator species which belong to different orders and their family's abundance

ranged from 4.54 to 54.4 with a mean 13.45 during 2020-2021, 0.0 to 52.4 with a mean 14.51 during 2021-2022 and 0.0 to 64.7 with a mean 20.39 during 2022-2023 in Kodagu district. Analysis of variance of pollinator species abundance recorded at different agro-ecosystems didn't show significant difference ($F=1.225$; $p<0.05$) during 2020 to 2023 (Table 5). Further, species belong to *Apidae*, *Nymphalidae*, *Pieridae*, *Syrphidae*, *Vespidae* and *Formicidae* relative abundance was 45.4, 36.3, 31.8, 27.3, 22.7 and 18.2 respectively and it was more compared to other family members, where their relative abundance was less than 15 during 2020-2021. In 2021-2022, the species belong to *Apidae*, *Nymphalidae*, *Syrphidae*, *Pieridae*, Lycaenidae, *Formicidae* and *Papilionidae* relative abundance was 52.4, 33.3, 28.6, 23.8 and 19 each and it was more compared to other family members, where their relative abundance was less than 15. However, during 2022-2023, the species belong to *Apidae*, *Nymphalidae*, *Pieridae*, *Syrphidae*, *Vespidae*, *Formicidae*, *Papilionidae* and *Libellulidae* relative abundance was 64.7, 58.8, 47.1, 35.2, 23.5 and 17.6 each. It was more compared to other family members, where their relative abundance was less than 15 (Table 5). Accordingly, the diversity indices of different insect pollinators indicated considerable difference at various agro-ecosystems of Kodagu district during 2020 to 2023 (Table 6). The insect pollinator dominance was high (0.09351) during 2022-2023 and it was followed by 0.06587 and 0.06498 respectively during 2020-2021 and 2022-2022. Surprisingly, the Simpson ('D') and Shannon diversity ('H') indices and Shannon Evenness (H/S) indicated considerable reduction of pollinators from 2020 to 2023 (Table 6). The Simpson ('D') index of insect pollinators was 0.9341, 0.935 and 0.906 during 2020-2021, 2021-2022 and 2022-2023 respectively. Similarly, the Shannon ('H') index of insect pollinators was 2.926, 2.917 and 2.603 respectively during 2020-2021, 2021-2022 and 2022-2023. Moreover, similar trend was recorded with Shannon Evenness with respect to the insect pollinators at different agro-ecosystems of Kodagu district (Table 6). It is evidenced from the biodiversity indices that the process of insect pollinators decline is set on. Overall, 2.8% insect pollinators decline was recorded during the study period (2020-2023) in Kodagu district (Table 7). Moreover, Figure 2 shows the insect pollinators diversity profile during different years in Kodagu district.

Table 6: Diversity indices of insect pollinators at Kodagu district.

Sl. No.	Diversity Indices	Year		
		2020-21	2021-22	2022-23
1.	Taxa_S	22	21	17
2.	Individuals	65	64	59
3.	Dominance_D	0.06587	0.06498	0.09351
4.	Simpson_1-D	0.9341	0.935	0.9065
5.	Shannon_H	2.926	2.917	2.603
6.	Evenness_e^H/S	0.8475	0.8803	0.7944

Table 7: Insect pollinators recorded in Kodagu district.

Year	Insect Pollinators	% Occurrence	% Decline
2020-21	66	34.2	-
2021-22	66	34.2	0.0
2022-23	61	31.6	2.8
Total	193	100.0	2.8

Note: Data is based on Table 5.

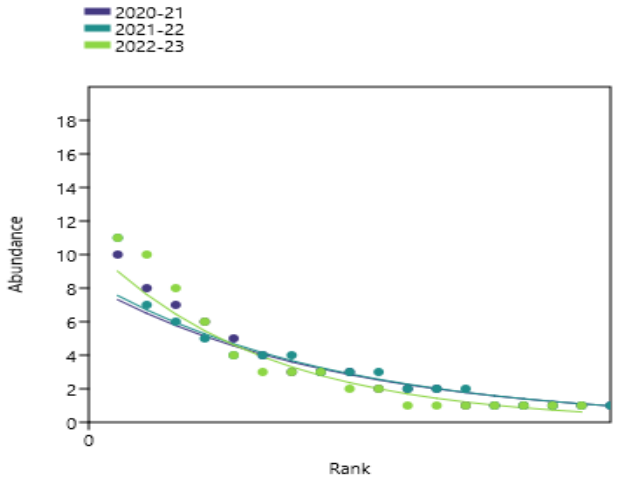

Figure 2: Diversity profile and insect pollinator's abundance during 2020 to 2023.

DISCUSSION

In most of the terrestrial ecosystems, many species of insects are considered as major pollinators keeping ecosystems functioning well.[69] Various insect species anticipated significant role by connecting the link between plants and ecological processes.[69,70] In order to achieve pollination, insect pollinators visiting flowers and in turn they get floral rewards from the flowering plant species and demonstrated the process of plants-pollinators interaction.[10] During the present investigation, 79 insect species were encountered as pollinators on different flowering plant species at various

agro-ecosystems of Kodagu district. Insect pollinators represented by six orders and 22 families at plantation crops, paddy fields, meadows, social/agro forests, horticultural gardens and natural and man-made habitats of Kodagu district. Similar type of observations were reported by[10,12,14,16,18,19,21,23,24,28-32,40,42,43,45,46] at different agro-ecosystems both in India and abroad. Earlier,[23,33] has observed 50 species of insect pollinators on different flowering crops in Nepal. Among them, *Apidae* family members of the order *Hymenoptera* were highest (65.5%) and it was followed by *Formicidae* (17.3%) of the order *Hymenoptera* and *Nymphalidae* family members (2.65%) of the order *Lepidoptera* compared to other insect pollinators.[45] have recorded 34 species of *Apis* and non-*Apis* pollinators and among them again *Apidae* family members were relatively high compared to *Syrphidae*, *Nymphalidae* and *Pieridae* family members. However, at various agro-ecosystems of Kodagu, Lepidopteron species were more (30) and it was followed by *Hymenopterans* (26) and *Dipterans* (13) compared to the *Coleopterans*, *Odonates* and *Hemipterans*. Surprisingly, *Hymenopterans* predominated more (86.3%) at different agro-ecosystems and it was followed by Lepidopteron species (8.1%). Obviously, *Coleopterans*, *Dipterans*, *Hemipterans* and *Odonates* per cent occurrence was less than 2%. Further, density and relative abundance of pollinators which belong to different insect orders indicated considerable variation. Pollinator's density was 0.32, 0.30, 0.23, 0.19, 0.16 and 0.12 respectively in *Hymenopterans*, *Hemipterans*, *Odonates*, *Lepidopteran*s, *Coleopterans* and *Dipterans*. Moreover, the relative abundance was 345.14, 106.30, 41.73, 29.68, 27.25 and 13.62 in *Hymenopterans*, *Hemipterans*, *Odonates*, *Coleopterans*, *Lepidopteran*s and *Dipterans* respectively. Further, on an average the pollinator's density and their relative abundance was respectively 0.22 and 93.95 per 10 square feet area in Kodagu.

Several researchers[4,15,18,20,21,23,24,30,32,34-36,42-46,52,56,59,60,66,71-73,75,77] have reported only few pollinators (e.g. Carpenter bee, *Odonates* , Stingless bees, Blow flies, Flies, etc.,) on various agricultural and horticultural crops at greenhouses, agricultural lands, horticultural gardens, institutional campuses and other diversified agro-ecosystems at different parts of India and the world. However, present study revealed all the insect pollinators and their per cent composition. This type of observations is sparse at many agro-ecosystems. Hence, present study provided a critical insight on locally existing insect pollinators which involved in the process of pollination at various ecosystems. Compared to the present investigation in Kodagu,[13,15,20,36,51] have reported the flies, carpenter bees, dragonflies, damselflies, butterflies, hover flies and other insect pollinators on various plantation crops including on few selected weeds. Further,[36,38,39,41,42,48,55,57-60,66,72,74,76] have reported the insect pollinators like honeybees and non-*Apis* species, flies and other insect pollinators at different landscapes in India. All these reports suggested that insect pollinator's distribution, diversity and pollination potentials are not alike, but vary considerably due to various reasons. These variations are multi factorial in their existence, interdependent and difficult to predict. Despite, all these previously published reports; attempt was made to inventorying the insect pollinator's distribution and diversity at different agro-ecosystems of Kodagu during the present investigation. Hence, present study is quite unique in its presentation and reveals the general insect pollinators of various flowering plants exist at diversified ecosystems of Kodagu.

Further, pollinator species belong to *Apidae*, *Nymphalidae*, *Pieridae*, *Syrphidae*, *Vespidae*, *Formicidae*, *Papilionidae* and *Libellulidae* relative abundance was more compared to other family members and indicated considerable variation at various agro-ecosystems of Kodagu district during 2020 to 2023. Furthermore, Simpson index ('D') of insect pollinators was ranged from 0.906 to 0.935 and Shannon ('H') index of insect pollinators was minimum 2.603 and maximum 2.926 with Shannon Evenness 0.7944 to 0.8475 during 2020 to 2023 and indicated considerable reduction during 2021-2022 and 2022-2023 and demonstrated the process of insect pollinators decline. Overall, 2.8% insect pollinators decline was recorded during the study period (2020-2023) in Kodagu district and it was evident in the insect pollinator's diversity profile. Similar type of observations was reported by[5,7-9,27,33,46-48] at different parts of the world. Obviously, plant-insect pollinators interaction is a very sensitive activity, disturbed due to various anthropogenic activities,[48] which destroyed, fragmented the pollinator's habitat. As a result, insect pollinators are facing difficulty to obtain their food and nesting resources[10] in turn majority of cross-pollinated crops productivity gets affected[6] and man unable to reap good agriculture crop products.[3,8,11,23] Further, insect pollinators are useful to mankind in terms of economic, aesthetic and cultural aspects.[64] Therefore, pollinators presence and pollination process by insect pollinators is a crucial to upkeep the ecosystems healthy and biologically diverse. Further, Present study suggests preparing floral calendar of insect pollinators of Kodagu district.[63,77] have prepared the floral calendar of bees at southern Karnataka and Paithan Taluk of Aurangabad district of Maharashtra respectively. Thus, various researchers have witnessed the influence of

flowering flora for the survival of insect pollinators in their investigations. Bees and other insects interact with flowering plants[77] and in turn flowering plants increase the wild bee population.[78] Native flora could be managed by arthropod pollinators.[79] Insect pollinators visit various flowering plant species[80] including many weed species.[81] Thus, insect pollinator's conservation is need of the day around the globe. Our observations supports the observations of.[1,6,10,18,21,22, 26,28,32,41,45,55,57,71,73]

CONCLUSION

Kodagu district has diversified landscape, experiencing varied climatic conditions, which could help develop different natural vegetation midst Western Ghats. Different flowering plant species grow along with weeds at various agro-ecosystems; provide floral sources to different animals including insect species. During the present investigation, 79 insect pollinators which belongs to six major insect orders, their distribution, diversity and abundance has been recorded along with their declining trend at various agro-ecosystems of Kodagu district. Although, present investigation has provided a brief insight on few pollinating insect species but, it emphasizes the need of insect pollinator's preservation to restore the local biodiversity at diversified agro-ecosystems amidst Western Ghats.

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SUMMARY

Total 79 insect pollinator species were found at seven types of agro-ecosystems. Insect pollinators belongs 69 genera, which represented 22 families of the orders Coleoptera, *Diptera*, *Hemiptera*, *Hymenoptera*, *Lepidoptera* and *Odonata*. *Hymenopterans* were more (86.3%) compared to other group of insect orders. Surprisingly, *Coleopterans*, *Dipterans*, *Hemipterans* and *Odonates* per cent occurrence was less than two and thus, the diversity indices revealed considerable variations between the insect pollinator species. Further, 2.8% insect pollinators decline was recorded at various agro-ecosystems and indicated that locally existing insect pollinators are at risk in Kodagu district. On this line in depth research is necessitated to protect the local pollinators in Kodagu district.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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